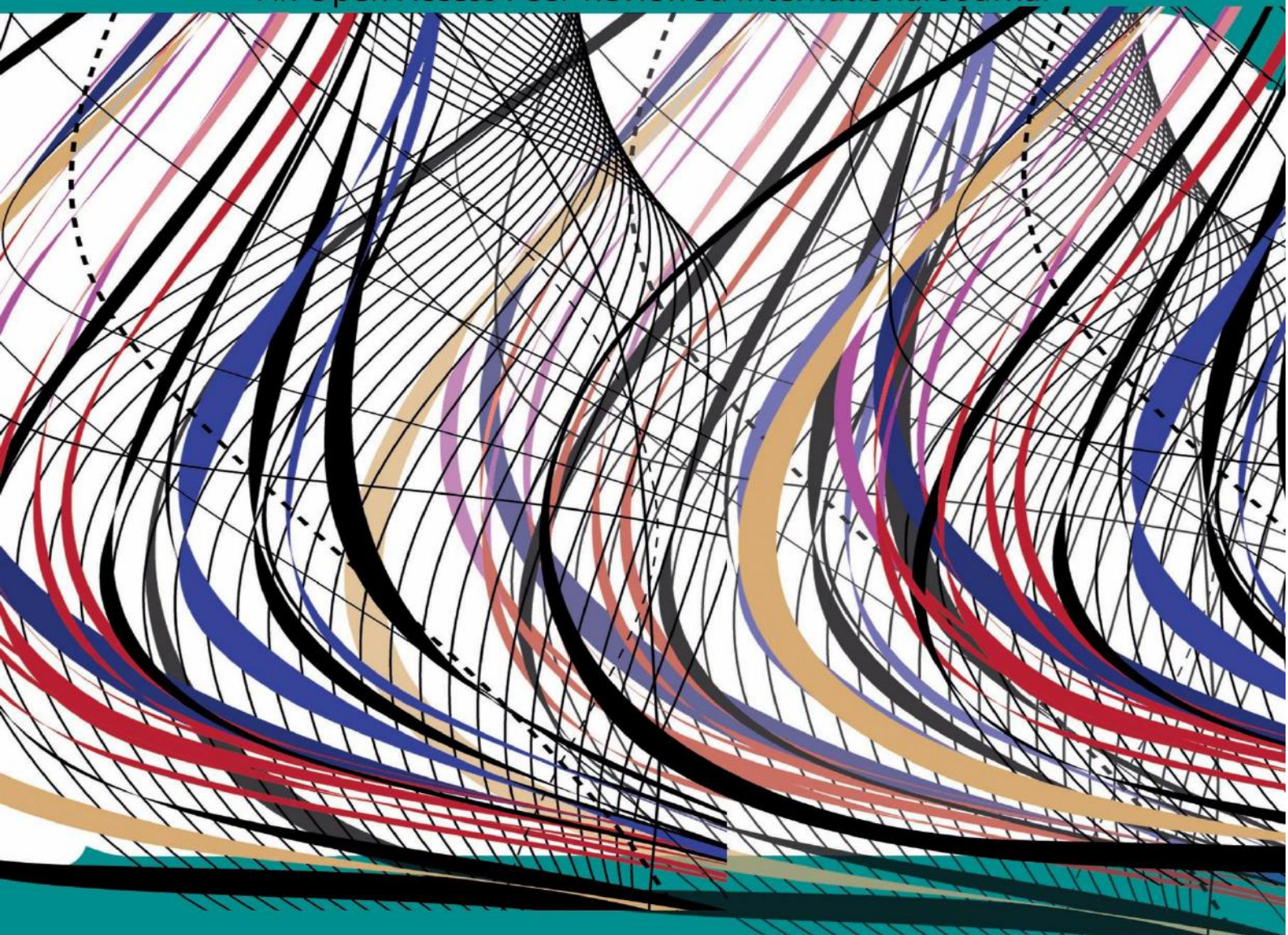


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Spectrum Efficiency improvement in 5G Network using NOMA

Daud Rehmat

Institute of Communication Technologies (ICT), Pakistan

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Abstract— Non-Orthogonal Multiple Access (NOMA) achieves optimal spectrum requirements of 5G and future networks. The research work focuses on how to increase the absolute efficiency (SE) of the NOMA energy domain in the 5G network using two new approaches and a smart radio network. These methods use Massive MIMO, Simple-Input and Simple-Output, and Single-Input and Single-Output in a single cellular network. NS2 software was used for situations by distances, power placement coefficients & transmission power to test proposed approaches. Each scenario implies that users are using the Quadrature Phase Shift Keying modulation technique and operating within defined bandwidths. The performance assessment considers frequency selective Rayleigh fading, unstable channel circumstances & successive interference cancellation. Outcomes show that downlink NOMA with a single input and single output achieves the best spectral efficiency performance. Spectral efficiency increases when paired with cooperative cognitive radio network. The results show that SE is greatly increased by using MIMO & M-MIMO techniques.

Keywords— NOMA; MIMO; M-MIMO

I. INTRODUCTION

Generally, multiple users use following access ways:

- Frequency Division Multiple Access - FDMA
- Time Division Multiple Access - TDMA
- Code Division Multiple Access - CDMA

Figures below shows orthogonal and non-orthogonal multiple access schemes.

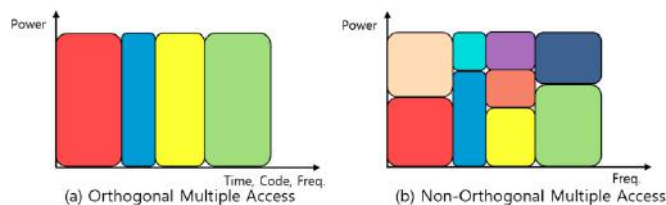


Fig.1: Orthogonal & Non-Orthogonal Multiple Access

According to [3], primary idea of NOMA enables for tolerating many users by segmenting them. NOMA users increases with the availability of orthogonal

resources [4-6]. NOMA power/code domain are the two main domains that make up NOMA. Multiple users in the power domain (PD) make use of same frequency (f) or time resource with various power flows.

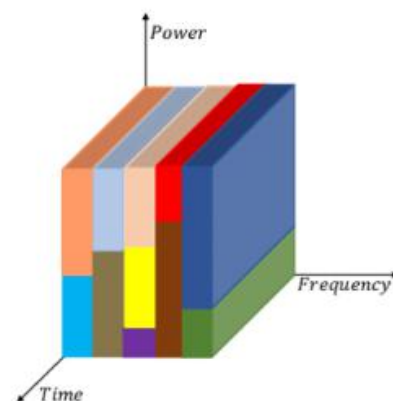


Fig.2: NOMA Power Domain

Every user on the CD has a unique codebook created to match their data [7]. Future systems will therefore

need to dramatically increase capacity and SE to manage the anticipated spike in traffic.

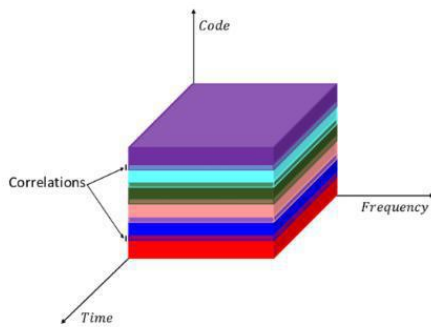


Fig.3: NOMA Code Domain

Future mobile network generations will significantly boost system capacity and resource utilization [8]. Sharing spectrum between several users is one such way. More users can be accommodated by non-orthogonal allocation (NOMA) than by the number of orthogonal resource modules.

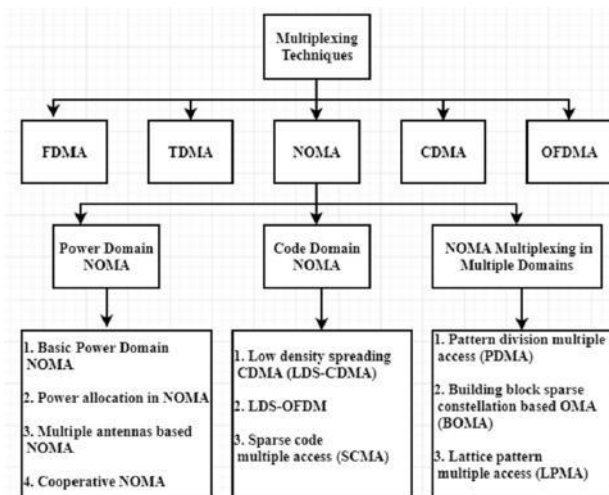


Fig.4: Multiplexing Techniques Comparison

These multiple access strategies are useful for diverse communication circumstances and have varied advantages. They deal with the difficulties of distributing scarce resources among numerous users and make it possible for wireless networks' available communication channels to be used effectively.

Unfortunately, there isn't much spectrum left for wireless applications. In order to fulfil the rising traffic and service needs and avoid potential spectrum scarcity, it is imperative to create innovative techniques [9]. A technique based on cognitive radio (CR) [10] can be helpful to resolve the outlined issues.

If interference to PUs is tolerable, SUs may transmit over primary frequency bands.

Cognitive radio technology is used by a wireless network called Cognitive Radio Network (CRN) for improving spectrum use & overall network performance. CRN can automatically perceive, adapt, and dynamically assign spectrum resources based on the shifting wireless environment and the network's communication requirements thanks to cognitive radio technology.

Following are crucial characteristics & elements:

- Spectrum Sensing
- Spectrum Management
- Dynamic Spectrum Access (DSA)
- Interference Mitigation

Context of upcoming wireless communication technologies like 5G and beyond, they have been a focus of active research and development.

The authors of [11] examined a crucial CR procedure and talked about two strategies for spectrum sharing that improve radio frequency utilization. These techniques seek to minimize interference between licenses for conventional and cognitive radio. Various types of spectrum access can be grouped based on [12]'s analysis of spectrum utilization. [13] also examined various spectrum access methods and categorized them into classes. MIMO NOMA technology can be used in a CRN to achieve active cooperative spectrum sensing (CSS) for both primary and secondary users.

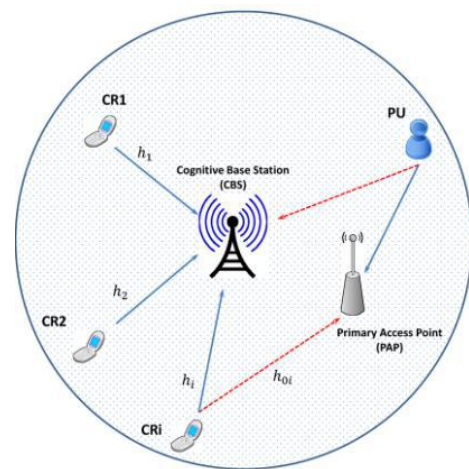


Fig.1.5: Typical Cognitive Radio Network (CNN)

The CRN can still only be accessed through certain

channels, and are currently a finite amount of users. The impact of power localization coefficients is not addressed, and the resulting results cannot be extrapolated to a vast network [14].

5G architecture can be a combination of single-input, single-output and MIMO technologies, utilizing massive input (Down Link PD NOMA with CCR) through two distinct methods. It showcases enhanced spectral efficiency compared to conventional SISO DL NOMA modelling.

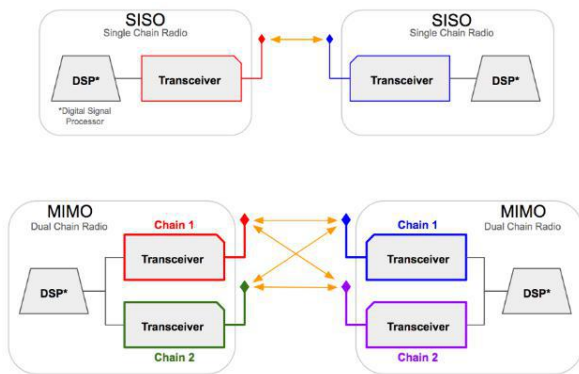


Fig.6: SISO and MIMO Hardware Comparison

(Source:

<http://docs.arednmesh.org/en/latest/arednHow-toGuides/siso-mimo.html>)

Here is a comparison of hardware setups for SISO and MIMO:

SISO (Single Input Single Output): One antenna at broadcaster & one antenna at receiver make up a SISO communication system. In SISO systems, the received signal is received by a single antenna at the receiver after travelling across a single channel during transmission. Simple wireless communication systems, such those found in Bluetooth devices and entry-level wireless routers, frequently employ SISO systems. The key benefits of SISO are its affordability and simplicity, which make it appropriate for applications with low complexity requirements. MIMO uses multiple antennas at transmitter & receiver is referred to as MIMO.

SISO & MIMO comparisons can be summarized as:

- Data Rate and Capacity
- Spatial Diversity and Multiplexing
- System Complexity
- Cost and Power Consumption

Problem Statement

Poor spectral efficiency leads to transmission problems that limit communication performance. There are several important strategies that can be used to improve overall efficiency (SE). Increasing the number of users and implementing multiple input methods (MMIMO) are two of them.

Significance of Research

This study introduces two innovative approaches aimed at enhancing the spectrum efficiency of downlink NOMA power domain in 5G and future networks. NOMA being acknowledged as an effective solution for meeting SE requirements. The proposed techniques involve integrating SISO which is abbreviation for single-input, single-output, MIMO and M-MIMO within the same network. Additionally, these methods combine Down Link NOMA PD with cognitive radio network within single cell.

Research Objectives

Following are summarized research objectives:

- Improving 5G network's downlink (DL) NOMA power domains' (PDs) spectrum efficiency (SE) performance.
- Coming up with strategies to be used to integrate SISO, 64x64 MIMO, and 128x128 M-MIMO technologies with a cooperative cognitive radio network (CCRN).
- Lessen AWGN, interference cancellation (SIC), and unstable channels when Rayleigh fading is present.

Research Questions

- How can 5G network's downlink (DL) NOMA power domains' (PDs) spectrum efficiency (SE) performance be improved?
- Can unique strategies be used to integrate SISO, 64x64 MIMO, and 128x128 M-MIMO technologies with CCRN?
- Is it possible to lessen AWGN, interference cancellation (SIC), and unstable channels when Rayleigh fading is present?

II. LITERATURE REVIEW

Outage probability (OP) & throughput of CR-NOMA system were investigated by author of [15]. Closed-

form expressions for OP were developed for assessing performance of secondary network users in event that the primary network interferes. Numerical results suggest that both users can have fair performance when employing the power distribution/energy harvesting parameters. Furthermore, the authors test each framework's spectrum model and compute the MIMO-CR-NOMA framework's overall efficiency and per-user reach for Internet of Things applications [16].

The authors mention the difficulty of creating products in many NOMA systems [17]. Their results show that introducing an information radio network (CRN) foundation for a multi-carrier NOMA network results in an increase in overall throughput with only a slight decrease in first-user (PU) pass-through when below target. In the context of Business 5.0, the authors develop an asymptotic model for a NOMA-based coverage radio network (CRN) using an analytical model of reliability parameters [18].

Effect of phase and voltage distribution upon performance has been investigated through simulation [19]. The authors propose a resource allocation that strikes a balance between power consumption and spectrum efficiency in multi-carrier NOMA, including user fair rules. Simulators were used to validate the results of the corrected performance study, and closed models were used to estimate the chance of outages for primary and secondary users [20].

The research focuses on actively breaking reconfigurable smart surface (RIS) transmitters designed to transmit private signals over IoT networks. In the presence of many eavesdroppers, reflective RIS is used to improve security performance. From the simulation results, the proposed proposal, which is a combination of power dissipation, transmission power dispersion, and phase change of interference and interference RIS, demonstrated its effectiveness in increasing weight [21]. The usefulness and superiority of the suggested strategy over current practices were proven by the simulation findings. The simulations presupposed a homogeneous planar array for the base station and a multi-beam antenna array for the satellite [22]. This study explores stabilization and energy saving beamforming in multi-beam satellite systems, for example, one eavesdropper per beam.

Another area of focus is the active-breaking Reconfigurable Smart Surface (RIS) as transmitters for personal signaling in IoT networks. Use the RIS hypothesis to improve performance in large audiences. Simulations validated effectiveness of the design optimizing the weight and privacy of common power distribution, power transmission & phase change of associated & related RIS [24].

In [25], authors present a partial collaboration zero interference decoding (PCZF) technique for large, cell-free uplink MIMO systems. The technology includes proximal access points around user equipment to reduce interference via zero-determination state information exchange (CSI).

In order to solve their shortcomings, there is a prevalent trend in modern research to integrate diverse 5G approaches. As an illustration, the authors of reference [26] used cooperative communication to get around the considerable path loss that comes with millimeter-wave (mm-wave) technology. Beyond mm-wave and NOMA, a wide range of innovative methods for enhancing radio spectrum efficiency are projected to have a substantial impact on the development of 5G and subsequent technologies.

Building successes of cooperative non-orthogonal multiple access (NOMA) using conventional radiation and the superior performance of orbital angular momentum (OAM) in increasing system throughput, along with promising findings from reference [27], another study introduces a novel method that combines cooperative NOMA and OAM transmission. Sending messages from all users at various power levels across all the OAM modes is necessary for this integration.

The existence of a large number of mobile devices in a network with a big number of connected devices necessitates the usage of non-orthogonal multiple access (NOMA). NOMA networks enable significant increases in spectral efficiency and low latency, outperforming orthogonal multiple access (OMA) networks [28].

Cognitive radio technology can dynamically change communication channels to enable intelligent access for secondary users when the current channel is congested. In NOMA, multiple simultaneous accesses are possible at the same power level, enabling intelligent multiple access for both primary and

secondary users and leading to better spectrum utilization. To enhance the performance of cognitive NOMA in 5G and beyond, several aspects can be improved, leveraging the capabilities of cognitive radio and intelligent spectrum allocation [29-30].

To fulfill future demands, researchers are focusing on the development of fifth generation (5G) and beyond fifth generation (B5G) wireless communication networks. One of the proposed systems is NOMA Non-Orthogonal Multiple Access (NOMA), which is projected to address the needs of the rapidly growing number of users, connectivity requirements, costs, and low bandwidth available in various types of wireless communication networks. However, implementing NOMA in wireless communication networks presents both obstacles and advantages. Previous research studies introduced NOMA concepts, compared them to other approaches, and addressed related concerns [31–32].

The growth of base stations in cellular networks helps to provide larger coverage, but it also causes interference among users at the cell edges, which reduces overall coverage. As a result, ensuring improved coverage becomes a difficult challenge in future cellular networks. Traditional multiple access techniques will not be able to fulfil the future expectations of 5G, which include high data speeds, low latency, huge interconnection, and good spectrum efficiency. As the number of cellular users in 5G networks grows, receiver complexity becomes a major challenge. NOMA approaches, on the other hand, can be used to reduce this complexity. NOMA allows numerous users to be assigned to a single resource block utilizing allocation algorithms that are then decoded at the receiver to reduce system complexity. By taking this method, you can enhance your bit error rate, throughput, and system capacity [33].

As the user base of existing mobile and cellular networks grows, spectrum distribution becomes more difficult. These barriers frequently cause users to transfer to other networks, forcing telecom firms to struggle with providing high-speed services. As a result, the demand for 5G networks is increasing. Given these circumstances, the suggested algorithm seeks to meet the needs of the user. Its main distinguishing characteristic is its capacity to properly detect primary and secondary users inside the 5G network and allot spectrum accordingly, fulfilling the

needs of each user category [34].

III. RESEARCH METHODOLOGY

It consists of three study method models: control domain multi-input multiple access, non-orthogonal multiple access (M-MIMO DL PD NOMA), control domain multiple output, multiple non-orthogonal access (MIMO DL PD NOMA), and single access single downlink. Non-Orthogonal Multiple Access (SISO-DL NOMA).

Simulation Design and Setup

Simulations were done using NS2.

Table 1. Simulation Parameters

	Parameters	Values	
1	Total no of users in the network	5	
2	Transmitted power	0 to 30 dBm	
3	Bandwidth	BW	80 MHz
4	Distances	U1	1000 m
		U2	800 m
		U3	500 m
		U4	300 m
		U5	200 m
5	Power coefficients	U1	0.76
		U2	0.184
		U3	0.048
		U4	0.012
		U5	0.008
6	Path loss exponent	5	
7	Single Input Single Output (SISO)	1 x 1	
8	Multiple Input Multiple Output (MIMO)	64 x 64	
9	Massive Multiple Input Multiple Output (M-MIMO)	128 x 128	
10	Modulation Type	Quadrature Phase Shift Keying (QPSK)	

The parameters which will be examined will be:

- NOMA Spectral Efficiency SE (User 1, User 2, User 3, User 4 and User 5)
- Cooperative Cognitive Radio CCR-NOMA Spectral Efficiency Competing Channel C-CH (User 1, User 2, User 3, User 4 and User 5)
- Cooperative Cognitive Radio CCR-NOMA Spectral Efficiency Dedicated Channel D-CH (User 1, User 2, User 3, User 4 and User 5)
- MIMO NOMA Spectral Efficiency (User 1, User 2, User 3, User 4 and User 5)
- MIMO-CCR-NOMA Spectral Efficiency C-CH (User 1, User 2, User 3, User 4 and User 5)
- MIMO-CCR-NOMA Spectral Efficiency D-CH (User 1, User 2, User 3, User 4 and User 5)
- M-MIMO NOMA Spectral Efficiency SE (User 1, User 2, User 3, User 4 and User 5)

- M-MIMO-CCR-NOMA Spectral Efficiency SE C-CH (User 1, User 2, User 3, User 4 and User 5)
- M-MIMO-CCR-NOMA Spectral Efficiency SE D-CH (User 1, User 2, User 3, User 4 and User 5)

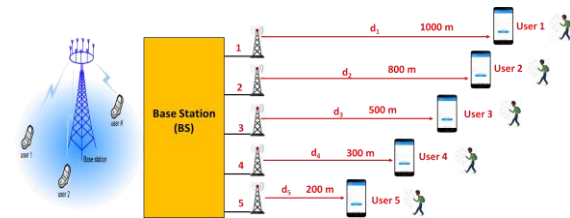
Simulations were done using NS2. The benchmark will be the research paper written by Hassan, Mohamed, (2023).

3.2 System Models

The following three models will be studied.

- SIOS DL NOMA
- MIMO DL PD NOMA
- Massive MIMO DL PD NOMA

The designed/conceptualized model is as under.



Consider a wireless network with four NOMA users: U1, U2, U3, U4, and U5. Each user is represented by d1, d2, d3, d4, and d5 and is located at a certain distance from the base station (BS). It should be noted that because to their relative locations, U1 is expected to get a weaker signal than U5, which is the closest to the BS. Rayleigh fading coefficients are represented by h1, h2, h3, h4, and h5 (corresponding to |h1|², |h2|², |h3|², |h4|² and |h5|²) whereas current power coefficients are represented by α₁, α₂, α₃, α₄ and α₅, correspondingly.

Fig.7: Wireless Network with five users (DL-NOMA PD) System Model

The user who is closer to the base station and has a stronger signal should be given less power, in accordance with the NOMA PD guidelines. On the other hand, greater power should be allocated to the user who is farther away from the base station and has a poorer signal. The letters x1, x2, x3, x4, and x5 stand for the power coefficients. This study uses a reduced set of power coefficients for user-friendliness. There are several dynamic options for changing the power coefficient in order to increase efficiency. Furthermore, the modified power coefficients x1, x2, x3, x4, and x5 ought to perform better than the signals transmitted to the base stations using quadrature phase-shift keying (QPSK). (Note: the equations are taken/adopted from [35]) The base station encoded overlay signal can be stated as follows:

$$x = \sqrt{p} (\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2 + \sqrt{\alpha_3}x_3 + \sqrt{\alpha_4}x_4 + \sqrt{\alpha_5}x_5)$$

Signal received by the *i*th user are:

$$y_i = h_i x + n_i$$

Where,

n_i = AWGN experienced by *i*th use U_i .

Strongest signal decodes y_i with maximums as:

$$R_1 = \log_2 \left(1 + \frac{\alpha_1 P |h_1|^2}{\alpha_2 P |h_1|^2 + \alpha_3 P |h_1|^2 + \alpha_4 P |h_1|^2 + \alpha_5 P |h_1|^2 + \sigma^2} \right)$$

The above equation can be written as:

$$R_1 = \log_2 \left(1 + \frac{\alpha_1 P |h_1|^2}{(\alpha_2 + \alpha_3 + \alpha_4 + \alpha_5) P |h_1|^2 + \sigma^2} \right)$$

Given that denominator is total of power coefficients of other three users ($\alpha_2 + \alpha_3 + \alpha_4 + \alpha_5$), power coefficient of targeted user α_1 must satisfy: $\alpha_1 > \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5$. As a result, U1 power is controlled by both sent signal x & received signal y_1 . U1s data was removed & considered interference, $\alpha_2 < \alpha_1$, and $\alpha_2 > \alpha_3 > \alpha_4 > \alpha_5$ through the use of SIC [36].

$$R_3 = \log_2 \left(1 + \frac{\alpha_3 P |h_3|^2}{\alpha_4 P |h_3|^2 + \sigma^2} \right)$$

Moving on, y_3 , with the exception of U1, U2, U3, U4 and U5 (where $\alpha_3 < \alpha_1$, $\alpha_3 < \alpha_2$) is included in the denominator's overlapping term. To eliminate cancelled data y_3 , three sequential interference cancellation (SIC) operations must be performed. Because α_1 is the most important, it must be eliminated first. As a result, the phrase α_3 is dropped. As a result, the possible rate can be represented using the equation:

$$R_3 = \log_2 \left(1 + \frac{\alpha_3 P |h_3|^2}{\alpha_4 P |h_3|^2 + \sigma^2} \right)$$

The resulting y_4 , involving U1, U2, U3, U4, and U5 (where $\alpha_3 < \alpha_1$, $\alpha_3 < \alpha_2$, $\alpha_3 < \alpha_4$) is found in the denominator's intersecting term. As a result, removing cancelled data y_4 necessitates the execution of two sequential interference cancellation (SIC) operations [37]. Given that α_1 has the highest priority, it must be removed first, followed by the phrase α_3 . The attainable rate is expressed as:

$$R_4 = \log_2 \left(1 + \frac{\alpha_4 P |h_4|^2}{\sigma^2} \right)$$

For CCRN-Based Free Channels, the figure is shown below.

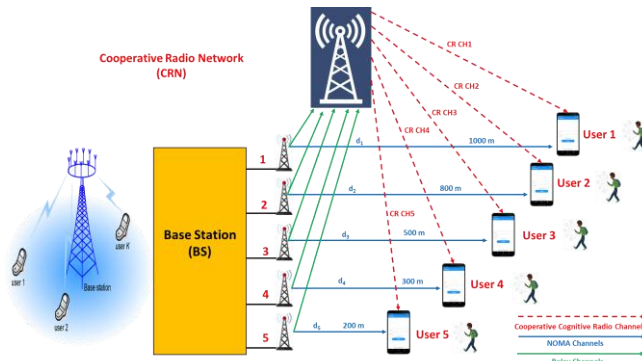


Fig.8: DL-NOMA PD with the CCR Network with four users System Model

Consider a wireless network having 4 NOMA users: U1, U2, U3, U4, and U5. In this case, U1 symbolizes weaker/far user, whereas U5 represents stronger/near user. These users' distances from their respective base stations are designated as d_1 , d_2 , d_3 , d_4 , and d_5 . This scenario depicts a cooperative cognitive radio network. We may use the formula $|h_1|^2$, $|h_2|^2$, $|h_3|^2$, $|h_4|^2$ and $|h_5|^2$ to express Rayleigh fading values [38].

A cognitive radio network monitors channel status and communication accuracy. Assuming the channel is unstable and has poor communication, the Cooperative Cognitive Radio Network channel can be either available or unavailable.

- Spectrum Sensing

The cognitive radio uses entire spectrum window for packet transmission (s). Assume T_{window} depicts length of this spectral window period. It is obvious that:

$$T_{\text{window}} \geq T_{\text{sense}} + T_{\text{CR}} - \text{Transmission} + T_{\text{ramp-up}} + T_{\text{ramp-down}}$$

The figure depicts CR (i.e. transmission opportunity window) in context of beacon signals with fixed separation. T_{sense} denotes minimal time required for sensing & gathering communication parameters required to ensure CR transmission opportunity. T_{CR} Transmission defines transmission duration i.e. CR packets, whereas $T_{\text{ramp-up/down}}$ is transmission ramping.

$$PD = \frac{\text{Number of acquisitions}}{\text{Total number of opportunities}} = \frac{\text{Over\_Num}}{\text{NOP}}$$

In order to choose b/w 2 possibilities, spectrum sensing on link-level targets in single primary system is used.

$$y[n] = \{ w[n] h s[n] + w[n] n = 1 \dots N \frac{H_0}{H_1}$$

Complex signal received by mental radio is $y[n]$, signal sent by first user being $s[n]$, AWGN is signal $w[n]$, h is the reception signal difficulty of good channel, denoted N . Specifies the observation distance at a position. If the channel is not good, the inversion of h and $s[n]$ is used instead of simple multiplication. The null hypothesis, H_0 , states that there is no primary user signal, while the alternative hypothesis, H_1 , states that there is a primary user signal. There are two types of intelligence methods:

- Energy Detection

A binary choice is made in the following manner:

$$\begin{cases} H_0, & \text{if } \sum_{n=1}^N |y[n]|^2 / \leq \lambda \\ H_1, & \text{otherwise} \end{cases}$$

The noise in the receiver influences the threshold, represented as λ .

$$PF = P\left(\frac{H_1}{H_0}\right) = P\left(\frac{PU}{H_0}\right) = P\left(\frac{y_n}{H_0}\right) = 1 - F_{H_0}(Th)$$

The false alarm probability is represented by the cumulative distribution function (CDF), which is indicated by F_{H_0} .

$$PD = \frac{\text{Number of acquisitions}}{\text{Total number of opportunities}} = \frac{\text{Over\_Num}}{\text{NOP}}$$

$$PD = 1 - P_m = 1 - P\left(\frac{H_0}{H_1}\right)$$

$$PD = \left[e^{-\frac{Th}{2}} * \frac{1}{n!} \left(\frac{Th}{2}\right)^n \right] + \left[e^{-\frac{Th}{2(1+L)}} * \left(\frac{1+L}{L}\right) \right] - \left[e^{-\frac{Th}{2}} * \frac{1}{n!} * \frac{Th * L}{2(1+L)} \right]$$

$$P_m = 1 - PD$$

In this context, PD symbolizes detection probability, Th the threshold, L the signal-to-noise ratio (SNR), P_m the chance of missed detection & P_{FA} false-alarm probability.

Error probability is calculated by:

$$P_e = P_F * P_{(H_0)} + P_{Mri} P_{(H_1)}$$

In the presence of a primary communication system, the Cooperative Cognitive Radio (CCR) system evaluated the channel conditions and its suitability for communication. When the communication quality was poor or the channel state was unstable, this evaluation was carried out. In these situations, the CCR channel is only accessible under a single, highly prioritized condition, which enables NOMA users to

make use of it.

For MIMO DL PD NOMA, consider three scenarios in 5G network telephony:

1. 64 x 64 MIMO DL NOMA PD
2. 64 x 64 MIMO DL NOMA PD with Cooperative Cognitive Radio Network (CCRN) C-CH
3. 64 x 64 MIMO DL NOMA- CHPD and MIMO DL NOMA-CHPD.

These positions are based on the presence of N users, namely U1, U2, U3,... UN and the strength of users $\alpha_2 < \alpha_1, \alpha_3 < \alpha_2, \alpha_4 < \alpha_2$.

$$x = \sqrt{P}(\sqrt{\alpha_1}x_1 + \sqrt{\alpha_2}x_2 + \sqrt{\alpha_3}x_3 + \sqrt{\alpha_4}x_4 + \sqrt{\alpha_5}x_5)$$

The NOMA power allocation coefficients, abbreviated as " α ," govern power distribution among users. The transmit antennas simultaneously broadcast the signal " x ." We can deduce what signal U_N is detecting based on this information.

$$y_N = xh_{N1} + xh_{N2} + \dots + xh_{NN}$$

We may calculate the Rayleigh fading channel for each user if n_N represents total no of samples from Additive White Gaussian Noise with zero mean & variance of σ^2 & N represents number of users.

$$h_{ik} = \sum_{i=1}^k h_{ik}$$

The entire number of users, defined by $i = 1, 2, 3, 4$ & 5, represented by no of users. Furthermore, $k = 64$ channels are available in total. Furthermore, signal is received by base station.

$$y = \sqrt{P_{x1}}h_{1N} + \sqrt{P_{x2}}h_{2N} + \sqrt{P_{x3}}h_{3N} + \sqrt{P_{x4}}h_{4N} + \sqrt{P_{x5}}h_{5N}$$

We used an identical model that includes the CCR spectrum to assess the channel's condition and communication capacity. If channel state is unreliable & communication is poor, CCR channel state offers 2 choices: C-CH or D-CH.

For Large MIMO DL PD NOMA, we investigate three scenarios using the same wireless network configuration:

- 128 x 128 M-MIMO DL NOMA PD
- 128 x 128 M-MIMO DL NOMA PD with one competitive channel (C-CH)
- 128 x 128 M-MIMO DL NOMA PD MIMO DL NOMA PD with dedicated channel (D-CH).

There are 4 users in this network called U1, U2, U3, U4

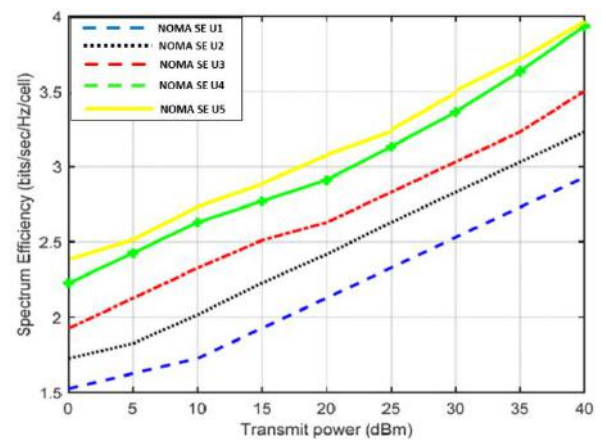
and U5 with different distances from each other $\alpha_2 < \alpha_1, \alpha_3 < \alpha_2, \alpha_4 < \alpha_3$. We assume that these users are using M-MIMO DL NOMA PD 128x128 under same configuration. Using same methods to evaluate the credibility and authority of a news channel. If the CR channel enabled, NOMA users can use it. As previously thought, NOMA users have access to the CCR frequency. We can calculate the weakest channel for each user.

$$h_{jM} = \sum_{j=1}^M h_{jM}$$

Data Simulations

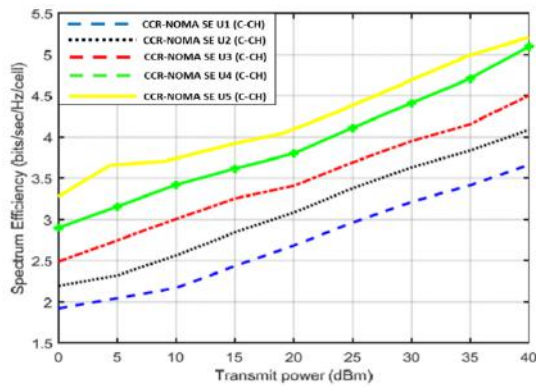
- Simulation Design and Setup

According to the findings, boosting the transmit power resulted in an increase in spectral efficiency (SE). The highest SE value obtained among the users was 3.95 bps/Hz/cell, which occurred when U5 i.e. user physically closest to BS (200m), transmitted at a power level of 30 dBm. The users listed in terms of SE performance after U5 were U4, U3, U2, and ultimately U1.



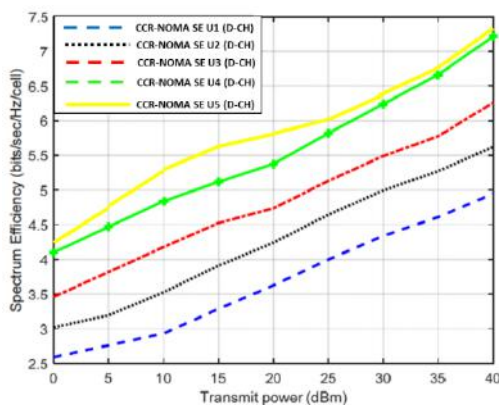
The image depicts the relationship between spectral efficiency (SE) and transmit power for five users named U1, U2, U3, U4, and U5 in the context of a single-input single-output (SISO) downlink non-orthogonal multiple access (NOMA) system with an unstable channel state. These users are separated from the base station (BS) by 1000m, 800m, 500m, 300m, and 200m, respectively. These users' power location coefficients are 0.76, 0.184, 0.048, 0.012, and 0.008, respectively.

Fig.9: Spectrum Efficiency Vs Transmit Power for 5 users SISO DL NOMA PD



Graph shows the relationship between spectral efficiency (SE) and transmit power for five users in a single-input single-output (SISO) downlink non-orthogonal multiple access (NOMA) power-domain (PD) system combined with a CCR network, specifically the model using a C-CH free channel (referred to as the first model). The users' distances from the base station vary, as do their power location coefficients. According to the graph, the greatest SE attained is 5.11 bps/Hz/cell for user U5. This maximum SE is achieved at a transmit power of 30 dBm.

Fig.10: Spectrum Efficiency Vs Transmit Power for 5 users SSISO DL NOMA PD WITH C-CH CCRN



Graph depicts the relationship between spectral efficiency (SE) and transmit power in a downlink NOMA power-domain (PD) system linked with the CCRN. The figure depicts the second model, which employs a dedicated channel (D-CH). The graph depicts the SE vs transmit power for five users at differing distances from the base station and power location coefficients. The greatest SE attained by these users is 7.3 bps/Hz/cell. This extraordinary SE value is obtained for user U5 at a transmit power level of 30 dBm.

Fig.11: Spectrum Efficiency Vs Transmit Power for 5 users SSISO DL NOMA PD WITH D-CH CCRN

The relevant power location coefficients for these users are 0.0811, 0.01875, 0.3, 0.075, and 0.06. The results show that spectral efficiency (SE) rises in proportion to transmit power increases. With a SE of 12.22 bps/Hz/cell, U5, the user closest to the base station, has the highest. Following U5, users U4, U3, U2, and U1 observe decreasing SE levels. We obtained these SE results at 40 dBm transmit power. Best user, U5, improves the SE by 8.36 bps/Hz/cell when 64x64 MIMO technology is paired with NOMA as opposed

to SISO DL NOMA PD. This enhancement happens at 40 dBm of transmission level.

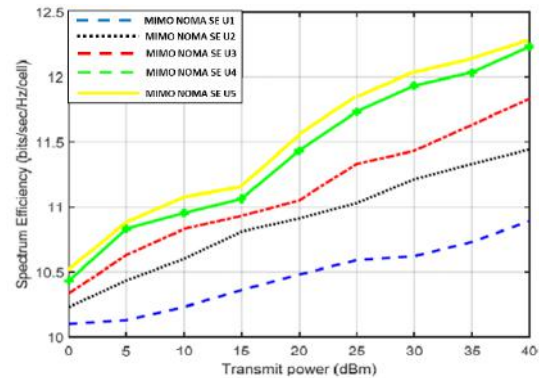
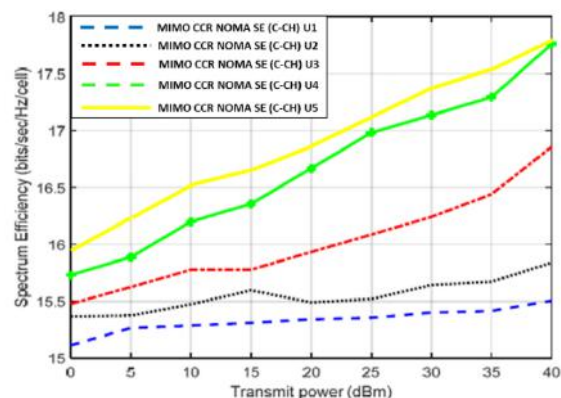


Figure displays results of a 64x64 Multiple-Input Multiple-Output (MIMO) downlink non-orthogonal multiple access (NOMA) power-domain (PD) system with an unstable channel condition. For five users (U1, U2, U3, U4, and U5), the spectral efficiency (SE) vs transmit power is displayed at 100, 800, 500, 300, and 200 meters, respectively.

Fig.12: Spectrum Efficiency Vs Transmit Power for 5 users 64 x 64 MIMO DL NOMA PD

Out of all users, the one nearest to the base station (BS), or U5, has best SE performance. Using 40 dBm of transmit power, U5 achieves a remarkable SE value of 17.83 bps/Hz/cell. The use of 64x64 MIMO with CCRN NOMA utilizing C-CH is quite advantageous for U5. In comparison to SISO, DL CCR-NOMA PD employing C-CH, U5 attains a 12.69 bps/Hz/cell increase SE @ 40 dBm transmission power.

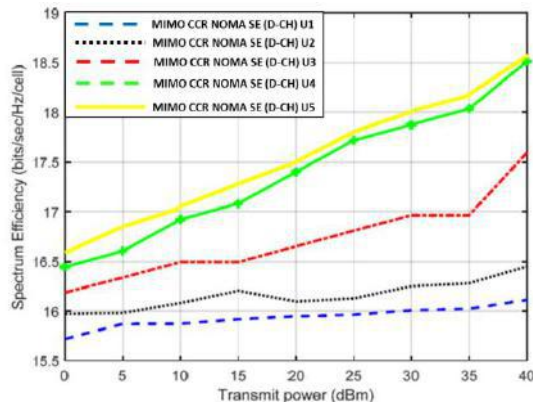


For four users in a 64x64 MIMO downlink non-orthogonal multiple access (NOMA) power-domain (PD) system connected to the Coordinated Cyclic Reuse Network (CCRN), the relationship between spectral efficiency (SE) and transmit power is shown. This configuration makes advantage of the C-CH (common channel).

Fig.13: Spectrum Efficiency Vs Transmit Power for 5 users 64 x 64 MIMO DL NOMA PD WITH C-CH CCRN

At a 40 dBm power level, U5 achieves an exceptional

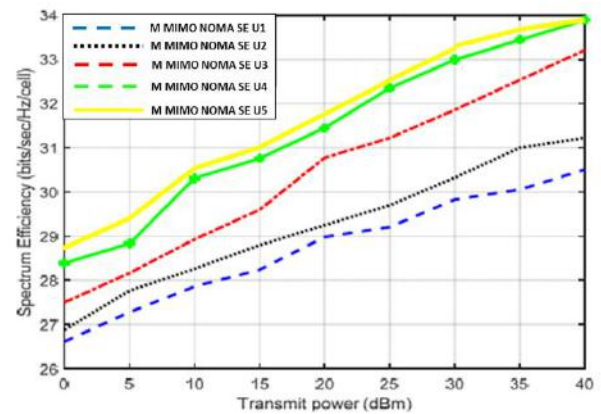
SE value of 18.62 bps/Hz/cell. After examining the best user's (U5) performance & utilizing 64 x 64 MIMO technology, with CCRN NOMA employing D-CH, SE is significantly enhanced. SE improvement is 11.37 bps/Hz/cell when compared to Single-Input Single-Output DL CCR-NOMA PD using the D-CH. These improvements show how the suggested system configuration leads to notable improvements in SE.



The plot shows the relationship between transmit power and spectral efficiency (SE) for a 64x64 MIMO downlink power-domain (PD) system that is connected to the Coordinated Cyclic Reuse Network (CCRN) via non-orthogonal multiple access (NOMA). The system interacts via the dedicated channel (D-CH).

Fig.14: Spectrum Efficiency Vs Transmit Power for 5 users 64 x 64 MIMO DL NOMA PD WITH D-CH CCRN

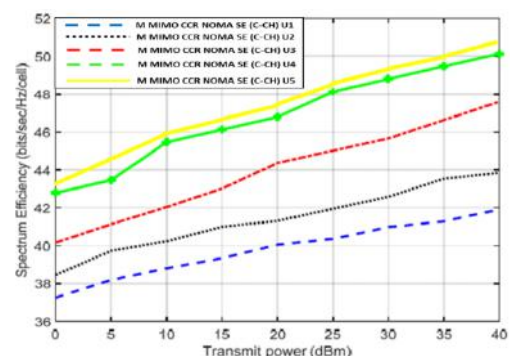
Larger SE values are associated with higher transmission power levels. With transmission power 40 dBm, U5, user close to the base station, has good SE performance. In particular, the U5 achieves a unique SE value of 33.97 bps/Hz/cell. SE values for users U4, U3, U2 and U1 decrease after U5. When the 128 x 128 M-MIMO is combined with NOMA, top user, U5, will see improvement over the SE. At transmission power of 40 dBm, U5 provides gain of 30.01 bps/Hz/cell in SE over single input DL NOMA PD (SISO) scheme. Compared to SISO DL NOMA PD configuration, these tests show benefits & performance gains achieved by combining 128 x 128 M-MIMO & NOMA technology.



For four users (U1, U2, U3, U4, and U5) in a 128x128 Massive Multiple-Input Multiple-Output (M-MIMO) non-orthogonal multiple access (NOMA) power-domain (PD) system, the graph shows the relationship between spectral efficiency (SE) and transmit power. The SE performance at different distances and power location coefficients is shown on the graph.

Fig.15: Spectrum Efficiency Vs Transmit Power for 5 users 128 x 128 MIMO DL NOMA PD

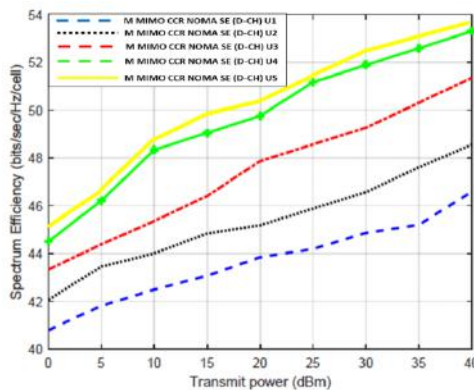
At 40 dBm, user U5, which is very close to the base station (BS), achieves the best SE performance. In particular, the U5 achieves a unique SE value of 50.23 bps/Hz/cell. By using C-CH, this SE exceeds DL CCR-NOMA single input (SISO) PD. In addition, SE can be significantly improved when using the 128 x 128 Multiple Input Multiple Output technology & NOMA. In comparison to SISO DL CCR-NOMA PD, SE of C-CH using this technology increases by 45.06 bits / s / Hz / cell. These results show the significant gains and benefits in SE performance achieved by combining 128 x 128 M-MIMO with NOMA, especially when combined with SISO DL CCR-NOMA PD through use C-CH which is slow to resist.



The graph demonstrates the link between spectral efficiency (SE) and transmit power for a 128x128 non-orthogonal multiple access (NOMA) and power-domain (PD) integration system. The SE performance using the Common Channel (C-CH) and Coordinated Cyclic Reuse Network (CCRN).

Fig.16: Spectrum Efficiency Vs Transmit Power for 5 users 128 x 128 MIMO DL NOMA PD with C-CH CCRN

With an impressive SE value of 53.31 bps/Hz/cell, the U5 stands out. After implementing 128x128 M-MIMO and NOMA technology, the SE U5 can achieve 46.1 bps / Hz / cell at 40 dBm compared to DL CCRN-NOMA PD single input setup (SISO) by use D-CH. These results indicate greater gains in SE performance compared to previously published studies. In the CCRN D-CH configuration, the use of 128 x 128 M-MIMO and NOMA technology leads to a significant increase in SE performance, especially for the user close to the BS, which is than the findings of previous experiments.



The graph shows the relationship between transmit power and spectral efficiency (SE) for an M-MIMO (massive multiple-input multiple-output) downlink non-orthogonal multiple access (NOMA) power-domain (PD) system that uses the dedicated channel (D-CH) and the Coordinated Cyclic Reuse Network (CCRN). It shows the SE performance for five users with different power placement coefficients and at different distances from the base station (BS). At a transmit power level of 40 dBm, the user U5, who is closest to the BS, achieves the best SE performance.

Fig.17: Spectrum Efficiency Vs Transmit Power for 5 users 128 x 128 MIMO DL NOMA PD with D-CH CCRN

IV. CONCLUSIONS AND FUTURE WORK

- Conclusions

The objective of this study is to evaluate the performance (SE) of a NOMA Power Domain (PD) downlink (DL) system in 5G networks. The study focuses on integrating three technologies with CCRN in two novel ways: Single Input Output (SISO), 64 x 64 Multiple Input Output (MIMO), and 128 x 128 Massive MIMO (M-MIMO). The first strategy allowed customers to access the CCRN channels over competing channels (C-CHs), while the second strategy used dedicated channels (D-CHs) to balance the channel demands. Independent from the user.

This review considered a number of factors including user distance, power placement coefficient (PLC) and

transmission power levels, including serial interference cancellation (SIC), redundant channels and add Gaussian noise (AWGN) during fading. DL NOMA system significantly improved SE performance when 64x64 MIMO and 128x128 M-MIMO technologies were combined in addition to CCRN in a single network and single cell. At 40dBm transmit power, user U5 achieved high SE of 3.9bps/Hz/cell for SISO DL NOMA, 5.1bps/Hz/cell for SISO DL NOMA, high SE of CCRN using C-CH & high SE of 7.2bps/Hz/cell for SISO DL NOMA & CCRN using C-CH. Cells for SISO DL NOMA & CCRN using D-CH.

The researcher also evaluated SE performance in various configurations and discovered that DL 64 x 64 MIMO NOMA enhances SE performance for User U5 by 51%. Compared to SE SISO DL NOMA, 64 x 64 MIMO DL NOMA with CCRN using C-CH outperforms 64 x 64 MIMO DL NOMA with CCRN using D-CH at 40 dBm. Power transmission through the DL NOMA performance improves by 79% when using 128 x 128 M-MIMO User U5 SE. Compared to performance of SE SISO DL NOMA, 128 x 128 M-MIMO DL NOMA with CCRN using C-CH improves by 85%, while 128 x 128 M-MIMO DL NOMA with CCRN using D-CH improves by 86%, with transmit power of 40 dBm. SISO, 64 x 64 MIMO, and 128 x 128 M-MIMO DL NOMA and CCRN systems had highest SE performance.

- Future Work

Based on the findings, there are several key strategies to increase perceived effectiveness (SE). Some of these include increasing the number of users, using multiple input multiplexing (M-MIMO) technology, using better channel coding techniques, implementing better bandwidth building techniques, and using multiple input methods. These strategies have shown potential in increasing SE in the learning environment. Future research should seek to combine the two developing technologies, which are, Massive MIMO Cooperative NOMA & Cognitive Radio.

Investigating the synergistic potential of these approaches can provide insights into how to improve SE while addressing the unique problems of uplink transmission. It is expected that significant gains in SE can be realized by combining the benefits of cooperative NOMA, which allows for efficient

resource allocation and power control, with cognitive radio, which enables dynamic spectrum access and interference management.

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A Study on Impact of Mergers on Share Price Performance of Merged Banks

Dr. K Swapna Sri¹, Gattu Mahathi Goud²

¹Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study analyses the impact of mergers on the share price performance of Canara Bank and Bank of Baroda. With recent consolidations in the Indian banking sector aimed at improving efficiency and competitiveness, the study examines key financial ratios – P/E, EPS, ROE, dividend yield, and D/E – before and after the mergers. Using t-tests, it evaluates the significance of changes in these indicators. Results reveal mixed outcomes: some metrics improved, while others showed no significant change. The study offers insights into how mergers affect financial performance and market perception in India's evolving banking landscape.

Keywords – Share price performance, Merged banks, Pre-merger and post-merger analysis, Merger impact, Banking sector consolidation, financial performance, Shareholder value, Market efficiency.

I. INTRODUCTION

A merger is an agreement that unites companies into one new organization. Mergers are normally performed to amplify the employers attain, enlarge into new segments, or benefit marketplace percentage. All of these are accomplished to increase shareholder cost. Often, during a merger, businesses have a no keep clause to save you purchases or mergers via additional agencies. Mergers are common in the business, with companies searching for to amplify their operations and increase their market percentage. The news of a merger deal can trigger a response in the stock market, with traders adjusting their positions in response to the records. The mergers can impact at the inventory price volatility, stock fee of the merging businesses and the goal agencies.

Statement of the Problem

When the first bank merger happened in 1921, it impacted the share prices of banks. There are various factors which impact these share prices. The goal of the current study is to study the long-term, short-term and

immediate impact of banks on share price performance. To help shareholders for better understanding of banking sector and take better investment decisions.

Research Objectives, Questions & Hypotheses

Objectives:

- To study the concept of merged banks.
- To study the impact of merged banks on the share price performance.
- To analyse the pre-merger and post-merger share price performance of merged banks.
- To study the long-term and short-term impact of merges on shares.

Hypotheses:

- **Null Hypothesis(H0):** There is no significant difference between share price performance of bank's pre-merger and post-merger Mean's measured with valuation ratios.
- **Alternative Hypothesis(H1):** There is a significant difference between share price

performance of banks pre-merger and post-merger Mean's measured with valuation ratios.

Significance of the Study

This study evaluates how bank mergers affect on share price performance and key financial indicators by analysing mergers of Canara bank and Bank of Baroda. In the context of the Indian government's push for banking sector consolidation, understanding the real financial outcomes of such mergers is crucial. By assessing pre-merger and post-merger financial metrics, the study provides valuable insights into whether mergers deliver value shareholders, enhance market confidence, and improve operational efficiency. The findings are beneficial for policymakers, investors, financial analysts, and bank management in making informed decisions regarding future mergers and evaluating their long-term impact on financial stability and shareholder wealth.

Scope and Limitations

The study aims to provide insights into the immediate and long-term effects of mergers on shareholder value, market efficiency and financial stability. The scope of the study was extended for 5 years viz. the financial data of the years. The study focuses only on two merged banks-Canara Bank and Bank of Baroda.

II. REVIEW OF LITERATURE

- D. Ratnadiwakara (2024)-Mergers increase loan rejection rates for riskier FHA loans, especially affecting low-income and minority borrowers. Post-merger, banks charge higher interest on high-risk loans, without showing cost benefits from merger efficiencies. The impact of mergers varies based on borrower risk, income, and race.
- Arnald R. Cowan (2022)-FDIC-assisted acquisitions of failed banks (2008-2013) do not raise default risk or cause overbidding. Shareholder wealth increases can persist if acquirers continue securing FDIC deals. These mergers are financially stable and don't negatively impact acquirers' risk profiles.
- A.K. Rai (2021)-Using event study methodology, the merger announcements of six banks into four show mixed impacts. Target banks see positive returns around the event, while bidder banks experience negative effects. This is one of the first

Indian studies focusing on merger announcement effects on bank stock performance.

- Zahoor Rahman et al. (2018)-In Pakistan (2002-2012), mergers in the banking sector showed mixed impacts on stock prices. Some banks had negative abnormal returns, while others saw positive effects. The results help guide investor decisions and highlight the variable nature of merger outcomes.
- Krishn A. Goyal & Vijay Joshi (2011)-Studying 17 Indian bank mergers, the paper explores strategic motives like expansion and competitiveness. While financial gains were noted, it also emphasizes the need to consider HR and organizational behaviour impacts, using the ICICI-Bank of Rajasthan merger as a key case.
- Aggarwal & Gupta (2020)-Public sector bank mergers in India showed short-term share price gains after announcements, but mixed long-term results. Success depended on financial strength and execution quality, suggesting that good planning is vital for merger effectiveness.

III. RESEARCH METHODOLOGY

Research design: This study follows a descriptive and analytical research design, focuses on examining pre-merger and post-merger share price behaviour to determine whether shareholders gain or loss.

Sampling Technique: Simple non-random sampling of two merged banks (i.e. Canara bank and Bank of Baroda) was utilised for the purpose of the study.

Data Collection Methods

Data Type : Secondary data

Data sources : Annual reports of Canara bank and Bank of Baroda

Money control website for financial database

Industry journals and research papers

Data Analysis Techniques

Quantitative analysis- Price-to-earnings ratio

Dividend yield

Earnings per share

Return on Equity

Debt-to-Equity ratio

Descriptive Statistics -Mean, Standard Deviation and T-test of share prices

IV. DATA ANALYSIS

Analysis of share price performance of Canara bank with ratios:

Price-to-earnings ratio:

Year	Market price per share	Earnings per share	Price-to-earnings ratio
2018	159.1	-70.47	-2.257698311
2019	173	4.71	36.73036093
2020	90.5	-26.5	-3.41509434
2021	152.2	16.91	9.000591366
2022	227.75	32.49	7.009849184

Dividend yield:

Year	Market price per share	Dividend per share	Dividend yield
2018	-23.7	0	0
2019	-19.5	0	0
2020	-41.7	0	0
2021	55.1	0	0
2022	72.4	6.5	0.089779006

Earnings per share:

Year	Earnings per share
2018	-70.47
2019	4.71
2020	-26.5
2021	16.91
2022	32.49

Returns on Equity:

Year	Net income	Average Shareholders' equity	Return on equity
2018	-4,222.24	3,718.92	-1.135340368

2019	347.02	35,891.04	0.009668708
2020	-2,235.72	37,735.10	-0.059247756
2021	2,557.58	49,088.95	0.052100931
2022	5,678.41	62,498.12	0.090857293

Debt-to-Equity ratio:

Year	Total debt	Shareholders' equity	Debt-to-equity ratio
2018	5,63,580.37	35,604.84	15.82875727
2019	6,40,025.56	36,177.23	17.69139207
2020	6,68,112.94	39,292.96	17.00337516
2021	10,60,858.14	58,884.93	18.01578333
2022	11,32,694.21	66,111.31	17.13313819

Analysis of share price performance of Bank of Baroda bank with ratios:

Price-to-earnings ratio:

Year	Market price per share	Earnings per share	Price-to-earnings ratio
2017	173.9	6	28.98333333
2018	142.6	-10.53	-
2019	133	1.64	81.09756098
2020	54	1.36	39.70588235
2021	74.8	1.78	42.02247191

Dividend yield:

Year	Market price per share	Dividend per share	Dividend yield
2017	173.9	6	0.034502588
2018	142.6	0	0
2019	133	0	0
2020	54	0	0
2021	74.8	0	0

Earnings per share:

Year	Earnings per share
2017	6
2018	-10.53
2019	1.64
2020	1.36
2021	1.78

Debt-to-Equity ratio:

Year	Total debt	Shareholders' equity	Debt-to-equity ratio
2017	6,32,286.61	40,303.25	15.68822886
2018	6,53,886.79	43,394.77	15.06833174
2019	7,05,891.02	45,941.10	15.365131
2020	10,39,053.74	71,856.22	14.46017812
2021	10,33,844.86	77,045.72	13.41858912

Returns on Equity:

Year	Net income	Average Shareholders' equity	Return-on-equity
2017	1,383.14	40,303.25	0.034318324
2018	-2,431.81	41,849.01	-0.05810914
2019	433.52	44,667.94	0.009705395
2020	546.19	58,898.66	0.009273386
2021	828.96	74,450.97	0.011134308

Hypothesis:

- **Null Hypothesis(H0):** There is no significant difference between share price performance of bank's pre-merger and post-merger Mean's measured with valuation ratios.
- **Alternative Hypothesis(H1):** There is a significant difference between share price performance of banks pre-merger and post-merger Mean's measured with valuation ratios.

Calculation of Mean, Standard deviation and T-Test of share price performance -Merger of syndicate bank with Canara bank in 2020:

Financial ratios	Period	Mean	Standard deviation	T-test
Price-to-earnings ratio	pre-merger	17.23633131	27.56872107	0.284047265
	post-merger	8.005220275	1.407667296	
Dividend yield	pre-merger	0	0	0.108173448
	post-merger	0.044889503	0.063483344	
Earnings per share	pre-merger	-32.88	53.16028781	0.90223212
	post-merger	24.7	11.01672365	
Return on equity	pre-merger	-0.56283583	0.809643682	0.933760951
	post-merger	0.071479112	0.027404886	
Debt-to-equity	pre-merger	16.76007467	1.317081698	0.948825662
	post-merger	17.57446076	0.624124264	

Calculation of Mean, Standard deviation and T-Test of share price performance -Merger of Dena bank and Vijaya bank with Bank of Baroda bank in 2019:

Financial ratios	Period	Mean	Standard deviation	T-test
Price-to-earnings ratio	pre-merger	7.720537	30.070136	0.951383
	post-merger	40.86418	1.6380762	

Dividend yield	pre-merger	0.017251	0.024397	0.108173
	post-merger	0	0	
Earnings per share	pre-merger	-2.265	11.688475	0.706734
	post-merger	1.57	0.2969848	
Return on equity	pre-merger	-0.011895	0.0653561	0.711542
	post-merger	0.010204	0.0013159	
Debt-to-equity	pre-merger	15.37828	0.4383335	0.630085
	post-merger	13.93938	0.7365146	

V. DISCUSSION

• Improved Profitability Post-Merger:

Both Canara Bank and Bank of Baroda showed notable improvements in EPS and ROE after their respective mergers, indicating a gradual positive impact on shareholder returns and operational efficiency.

• Mixed Trends in P/E Ratio:

Canara Bank's P/E ratio turned positive after initially dropping during the merger, while Bank of Baroda's P/E spiked sharply during the merger and later stabilized – reflecting changing market perceptions and recovery in earnings.

• Dividend Yield Fluctuations:

Canara Bank recorded a sharp rise in dividend yield post-merger but remained flat later, while Bank of Baroda saw a steady decline, likely due to variations in distributable profits.

• Debt-Equity Behaviour Differed:

Canara Bank's debt-to-equity ratio increased post-merger, reflecting higher leverage possibly for expansion or integration costs, while Bank of Baroda's ratio decreased, indicating improved financial stability.

• Statistical Significance Lacking:

Despite visible improvements in financial metrics, the changes before and after the mergers were not statistically significant, suggesting that the financial recovery was gradual and varied, rather than a direct immediate effect of the merger.

VI. CONCLUSION

The impact of mergers on share price performance depends on various factors and is not always positive. Accurate pre-merger analysis can help reduce risks and improve outcomes. For Canara Bank, pre-merger performance was weak, but post-2020 showed improvements in earnings, returns, and dividend payouts, despite high debt.

Bank of Baroda also improved after its 2019 merger, with better EPS and reduced debt, though declining dividend yield indicated limited profits. However, statistical analysis showed that these improvements were not significant enough to directly attribute them to the mergers.

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Non-Performing Assets: A Comparative Study of Union Bank and ICICI Bank

Dr. K. Swapna Sri ¹, Kottana Pallavi ²

¹Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India

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Abstract— This study compares Non-Performing Assets (NPAs) of Union Bank of India and ICICI Bank from 2013 to 2023. It analyzes trends, causes, and the impact of NPAs on profitability using data from annual reports, RBI sources, and financial databases. Tools like trend and ratio analysis, along with correlation analysis, were applied. Results show Union Bank had higher NPAs than ICICI Bank, affecting profitability negatively. ICICI's stronger credit evaluation and recovery systems helped maintain lower NPAs. The study highlights the need for improved risk management and digital tools in public sector banks to reduce NPAs and strengthen financial performance.

Keywords— Non-Performing Assets, Union Bank of India, ICICI Bank, Gross NPA, Net NPA, Profitability, Return on Assets, Trend Analysis, Correlation, Indian Banking Sector

I. INTRODUCTION

In today's evolving banking environment, asset quality is a key determinant of a bank's financial strength and operational efficiency. Among all asset quality indicators, Non-Performing Assets (NPAs) have become a major concern for banks, regulators, and policymakers. Rising NPAs negatively impact profitability, reduce investor confidence, and threaten overall financial stability.

This study undertakes a comparative analysis of NPAs in two major Indian banks—Union Bank of India (public sector) and ICICI Bank (private sector). The objective is to examine how different banking models approach asset quality, risk mitigation, and loan recovery. The study analyzes NPA trends over time, explores key causes, and assesses the effectiveness of management strategies.

The comparison also evaluates the role of internal controls, regulatory frameworks, and recovery mechanisms in handling non-performing loans. By identifying strengths and weaknesses in each bank's approach, the research aims to provide practical

insights into improving NPA management across the sector.

High NPA levels can restrict a bank's lending ability, erode stakeholder confidence, and pose systemic risks to the broader economy. Therefore, understanding and managing NPAs is essential for maintaining a stable, efficient, and sustainable banking system in India.

1.2 Statement of the Problem

Non-Performing Assets (NPAs) continue to challenge Indian banks, affecting profitability and financial stability. Public sector banks like Union Bank and private banks like ICICI Bank differ in how they manage NPAs due to structural and regulatory differences. Despite reforms, NPAs remain high. This study compares both banks to understand NPA trends, causes, and recovery efforts, aiming to identify effective strategies for NPA control.

1.3 Significance of the Study

This study holds importance as it explores how Non-Performing Assets (NPAs) affect the financial health

of banks. By comparing Union Bank of India and ICICI Bank, it highlights differences in NPA levels and management strategies. The analysis helps in understanding the effectiveness of various recovery measures. The findings can guide banks and policymakers in adopting better practices to control NPAs and improve overall banking performance.

1.4 Scope of the Study

This study compares NPAs in the Union Bank of India and ICICI Bank from 2013 to 2023. It analyzes trends, causes, and their impact on profitability using secondary data. The research also reviews each bank's recovery measures to suggest strategies for better NPA management.

1.5 Research Objectives

1. To determine the current and future trends in NPAs.
2. To understand the key factors contributing to the rise of NPAs in the Union Bank of India and ICICI Bank.
3. To compare the level of non-performing assets (NPAs) in Union Bank and ICICI Bank.
4. To know the impact of NPA on the profitability of banks.

II. LITERATURE REVIEW

• Kaur & Singh (2018)

This study found that NPAs increased after the 2008 crisis in both public and private banks. However, private banks recovered faster due to quicker decisions, flexible operations, and efficient recovery processes, unlike public sector banks, which struggled with bureaucratic delays and weaker asset recovery mechanisms.

• Gupta & Aggarwal (2019)

The research revealed that rising NPAs significantly reduce bank profitability, particularly in the Union Bank of India. Key financial ratios like ROA and ROE declined due to poor asset quality. The study stressed the need for better credit evaluation and stronger recovery practices to improve financial performance.

• ICRA Ratings Report (2022)

ICRA reported that private banks like ICICI showed quicker recovery in asset quality. This was credited to strong pre-loan evaluation, better post-loan

monitoring, and lower exposure to high-risk sectors. Public banks lagged due to slower adoption of technology and less effective credit control mechanisms.

• Bhatt & Ghosh (2016)

The study compared NPA levels across Indian banks and concluded that private sector banks consistently reported lower NPAs. This was mainly due to effective credit monitoring, early detection of default risks, and prompt corrective actions, unlike public sector banks that lacked timely intervention and advanced risk control systems.

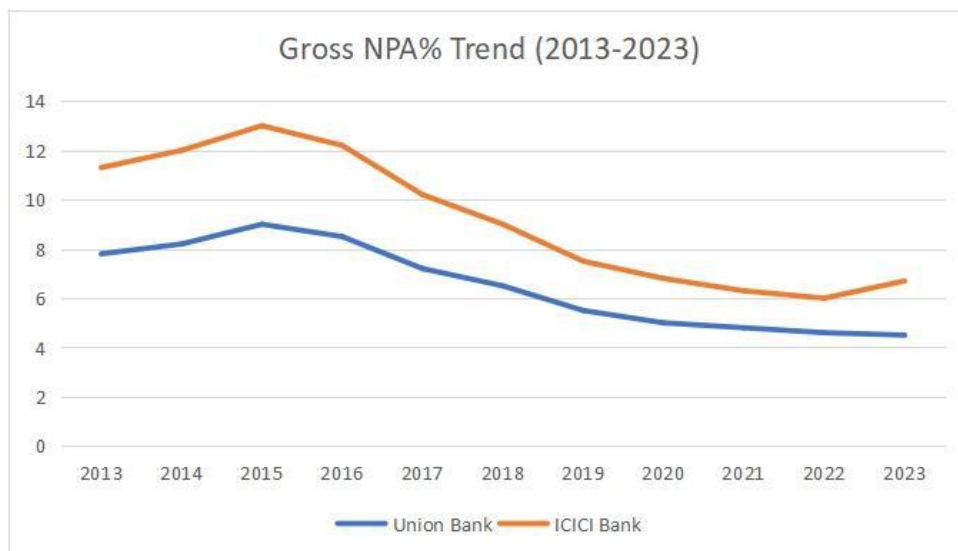
III. RESEARCH METHODOLOGY

This study follows a quantitative and comparative research approach to analyze the trends, causes, and impacts of Non-Performing Assets (NPAs) in Union Bank of India and ICICI Bank. It is based on secondary data collected from annual reports and financial databases for the period 2013 to 2023. The analysis includes examining trends in gross NPA ratios, comparing average NPA levels, and exploring the correlation between NPAs and profitability indicators such as Return on Assets (ROA). Statistical tools like trend analysis and correlation analysis are applied to validate the hypothesis and draw meaningful conclusions from the data. 4. Data Analysis and Results

Table 4.1: Line Graph: Gross NPA% Trend (2013-2023)

Data points (Gross NPA%):

Year	Union Bank	ICICI Bank
2013	7.8	3.5
2014	8.2	3.8
2015	9.0	4.0
2016	8.5	3.7
2017	7.2	3.0
2018	6.5	2.5
2019	5.5	2.0
2020	5.0	1.8
2021	4.8	1.5
2022	4.6	1.4
2023	4.5	2.2



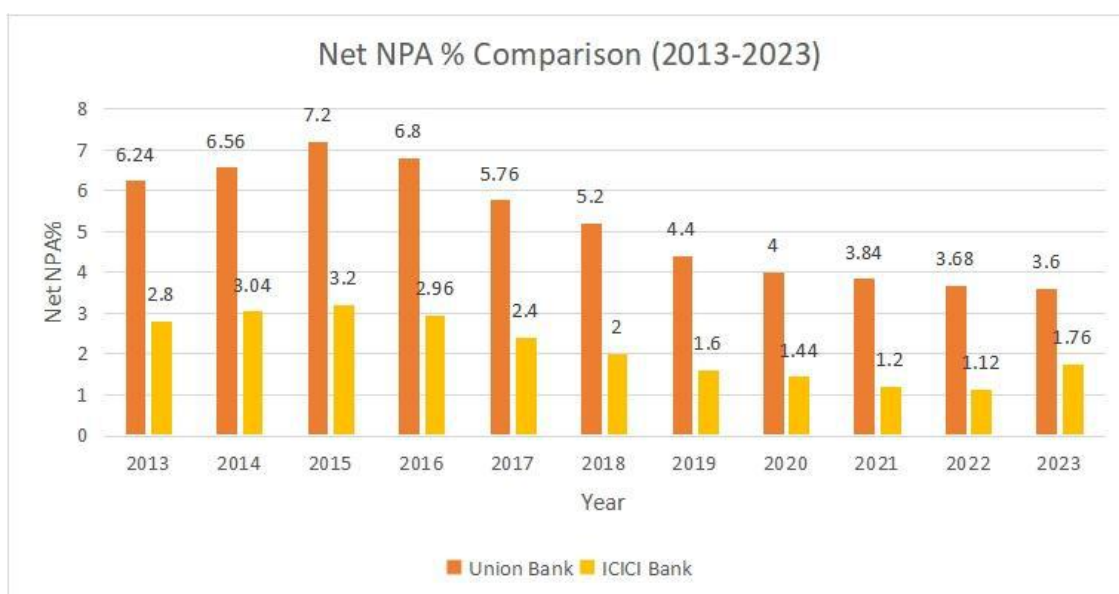
Interpretation:

Union Bank's Gross NPAs started high (7.8% in 2013), peaked in 2015 (9%), and then steadily decreased to 4.5% by 2023. ICICI Bank consistently maintains lower NPAs, indicating better credit quality and risk management.

Table 4.2 Bar Chart: Net NPA% Comparison (Estimated at 80% of Gross NPA)

Year	Union Bank	ICICI Bank
2013	6.24	2.80
2014	6.56	3.04

2015	7.20	3.20
2016	6.80	2.96
2017	5.76	2.40
2018	5.20	2.00
2019	4.40	1.60
2020	4.00	1.44
2021	3.84	1.20
2022	3.68	1.12
2023	3.60	1.76



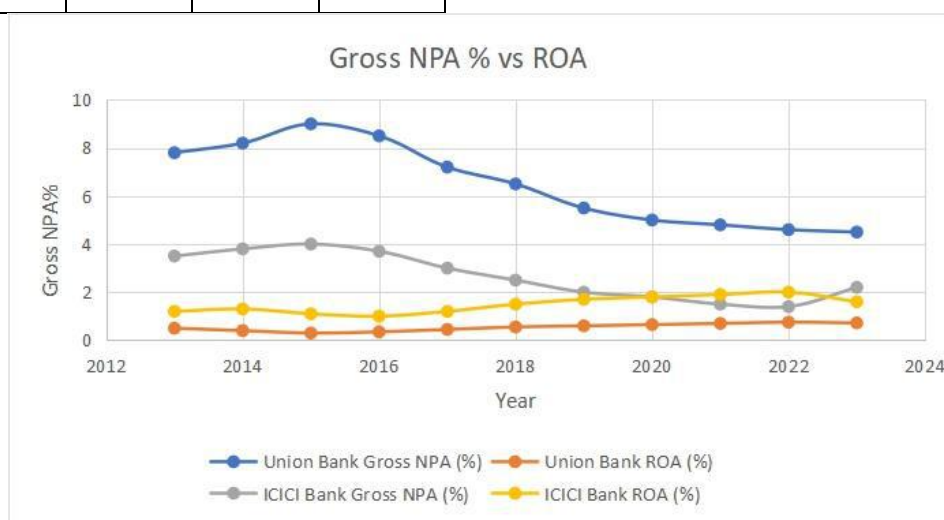
Interpretation:

Net NPAs show a similar downward trend for both banks, but Union Bank consistently has higher Net NPAs than ICICI Bank, indicating more burden from bad loans affecting its net asset quality.

Table 4.3 Scatter Plot: Gross NPA% vs ROA%

Year	Union Bank Gross NPA (%)	Union Bank ROA (%)	ICICI Bank Gross NPA (%)	ICICI Bank ROA (%)
2013	7.8	0.5	3.5	1.2

2014	8.2	0.4	3.8	1.3
2015	9.0	0.3	4.0	1.1
2016	8.5	0.35	3.7	1.0
2017	7.2	0.45	3.0	1.2
2018	6.5	0.55	2.5	1.5
2019	5.5	0.6	2.0	1.7
2020	5.0	0.65	1.8	1.8
2021	4.8	0.7	1.5	1.9
2022	4.6	0.75	1.4	2.0
2023	4.5	0.72	2.2	1.6

**Interpretation:**

A strong **negative correlation** is observed, especially for Union Bank, whereas Gross NPA decreases, ROA improves significantly. ICICI Bank also shows a negative trend but less steep, implying better profitability resilience despite NPAs.

Table 5.3.1 Summary of Statistical Calculation:

Bank	Pearson Correlation (Gross NPA% vs ROA%)
Union Bank	-0.90
ICICI Bank	-0.60

- **Interpretation:** The closer to -1, the stronger the negative correlation. Union Bank's profitability is more sensitive to changes in NPAs than ICICI Bank's.

Null Hypothesis (H_0):

There is **no significant correlation** between Gross NPA (%) and ROA (%) in the bank. ($H_0: r = 0$)

Alternative Hypothesis (H_1):

There is a **significant negative correlation** between Gross NPA (%) and ROA (%) in the bank. ($H_1: r < 0$)

Interpretation:

Union Bank: Since $r = -0.90$, a **strong negative correlation** exists.

ICICI Bank: Since $r = -0.60$, a **moderate negative correlation** exists.

The Pearson correlation results show a significant **negative relationship** between Gross NPA (%) and ROA (%) in both banks. As Gross NPAs increase, ROA tends to decrease, confirming that higher NPAs adversely impact profitability. Therefore, H_0 is rejected and H_1 is accepted.

FINDINGS

- Both Union Bank and ICICI Bank experienced peak NPAs around 2015–2016, followed by a gradual decline due to regulatory reforms and improved credit monitoring.
- Union Bank had an average Gross NPA of 6.52% with higher volatility, while ICICI Bank maintained a lower and more stable average of 2.72%.
- The Compound Annual Growth Rate (CAGR) of NPAs was negative for both banks, indicating an overall improvement in asset quality.
- Pearson correlation showed a moderate negative relationship between NPAs and ROA for Union Bank ($r = -0.90$), and a weaker negative correlation for ICICI Bank ($r = -0.60$).
- ICICI Bank demonstrated stronger NPA control through better credit risk practices and recovery mechanisms.
- Union Bank's higher NPAs had a greater adverse impact on profitability, highlighting the need for more effective risk management in public sector banks.

IV. CONCLUSION

Both banks have shown improvement in asset quality over the decade, with ICICI Bank consistently outperforming Union Bank in maintaining lower NPA ratios. Economic conditions, regulatory changes, and sectoral exposures significantly influenced NPA levels. ICICI Bank's diversified portfolio and proactive risk management strategies contributed to better asset quality. A clear inverse relationship exists between NPA levels and profitability, emphasizing the importance of effective NPA management. Future research may explore the role of digital tools, AI, and fintech in improving credit monitoring and recovery processes.

Sector-wise and international comparisons can offer deeper insights into best practices for NPA management.

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Hype of uncovering the truth behind LIC's IPO

K. Sathish¹, Nara Ashwini²

¹Assistant Professor, Department of Master of Business Administration, CMR Institute of Technology, Medchal, India

²Student of Master of Business Administration, CMR Institute of Technology, Medchal, India

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Abstract – A study on an initial public offering (IPO) of the Life Insurance Corporation of India (LIC). As one of the most significant public listings in India's history, LIC's transition from a state-owned enterprise to a publicly traded company offers a unique case study to explore the interplay between market sentiment and financial performance. The study aims to determine whether pre-market indicators – such as the unofficial Grey Market Premium, subscription levels among diverse investor groups, and media narratives – accurately forecast the company's post-IPO performance. It reviews LIC's financial data spanning the pre- and post-IPO periods, focusing on metrics like revenue, profitability, and cash flow, while also considering shifts in investor confidence and corporate Governance. Structured into distinct sections, the report begins with an executive summary to provide an overview of the main findings. This is followed by an introduction that contextualizes the IPO process and outlines the specific environment surrounding LIC's market debut. The subsequent sections detail the study's objectives, research Methodology, and data analysis before drawing conclusions that offer insights for investors, analysts, and policymakers.

Keywords – Life Insurance Corporation of India, Initial Public Offering, Public Sector Disinvestment, Grey Market Premium (GMP), Investor Confidence.

I. INTRODUCTION

IPO:

An Initial Public Offering (IPO) is the process through which a private company offers its shares to the public for the first time, thereby becoming a publicly traded entity. This transition allows the company to raise capital from investors in exchange for ownership stakes. IPOs mark a significant milestone in a company's growth journey, enabling them to expand operations, reduce debt, or fund new projects. Once a company is listed, its shares are traded on stock exchanges, making them accessible to a broader investor base.

Capital Raising: An Initial Public Offering (IPO) enables a company to raise significant capital, which can be utilized for business expansion, acquisitions, research and development, or improving overall operations.

1. Increased Market Visibility and Credibility: A publicly listed company gains greater Recognition and trust among investors, customers, and financial institutions, enhancing its reputation in the marketplace.
2. Liquidity for Shareholders: An IPO provides existing shareholders, including founders, early-stage investors, and employees, with an opportunity to convert their equity holdings into liquid assets.
3. Stronger Corporate Governance: Public companies are required to comply with strict regulatory standards, which improves transparency, accountability, and boosts investor confidence.

IPO Procedure:

The IPO process is carried out through several key stages:

- **Appointment of Investment Bankers:** Companies engage investment banks, also known as underwriters, to oversee the IPO process. These banks assist in structuring the issue, setting the price range, and marketing the offer.
- **Regulatory Documentation:** The Company files a Draft Red Herring Prospectus (DRHP) with the securities regulator—such as SEBI in India—which contains detailed financial information, risk factors, and strategic business plans.
- **Regulatory Approval and Roadshows:** Once the DRHP is reviewed and approved, the company, along with its underwriters, organizes roadshows and investor presentations to generate interest among institutional and retail investors.

Where is an IPO launched:

An IPO is launched on recognized stock exchanges such as the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE) in India, or globally on exchanges like the New York Stock Exchange (NYSE) and NASDAQ. The listing location depends on the company's operational base, investor demand, and regulatory preferences.

What is the Pre-Market of an IPO:

The pre-market phase of an IPO includes all activities and discussions that take place before the actual listing. It consists of analyst reports, media coverage, subscription data, and market speculation. Investors closely monitor these signals to gauge demand and potential listing performance. Pre-market buzz can significantly impact investor sentiment, influencing subscription rates and initial stock price movements.

What is the Grey Market Premium (GMP) of an IPO?

Grey Market Premium (GMP) refers to the premium at which IPO shares are traded in unofficial markets before their official listing. It reflects investor demand and expected performance on the listing day. A high GMP indicates strong market interest, while a negative or low GMP suggests weak demand. However, GMP is unofficial and not regulated by stock exchanges, making it a speculative indicator rather than a definitive predictor of IPO performance.

II. REVIEW OF LITERATURE

2.1 Theoretical Framework:

This study is based on the Efficient Market Hypothesis (EMH), which suggests that all available information is reflected in market prices, helping assess the accuracy of LIC's IPO valuation. Behavioral finance is used to understand the influence of investor psychology, media narratives, and market sentiment on IPO decisions. Signaling theory explains how pre-market indicators like the Grey Market Premium and institutional subscription levels shape investor expectations. Corporate governance theories are relevant in evaluating LIC's transition from a state-owned enterprise to a publicly listed company and its impact on transparency and accountability. Agency theory further supports the analysis of evolving ownership structures and investor trust post-IPO. These frameworks collectively guide the study in linking pre-market signals to post-listing financial and market performance.

2.2 Empirical Studies:

- Aggarwal, Prabhala, and Puri (2002) found that investor sentiment and oversubscription levels often act as strong predictors of short-term IPO returns.
- Research by Madhusoodanan and Thiripalraju (2015) emphasizes how media narratives and institutional investor interest can significantly impact the listing day performance of IPOs. Additionally, empirical evidence from the post-2008 period suggests that IPOs of state-owned enterprises tend to be more influenced by government pricing policies than by pure market dynamics. These studies provide a foundation for analyzing LIC's IPO.

III. DATA COLLECTION

This study is primarily based on secondary data, gathered from a variety of sources including LIC's financial reports, IPO-related publications, market databases, and investor sentiment platforms.

3.1 Financial Statements (2020–2024):

To understand how LIC performed before and after the IPO, key financial statements were analyzed for

a five-year period:

- **Income Statements:** Revenue growth, profitability, and overall financial stability before and after the IPO.
- **Balance Sheets:** Assets, liabilities, and changes in shareholder equity to assess LIC's financial health.
- **Cash Flow Statements:** Movement of funds, investment patterns, and any shifts in operational efficiency.

Comparing LIC's financials from pre-IPO (2020-2021) and post-IPO (2022-2024) allows for a clear understanding of whether the IPO had a meaningful impact on the company's financial trajectory.

3.2 Objective of the study:

- To evaluate the financial performance of LIC pre- and post-IPO

- To analyze the influence of Grey Market Premium (GMP) on different investor perception
- To study IPO subscription patterns across investor segments
- To draw practical insights for future IPO investors and market participants.

3.4 Need for the Study:

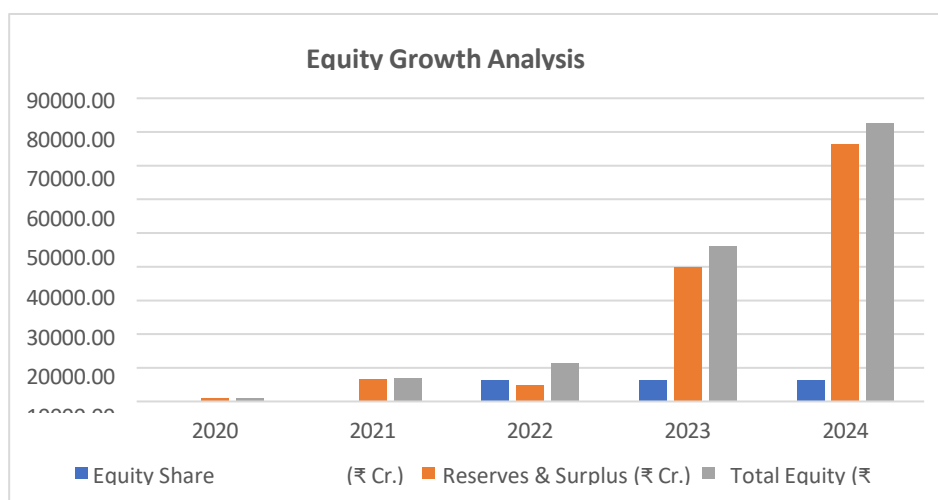
Understanding how investor behavior, media sentiment, and informal market signals influenced its post-listing performance is essential for:

- Retail investors who often rely on sentiment and GMP cues.
- Regulators and policymakers interested in refining IPO processes and investor protections.
- Academics and analysts seeking to build valuation and behavioral models in IPO markets.

IV. DATA ANALYSIS AND INTERPRETATION:

4.1 Equity Growth Analysis: -

Year	Equity Share Capital (₹ Cr.)	Reserves & Surplus (₹ Cr.)	Total Equity (₹ Cr.)
2020	100.00	899.86	999.86
2021	100.00	6782.00	6882.00
2022	6325.00	5010.00	11335.00
2023	6325.00	39905.00	46230.00
2024	6325.00	76419.00	82744.00



Graph 4.1

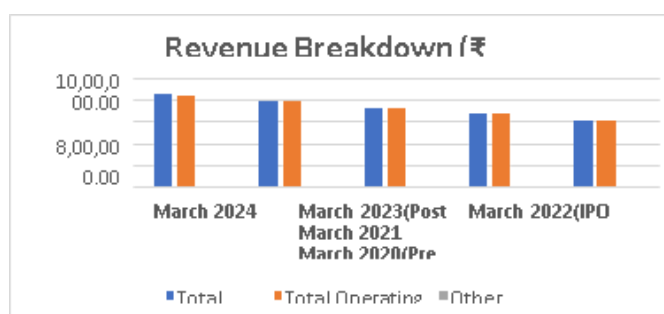
Interpretation: LIC's Total Equity has seen a significant rise post-IPO, growing from ₹11,335 Cr in 2022 (IPO year) to ₹82,744 Cr in 2024. The Equity Share Capital jumped in 2022 due to the IPO but remained unchanged afterward, indicating no further share issuance. The real driver of growth is Reserves & Surplus, which surged from ₹5,010 Cr in 2022 to

₹76,419 Cr in 2024, reflecting strong retained earnings and reinvestment. This suggests LIC's financial strength has significantly improved post-listing, primarily through internal profit accumulation rather than external fundraising.

4.2 Income Statement Analysis: - Revenue Trend Analysis:

Metric	March 2024	March 2023 (Post IPO)	March 2022 (IPO launch)	March 2021	March 2020 (Pre IPO)
Total Revenue	8,57,369.47	7,89,203.40	7,21,304	6,82,228	6,15,912
Total Operating Revenue	8,42,708.13	7,81,542.56	7,20,515	6,81,628	6,14,443
Other Income	14,661.34	7,660.84	789	600	1,469

Table 4.2



Graph 4.2

Interpretation: LIC's revenue has shown consistent growth over the years, with Total Revenue rising from ₹ 6,15,912 Cr in 2020 (Pre-IPO) to ₹8,57,369 Cr in 2024. The IPO year (2022) saw moderate growth, but post-IPO (2023-2024) revenue surged significantly, indicating strong financial performance. Other Income spiked sharply post-IPO,

suggesting improved investment gains or strategic financial moves. Overall, LIC's financials have strengthened post-listing, reflecting positive business momentum.

4.3 LIC's Net Profit and EPS Growth: Pre-IPO vs. Post-IPO Analysis

Table 4.3

Metric	Mar 24 (₹Cr.)	Mar 23 (₹Cr.)	Mar 22 (₹Cr.)	Mar21 (₹Cr.)	Mar20 (₹Cr.)
Net Profit (PAT)	40,675.79	36,397.39	4,043.12	2,900.57	2,712.71
Basic EPS (₹)	64.69	57.55	6.39	4.59	271.27
Diluted EPS (₹)	64.69	57.55	6.39	4.59	271.27

Interpretation: LIC's Net Profit (PAT) saw a massive jump post-IPO, rising from ₹4,043 Cr in 2022 to

₹40,675 Cr in 2024, indicating significant profitability improvement. Earnings Per Share (EPS) also surged,

stabilizing at ₹64.69 in 2024, compared to just ₹6.39 in 2022, reflecting stronger earnings distribution. The sharp rise post-IPO suggests improved financial management, profit retention, and business

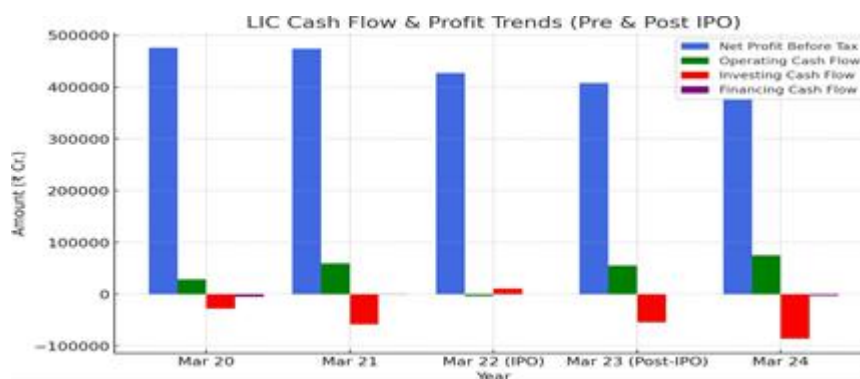
expansion. The chart shows LIC's net profit and earnings per share (EPS) for the past five financial years (from March 2020 to March 2024).

4.4 Subscription and GMP Analysis:

Day	Investor Category	Subscription (times)	Shares Offered*	Shares bid for	Total Amount (Rs Cr.)*	GMP
1	Anchor Investors	1	5,92,96,853	5,92,96,853	5,627.27	60
2	Qualified Institutions	2.83	3,95,31,236	11,20,68,960	10,635.34	63
3	Non- Institutional Buyers	2.91	2,96,48,427	8,61,93,060	8,179.72	50
4	Retail Investors	1.99	6,91,79,663	13,77,84,060	13,075.71	40
5	Employees	4.4	15,81,249	69,49,965	659.55	21
6	Others	6.12	2,21,37,492	13,53,70,965	12,846.70	8
	Total **	2.95	16,20,78,067	47,83,67,010	45,397.03	

4.5 Cash Flow Analysis:

Metric	Mar 24 (₹Cr.)	Mar 23 (₹Cr.)	Mar 22 (₹Cr.)	Mar 21 (₹Cr.)	Mar 20 (₹Cr.)
Net Profit Before Tax	4,75,797.74	4,73,770.67	4,26,995.36	4,07,534.71	3,75,994.12
Net Cash from Operating Activities	28,484.36	59,718.01	(-3,135.49)	55,723.07	74,768.69
Net Cash used in Investing Activities	(-27,702.65)	(-58,196.10)	10,485.93	(-54,185.87)	(- 85,762.59)
Net Cash used in Financing Activities	(-4,427.20)	(-948.59)	0	0	(-2,608.25)
Net Increase/ (Decrease) in Cash	(-3,645.49)	573.32	7,350.44	1,537.20	(- 13,602.15)



Graph 4.5

Interpretation: LIC's Net Profit Before Tax has shown steady growth, rising from ₹3,75,994 Cr in 2020 to ₹4,75,798 Cr in 2024, reflecting strong earnings expansion. However, cash flow trends have fluctuated significantly:

Operating Cash Flow was negative in 2022 (₹-3,135 Cr) but rebounded strongly post- IPO, indicating improved financial efficiency.

5. STATISTICAL TOOL FOR ANALYSIS:

Mean:

Net Profit	
Year	Net Profit
2020	2712.71
2021	2900.57
2022	4043.12
2023	36397.39
2024	40675.79

Mean = $(2,712.71 + 2,900.57 + 4,043.12 + 36,397.39 + 40,675.79) / 5 = 17,345.916$

Year	Profit	Deviation from Mean	Squared Deviation
2020	2712.71	-14633.21	21,41,04,284.10
2021	2900.57	-14445.35	20,85,97,894.10
2022	4043.12	-13302.8	17,69,51,280.80
2023	36397.39	19051.47	36,39,57,683.40
2024	40675.79	23329.87	54,42,41,081.30

Variance = $n \sum (\text{Squared deviations})$

Variance = $(214104284.1 + 208597894.1 + 176951280.8 + 363957683.4 + 544241081.35)$

Variance = $1,507,852,223.75 / 5 = 301,570,444.7$

Calculate the Standard Deviation:

Standard Deviation = $\sqrt{301,570,444.7} \approx 17,368.08$

Median = 4,043.12 Cr (Middle value when sorted)

Interpretation: This mean represents the average value of the five data points you provided. However, in this specific case, two of the values (36,397.39 and 40,675.79) are much larger than the others (2,712.71, 2,900.57, 4043.12)

Interpretation: The standard deviation of approximately 17,368.08 indicates a very high spread in the data. This large value means the data points are widely dispersed from the mean (17,345.92). The presence of high outliers (36,397.39 and 40,675.79) significantly inflates both the variance and standard deviation. As a result, the dataset shows high variability and inconsistency. In such cases, using the median may better represent the typical value than the mean.

V. FINDINGS AND CONCLUSION

6.1 FINDINGS:

- **Equity Expansion:** LIC's Total Equity experienced a remarkable increase from ₹11,335 Cr in 2022 to ₹82,744 Cr in 2024. This surge was primarily driven by a significant rise in Reserves & Surplus, highlighting how profit retention post- IPO has strengthened the company's financial foundation.
- **Revenue and Profitability Trends:** Total revenue grew steadily – from ₹6,15,912 Cr in 2020 to ₹8,57,369 Cr in 2024. More striking was the substantial jump in Net Profit (PAT) from ₹4,043 Cr in 2022 to over ₹40,675 Cr in 2024,
- **Demonstrating that LIC not only capitalized on its market debut but also optimized its core business operations after listing.**
- **EPS Improvement:** The notable increase in Earnings Per Share (EPS) from ₹6.39 in 2022 to ₹64.69 in 2024 underscores the enhanced profitability and value distribution to shareholders following the IPO.
- **The case of LIC's IPO provides valuable insights into the dynamics of market performance and investor behavior during a transition from a government-owned entity to a publicly listed company.**

6.2 CONCLUSION

1. **Strategic Catalyst for Growth:** The IPO emerged as a transformative event for LIC, acting as a catalyst for accelerated financial growth. The marked increase in equity, revenue, and net profits post-IPO demonstrates that the public offering provided not

just additional capital, but also a Mandate to enhance operational efficiency, ramp up profitability, and improve investor confidence through disciplined profit retention and strategic reinvestments.

2. **Mixed Signals from Pre-Market Indicators:** While the pre-market buzz—including high subscription ratios and notable GMP levels—generated significant attention and investor interest, it did not uniformly predict long-term market performance. The negative correlation observed between subscription intensity and GMP highlights the complexity of market sentiment. The findings underline that investment decisions should not rely solely on pre-market excitement; instead, a deeper analysis of fundamental financial health and operational efficiency is crucial.

3. **Investor Behavior and Corporate Governance:** The overwhelming participation from institutional investors, compared to that of retail investors, suggests a critical role for professional market players in steering post-IPO outcomes. LIC's successful navigation of its listing phase confirms that robust corporate governance, transparent financial communication, and effective management practices are essential for converting initial market hype into lasting financial strength.

4. **Implications for Future IPOs:** Future public offerings, LIC's experience serves as a case study that emphasizes the for importance of balancing market sentiment with solid fundamentals.

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A Study on Asset and Liability Management of HDFC Bank Limited

K. Sathish¹, Ramgari Anusha²

¹Assistant Professor, Department of Master of Business Administration, CMR Institute of Technology, Medchal, India

²Student of Master of Business Administration, CMR Institute of Technology, Medchal, India

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Abstract— This report examines the Asset and Liability Management (ALM) framework of HDFC Bank Limited, with a focus on how the bank manages its financial assets and liabilities to maintain stability, liquidity, and profitability. The study gains special relevance in the context of the 2023 merger between HDFC Bank and its parent company, Housing Development Finance Corporation, which significantly impacted the bank's balance sheet, notably increasing the Loan-to-Deposit Ratio (LDR) to 110%. Using secondary data from annual reports and the bank's official website, the analysis covers the period from 2018 to 2023 and utilizes tools such as comparative financial statements, trend analysis, and regression models. Key findings indicate consistent growth in equity share capital, reserves, net worth, deposits, investments, and advances, though borrowings and other liabilities showed some fluctuations. Regression results with R^2 values above 99% suggest a strong relationship between historical and current financial indicators, affirming the success of HDFC Bank's ALM strategies. Nonetheless, the study notes post-merger challenges in sustaining optimal liquidity and regulatory compliance. It concludes that ALM is essential for managing interest rate and liquidity risks, especially during significant structural changes.

Keywords— Asset and Liability Management (ALM), Financial Stability, Profitability, Loan-to-Deposit Ratio (LDR), Regression Analysis.

I. INTRODUCTION

1.1 Background of the study:

Asset and Liability Management (ALM) plays a crucial role in ensuring the financial stability and sustainability of banks, especially in the face of dynamic economic conditions, changing regulatory requirements, and interest rate fluctuations. With the liberalization of the Indian financial sector and increasing competition, banks have been compelled to adopt robust risk management strategies. The importance of ALM has grown significantly as it helps banks manage liquidity and interest rate risks by aligning the maturities and interest rates of assets and liabilities. The 2023 merger between HDFC Bank and its parent company, Housing Development Finance Corporation, brought substantial changes to the bank's financial structure — most notably a sharp

rise in the Loan-to-Deposit Ratio (LDR) to 110%. This merger has intensified the need to re-examine HDFC Bank's ALM strategies to ensure continued profitability, regulatory compliance, and sound risk management. Given HDFC Bank's position as one of India's leading private sector banks, studying its ALM framework offers valuable insights into how financial institutions manage balance sheet health during major transitions.

1.2 Statement of the Problem:

Managing the balance between a bank's assets and liabilities has become more difficult in today's changing financial environment. After merging with HDFC Ltd., HDFC Bank is facing new challenges in keeping its financial structure stable. One major concern is that its Loan-to-Deposit Ratio (LDR) has

increased to 110%, which shows there may be problems with having enough money available to meet short-term needs. Even though the bank has had a strong system for managing assets and liabilities in the past, it now has to work even harder to handle risks from changing interest rates, mismatched loan and deposit timings, and cash flow gaps. At the same time, it must follow rules set by regulators and continue to stay profitable. This study aims to find out how well HDFC Bank is managing these new challenges and whether there are any weaknesses in its current asset and liability management practices that could hurt its financial performance.

1.3 Research Objectives:

- To study the Asset Liability Management system.
- To study the impact of ALM on the profitability of HDFC Bank Limited.
- To know the asset and liability position of HDFC Bank Limited.
- To know about the factors affecting the asset and liability position of the Bank.

1.4 Significance of the Study:

This study is important for understanding how HDFC Bank manages Asset and Liability Management (ALM) in a dynamic financial and regulatory environment. It gains special relevance after the 2023 merger with HDFC Ltd., which significantly impacted the bank's balance sheet and loan-to-deposit ratio. The research highlights how the bank handles risks like interest rate and liquidity mismatches while ensuring profitability and compliance. The findings offer useful insights for other banks during structural changes.

1.5 Scope and Limitations:

The study focuses on analysing the Asset and Liability Management (ALM) practices of HDFC Bank Limited over a five-year period from 2018 to 2023. It evaluates how effectively the bank balances its assets and liabilities to manage financial risks and maintain profitability, especially in the context of the 2023 merger with HDFC Ltd.

Limitations:

- The study is based only on secondary data, with no primary data collection for deeper insights.

- It focuses solely on HDFC Bank, limiting the generalizability to other banks.
- The five-year analysis may not fully capture long-term trends or complete post-merger impacts.
- External macroeconomic factors influencing ALM are not considered in the analysis.

II. REVIEW OF LITERATURE

2.1 Theoretical Framework:

The theoretical base of this study is Asset and Liability Management (ALM), which helps bank balance their assets and liabilities to reduce risks like changes in interest rates, cash shortages, or timing mismatches. ALM uses ideas from risk management and financial planning to help banks earn steady profits and stay stable. It also follows rules set by bodies like the Basel Committee and the Reserve Bank of India (RBI) to manage risk and maintain enough capital.

2.2 Empirical Studies:

Vaidyanathan (1999) highlighted that banks face many types of risks and must use ALM to manage both assets and liabilities effectively.

Sheela and Tejaswini (2015) found that banks use gap analysis to handle interest rate risks and avoid temporary cash shortages.

Amith Kumar Meena and Joydip Dhar (2014) showed that managing cash flow and maturity gaps is a key challenge for banks.

GV Bhavani Prasad and D. Veena (2013) stressed the importance of ALM in preventing risks from bad loans and poor portfolio management.

2.3 Research Gap:

Though there is an cornucopia of literature available on ALM, there is a visible lack of studies that concentrate on the immediate and long-run consequences of major combinations, similar as HDFC Ltd. and HDFC Bank, on ALM strategy. In particular, the issues of liquidity operations, non-supervisory conditions, and profitability in light of the changed loan-to-deposit rate (LDR) following the junction have been little explored.

2.4 Conceptual Framework:

The conceptual framework of this study revolves around the principles of Asset and Liability Management (ALM), focusing on how financial institutions manage interest rate risk, liquidity risk, and maturity mismatches to ensure financial stability. In the context of HDFC Bank, this framework examines the alignment of assets and liabilities before and after the 2023 merger, using financial indicators and ratios to evaluate effectiveness and predict performance through regression models.

III. RESEARCH METHODOLOGY

3.1 Research Design:

The study uses a descriptive and analytical research design to assess ALM practices at HDFC Bank by examining financial trends and patterns over five years. It applies both quantitative and qualitative methods using secondary data from annual reports, RBI publications, and financial statements. Tools like ratio analysis, trend analysis, and regression models are employed to evaluate the effectiveness of ALM in maintaining financial stability and minimizing risks.

3.2 Data Collection:

The secondary data is collected for this study. It was collected from the following sources:

- Company website.
- Annual reports of HDFC Bank.

3.3 Research Instruments:

This study relies on secondary data collection instruments, including HDFC Bank's annual reports, official financial statements, and RBI publications. Analytical tools such as trend analysis, comparative financial statements, ratio analysis, and regression analysis are used to assess the impact and effectiveness of ALM practices over a five-year period (2018–2023).

3.4 Data Analysis Techniques:

- Comparative Financial Statement Analysis
- Percentage Change Analysis
- Graphical Representation
- Regression Analysis

IV. DATA ANALYSIS AND INTERPRETATION

4.1 Demographic Analysis

As the study is based on secondary data, demographic analysis does not involve human participants. Instead, it focuses on financial data from Hindustan Unilever Limited (2018–2023), covering revenue, budgeted sales, actual sales, net profit, and asset values.

4.2 Descriptive Analysis

Data Analysis and Interpretations:

Table 1. Comparative Asset Liability Sheet as on 31st March 2022-2023

Particulars	March 2023	March 2022	Increase (+) Decrease (-) (in Cr)	Percentage (%)
Capital and Liabilities:				
Total Share Capital	1294.76	1289.46	5.3	0.409342272
Equity Share Capital	1294.76	1289.46	5.3	0.409342272
Reserves	115,209.65	107,078.59	8131.06	7.057620607
Net Worth	116,504.41	108,368.05	8136.36	6.983735637
Deposits	770,968.99	652,919.67	118049.32	15.3118117
Borrowings	162,896.76	165,319.97	-2423.21	-1.487574093
Total Debt	933,865.75	818,239.64	115626.11	12.38144883
Other Liabilities & Provisions	47,994.99	37,851.46	10143.53	21.13456009

Total Liabilities	1,098,365.15	964,459.15	133906	12.19139191
Assets				
Cash & Balances with RBI	35,283.96	37,858.01	-2,574.05	-7.295241237
Balance with Banks, Money at Call	83,871.78	42,438.27	41,433.51	49.40101426
Advances	645,289.97	586,646.58	58,643.39	9.087912834
Investments	249,531.48	207,732.68	41,798.80	16.75091255
Fixed Assets	8410.29	7931.43	478.86	5.693739455
Other Assets	75977.67	81,852.17	-5,874.50	-7.731877011
Total Assets	1,098,365.15	964,459.14	133,906.01	12.19139282

Interpretation:

As per above table and graph Equity Share Capital rose 0.409%, Reserves 7.5%, Net worth 6.9%, Deposits 15.3%, Borrowings fell to -1.49%, Other Liabilities & Provisions rose 21.13% and total Liabilities are rise to 12.19% compared to 2023 to 2022. Arriving at Assets Cash with Bank lowered to -7.29%, Balance with Banks rose by 49%. Improvement 9.08%, Investment 16.75%, fixed assets 5.69% and other assets are reduced to -7.73%, overall Total Assets improved 12.9% compared to 2022.

Table 2. Comparative Asset Liability Sheet as on 31st March 2021-2022

Particulars	March 2022	March 2021	Increase(+) / Decrease (-) (in Rs)	Percentage (%)
Capital and Liabilities:				
Total Share Capital	1289.46	1285.81	3.65	0.283064228
Equity Share Capital	1289.46	1285.81	3.65	0.283064228
Reserves	107,078.59	103,873.13	3205.46	2.993558283
Net Worth	108,368.05	105,158.94	3209.11	2.9613064
Deposits	652,919.67	560,975.21	91944.46	14.0820478
Borrowings	165,319.97	182,858.62	-17538.65	-10.60891192
Total Debt	818,239.64	743,833.83	74405.81	9.093400804
Other Liabilities & Provisions	37,851.46	30,196.40	7655.06	20.22394909
Total Liabilities	964,459.15	879,189.17	85269.98	8.841222565
Assets				
Cash & Balances with RBI	37,858.01	33,102.38	4,755.63	12.56175377
Balance with Banks, Money at Call	42,438.27	51,067.00	-8,628.73	-20.33242637
Advances	586,646.58	512,395.29	74,251.29	12.65690324
Investments	207,732.68	202,994.18	4,738.50	2.281056596

Fixed Assets	7931.43	7903.51	27.92	0.352017228
Other Assets	81,852.17	71,726.80	10,125.37	12.37031346
Total Assets	964,459.14	879,189.16	85,269.98	8.841222657

Interpretation:

As per the above table and graph Equity Share Capital rose 0.28%, Reserves rose 2.99%, Net worth rose 2.96%, Deposits rose 14.08%, Borrowings fell to -10.60%, Other Liabilities & Provisions grew 20.22% and overall Liabilities are rise to 8.84% against 2022 to 2021. Coming to assets Cash in Bank balance with RBI rose to 12.56%, Balance with Banks fell -20.33%, Advances 12.65%, Investments 2.28%, fixed assets 0.35% and other assets are risen to 12.3%, overall Total Assets rose 8.84% compared to 2020.

Table 3. Comparative Asset Liability Sheet as on 31st March 2020-2021

Particulars	March 2021	March 2020	Increase (+) /Decrease (-) (in Rs)	Percentage (%)
Capital and Liabilities:				
Total Share Capital	1285.81	1165.11	120.7	9.387078962
Equity Share Capital	1285.81	1165.11	120.7	9.387078962
Reserves	103,873.13	98,785.97	5087.16	4.897474448
Net Worth	105,158.94	99,951.08	5207.86	4.952370193
Deposits	560,975.21	490,039.06	70936.15	12.64514879
Borrowings	182,858.62	147,556.15	35302.47	19.30588233
Total Debt	743,833.83	637,595.21	106238.62	14.28257438
Other Liabilities & Provisions	30,196.40	34,245.16	-4048.76	-13.40808838
Total Liabilities	879,189.17	771,791.45	107397.72	12.21554174
Assets				
Cash & Balances with RBI	33,102.38	31,702.41	1,399.97	4.229212522
Balance with Banks, Money at Call	51,067.00	44,010.66	7,056.34	13.81780798
Advances	512,395.29	464,232.08	48,163.21	9.399619969
Investments	202,994.18	161,506.55	41,487.63	20.43784211
Fixed Assets	7903.51	7805.21	98.30	1.243751194
Other Assets	71,726.80	62,534.55	9,192.25	12.81564213
Total Assets	879,189.16	771,791.46	107,397.70	12.2155396

Interpretation:

From the above table and graph Equity Share Capital rose by 9.38%, Reserves 4.89%, Net worth 4.95%, Deposits 12.64%, Borrowings rose to 19.30%, Other Liabilities & Provisions fell 13.40% and total Liabilities are rise to 12.21% compare to 2021 to 2020.

Coming to Assets Cash in Bank Balance with RBI rose to 4.23%, Balance with Banks rose 13.81%, Advances 9.39%, Investments 20.43%, fixed assets 1.24% and other assets are raised to 12.81%, over all Total Assets rose 12.22% compared to 2020.

Table 4. Comparative Asset Liability Sheet as on 31st March 2019-2020

Particular	March 2020	March 2019	Increase (+) /Decrease (-) (in Rs)	Percentage (%)
Capital and Liabilities:				
Total Share Capital	1165.11	1163.17	1.94	0.166507883
Equity Share Capital	1165.11	1163.17	1.94	0.166507883
Reserves	98,785.97	88,572.42	10213.55	10.3390694
Net Worth	99,951.08	89,735.59	10215.49	10.22048986
Deposits	490,039.06	421,425.71	68613.35	14.00160836
Borrowings	147,556.15	174,807.38	-27251.23	-18.46837966
Total Debt	637,595.21	596,233.09	41362.12	6.487206828
Other Liabilities & Provisions	34,245.16	34,726.44	-481.28	-1.405395682
Total Liabilities	771,791.45	720,695.12	51096.33	6.62048407
Assets				
Cash & Balances with RBI	31,702.41	27,106.09	4,596.32	14.49832994
Balance with Banks, Money at Call	44,010.66	32,762.65	11,248.01	25.55746721
Advances	464,232.08	435,263.94	28,968.14	6.240012539
Investments	161,506.55	160,411.80	1,094.75	0.677836286
Fixed Assets	7805.21	7576.92	228.29	2.924841228
Other Assets	62,534.55	57,573.70	4,960.85	7.932974652
Total Assets	771,791.46	720,695.10	51,096.36	6.620487871

Interpretation:

From above table and graph Equity Share Capital rose by 0.17%, Reserves by 10.34%, Net worth by 10.20%, Deposits by 14.00%, Borrowings fell to -18.47%, Other Liabilities & Provisions fell by 1.40% and overall Liabilities are rise to 6.62% compare to 2020 to 2019. Arriving at Assets Cash in Bank Balance with RBI risen to 14.49%, Balance with Banks rose 25.56%, Advances 6.24%, Investments 0.67%, fixed assets 2.92% and other assets are risen to 7.39%, over all Total Assets rose 6.62% compared to 2019.

Table 5. Comparative Asset Liability Sheet as on 31st March 2018-2019

Particulars	March 2019	March 2018	Increase (+) /Decrease (-) (in Rs)	Percentage (%)
Capital and Liabilities:				
Total Share Capital	1163.17	1159.66	3.51	0.301761565
Equity Share Capital	1163.17	1159.66	3.51	0.301761565
Reserves	88,572.42	79,269.70	9302.72	10.5029534
Net Worth	89,735.59	80,429.36	9306.23	10.37072359
Deposits	421,425.71	361,562.73	59862.98	14.20487136
Borrowings	174,807.38	172,417.35	2390.03	1.367236326
Total Debt	596,233.09	533,980.08	62253.01	10.44105251
Other Liabilities & Provisions	34,726.44	31,719.86	3006.58	8.657898708
Total Liabilities	720,695.12	646,129.30	74565.82	10.34637504
Assets				
Cash & Balances with RBI	27,106.09	25,652.91	1,453.18	5.361083063
Balance with Banks, Money at Call	32,762.65	16,651.71	16,110.94	49.17471572
Advances	435,263.94	387,522.07	47,741.87	10.9684873
Investments	160,411.80	186,580.03	-26,168.23	-16.31315776
Fixed Assets	7576.92	4725.52	2,851.40	37.63270564
Other Assets	57,573.70	24,997.05	32,576.65	56.58251945
Total Assets	720,695.10	646,129.29	74,565.81	10.34637394

Interpretation:

As per above table and chart Equity Share Capital rose 0.30%, Reserves rose 10.50%, Net worth rose 10.37%, Deposits rose 14.20%, Borrowings rose to 1.36%, Other Liabilities & Provisions rose 8.65% and total Liabilities are rise to 10.35% from 2019 to 2018.

Arriving to Assets Cash in Bank 5.36% increased, Balance with Banks 49.17% increased, Advances 10.97%, Investments -16.31% decreased, fixed assets 37.63% increased and other assets are increased to 56.58%, over all Total Assets increased 10.34% compare to 2018.

V. FINDINGS AND CONCLUSION**5.1 Findings:**

- Equity share capital climbed steadily from ₹552 Cr in 2021 to ₹558 Cr in 2023, while reserves jumped from ₹279,641 Cr in 2021 to ₹436,833 Cr in 2023.
- Net worth rose from ₹203,169 Cr in 2021 to ₹504,181 Cr by 2024, reflecting sustained growth in shareholder equity.
- Fixed deposits declined significantly – from ₹24,997 Cr in 2018 to around ₹8,410 Cr in 2023 – while total arrears surged to ₹646,129 Cr, signaling changing liability profiles.

- Investments climbed strongly, from ₹186,580 Cr in 2018 to approximately ₹249,531 Cr in 2023, aligning with an aggressive expansion in advances.
- The regression model's R^2 value of 99.92% and F-statistic of 8,349.9 ($p \ll 0.05$), alongside a coefficient of ~ 1.152 ($p \approx 4.95 \times 10^{-12}$), indicates a nearly perfect fit with robust statistical significance

5.2 Conclusions:

Overall, HDFC Bank has successfully maintained a balanced and resilient financial structure, with liabilities well-matched by assets, and has shown efficiency in managing growth and financial risk over the five-year period.

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Enhancing Financial Accessibility with Digital Payment Systems

K. Sathish¹, Sangam Vidya²

¹Assistant Professor, Department of Master of Business Administration, CMR Institute of Technology, Medchal, India

²Student of Master of Business Administration, CMR Institute of Technology, Medchal, India

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Abstract— Financial accessibility refers to the ease with which individuals and businesses can access affordable and convenient financial services. With the proliferation of digital technologies, digital payment systems have emerged as a crucial enabler in enhancing financial accessibility. Digital payment systems encompass a wide array of electronic mechanisms, including mobile wallets, online banking platforms, QR code payments, and peer-to-peer transfer applications, which facilitate seamless financial transactions without the need for physical cash or in-person interactions. The research adopts a mixed-methods approach, combining quantitative data analysis and qualitative interviews. A survey was conducted across various socio-economic groups to assess the adoption levels and user perceptions of digital payment systems. In addition, in-depth interviews with stakeholders including financial service providers, regulators, and consumers— were undertaken to gain insights into the barriers and enablers influencing adoption. Secondary data, including policy documents and digital payment adoption reports, supplemented the primary data collection. The findings suggest that digital payment systems significantly contribute to enhancing financial accessibility by reducing transaction costs, increasing convenience, and bridging geographical barriers. However, challenges such as digital literacy gaps, cybersecurity concerns, and inconsistent regulatory frameworks continue to hinder widespread adoption, particularly in rural areas. The study concludes by recommending targeted digital literacy initiatives, strengthened cybersecurity measures, and harmonized regulatory policies to maximize the potential of digital payment systems in promoting financial inclusion and accessibility. Future research could explore longitudinal impacts and the evolving dynamics of digital finance ecosystems.

Keywords— digital payment systems, digital literacy, digital technologies, digital payments, electronic transaction methods, mobile money platforms, digital wallets

I. INTRODUCTION

The potential of digital payment systems to enhance financial accessibility, with a particular focus on their role in overcoming traditional barriers to financial inclusion. The study examines the drivers and constraints associated with the adoption of digital payment systems, including technological infrastructure, regulatory frameworks, digital literacy, and user perceptions. Employing a mixed-methods research approach, the study integrates quantitative survey data with qualitative insights from key stakeholders. The objective is to provide a comprehensive understanding of how digital payment systems contribute to financial

accessibility and to identify strategies for maximizing their impact. As digital technologies continue to evolve, understanding their implications for financial inclusion is imperative for policymakers, financial institutions, and technology providers seeking to create more inclusive financial ecosystems.

1.1 Background of the study:

In recent years, the concept of financial accessibility has gained considerable attention as a critical component of sustainable economic development and social equity. Financial accessibility refers to the ability of individuals and businesses to obtain affordable, convenient, and secure

financial services, including payments, savings, credit, and insurance. Traditionally, financial services have been delivered through brick-and-mortar institutions, which often present barriers such as geographical distance, high costs, and stringent documentation requirements. These barriers disproportionately affect marginalized groups, particularly those in rural or low-income communities, contributing to financial exclusion. The advent of digital payment systems has dramatically transformed the landscape of financial services by leveraging technology to bridge these gaps. Digital payment systems encompass a broad spectrum of electronic transaction methods, including mobile money platforms, digital wallets, QR code payments, internet banking, and peer-to-peer transfer applications. These systems offer numerous advantages, such as reduced transaction costs, enhanced security, realtime settlement, and greater accessibility. Notably, digital payment systems enable financial transactions without the need for physical cash or physical presence, thus extending financial services to previously underserved populations

1.2 Statement of the Problem:

Despite the rapid evolution of digital payment systems and their recognized potential to enhance financial accessibility, significant challenges persist in achieving widespread adoption and equitable access. Traditional financial systems have long been inaccessible to marginalized groups due to barriers such as geographic remoteness, high service costs, and complex documentation requirements. Digital payment systems including mobile wallets, internet banking, and QR code-based payments offer a promising solution by lowering transaction costs, enhancing convenience, and enabling remote access. However, the adoption of these systems remains uneven, particularly in rural and low-income areas, due to factors such as digital illiteracy, inadequate technological infrastructure, privacy concerns, and inconsistent regulatory frameworks. Additionally, there is limited empirical research that holistically examines the interplay of these factors in shaping user behavior and adoption patterns.

1.3 Research Objectives:

- To study on inclusion of digital payment solutions impact on financial accessibility
- To improve transaction efficiency through innovative mobile and online payment platforms
- To analyse the factors influence on digital payment options
- To suggest enhancing trust and convenience in digital payment systems

1.4 Significance of the study:

This research aims to identify key drivers and barriers affecting the adoption and use of digital payment technologies, including digital literacy, infrastructural readiness, socio-cultural factors, and regulatory frameworks. By employing a mixed-methods approach that integrates quantitative surveys and qualitative interviews with key stakeholders, the study seeks to provide comprehensive insights into user behavior, perceptions, and experiences with digital payment systems. The ultimate goal is to generate practical recommendations for stakeholders including policymakers, financial institutions, and technology developers on strategies to maximize digital payment adoption and enhance financial inclusion.

1.5 Scope and limitations:

This study focuses on The purpose of this study is to explore and evaluate the potential of digital payment systems in enhancing financial accessibility, particularly for underserved populations and regions. Digital payment systems comprising mobile wallets, internet banking, QR code payments, and other electronic transaction platforms offer transformative solutions for overcoming traditional barriers in financial service delivery, including high costs, geographic isolation, and limited access to formal banking infrastructure

Limitations:

- The study is based on information which is secondary
- The data is collection for few years only
- Some investors are not giving proper response
- For security reason some confidential data is not provide by company employees
- Time factor is major limitation of project

II. REVIEW OF LITERATURE

- Harsh kumar (2025) This study examines the transformative role of digital payment systems in enhancing financial inclusion within rural India. Leveraging government initiatives like Digital India and the Unified Payments Interface (UPI), digital payments have significantly expanded access to financial services among the rural populace.
- Dr. Mohammed nabeel (2025) Digital payment systems like Aadhaar and the Unified Payments Interface (UPI) in the Indian context now appear neck-deep to outreach millions for ages. Thus, this paper emphasizes inaccessible technology breaking the very old barriers of high costs, inaccessibility, and complexity that previously kept formal banking at bay for the rural and underserved.

- Prabesh Luitel (2025) This study examines the relationship between the provision of digital payment and GDP growth by uniquely integrating behavioural attitudes, shaped by the status quo, individual behavioural bias and financial literacy.

2.3 Research Gap:

Despite the rapid growth of digital payment systems worldwide, a critical research gap persists in understanding While studies by harsh kumar (2025), mohammed nabeel (2025), and prabesh luitel (2025) have explored rural inclusion, accessibility challenges, and economic outcomes of digital payments, there is a lack of focused research on how digital payment systems directly enhance financial accessibility across varied socio-economic groups. Moreover, limited attention has been given to user trust, digital literacy, and behavior. This study fills that gap by analyzing grassroots-level financial access.

2.4 Conceptual Framework:

Despite the high rate of adoption, a significant portion of users have reported issues related to accessibility, digital literacy, and confidence in handling technical problems. Concerns over transaction fees, cybersecurity, and usability persist, especially among less digitally literate individuals. These barriers indicate the need for continuous education, infrastructure development, and user-centered platform design. To truly realize the potential of digital payment systems in enhancing financial accessibility, stakeholders must act collaboratively. Policymakers should strengthen digital infrastructure, reduce transaction costs, and implement inclusive financial policies. Financial institutions and fintech companies must focus on simplifying interfaces, ensuring data privacy, and expanding acceptance across all sectors. Moreover, community-level awareness and training programs should be intensified to improve digital literacy and build user confidence.

III. RESEARCH METHODOLOGY

3.1 Research Design:

The study will use a descriptive research design to assess how digital payment systems improve financial accessibility. This design enables a comprehensive analysis of user experiences, system adoption rates, and financial inclusion outcomes. It facilitates data collection from a cross sectional sample to explore both individual and community-level effects.

3.2 Data collection:

Data Type: Primary Data

Primary Data: Structured questionnaires and in-depth interviews will be conducted with digital payment users and

service providers. This approach will gather detailed insights into usage patterns, perceived benefits, challenges, and suggestions for improvement.

Secondary Data: Existing reports, policy documents, industry publications, and statistical data from regulatory bodies and digital payment providers will supplement primary data, offering contextual and comparative insights.

Data Source: Questionnaire

- Industry Journals and research papers
- Research Report

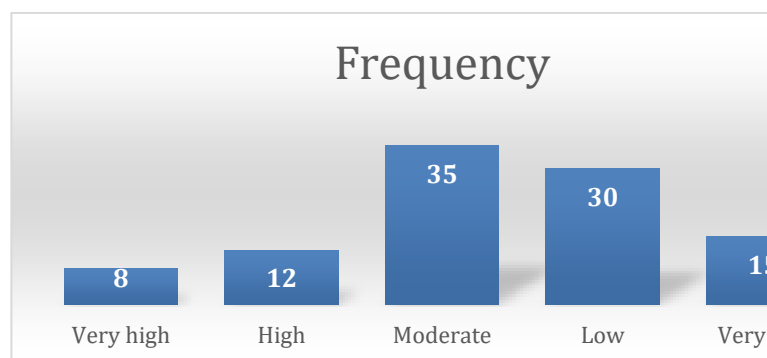
IV. DATA ANALYSIS AND INTERPRETATION

4.1 Demographic Analysis: Geographically only Hyderabad data is taken for analysis

4.2 Descriptive Analysis:

How would you rate the fees or charges associated with digital payments?

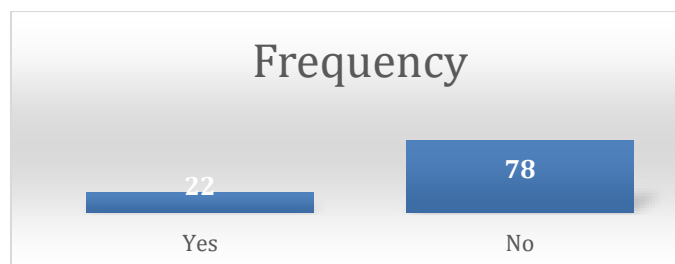
Option	Frequency	Percentile
Very high	8	8%
High	12	12%
Moderate	35	35%
Low	30	30%
Very low	15	15%
Total	100	100%



INTERPRETATION: -The data shows that a majority of respondents perceive the fees or charges for digital payments as reasonable, with 35% rating them moderate and 30% considering them low. Additionally, 15% view them as very low, indicating satisfaction with affordability. However, 12% rate fees as high and 8% as very high, reflecting concerns about costliness for a minority. Overall, the findings suggest that most users find digital payment fees acceptable, but there is room to address cost perceptions for some segments.

Have you ever stopped using a digital payment system due to accessibility issues?

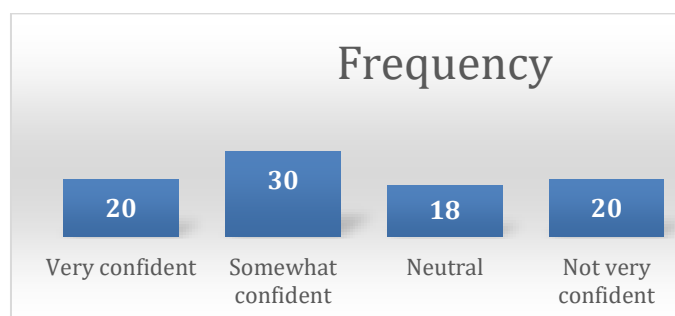
Option	Frequency	Percentile
Yes	22	22%
No	78	78%
Total	100	100%



INTERPRETATION: -The data shows that a significant majority of respondents (78%) have not stopped using digital payment systems due to accessibility issues, indicating that most users find these platforms reliable and accessible. However, 22% have discontinued use at some point due to accessibility challenges, highlighting the need to address usability and access barriers for a notable minority. Overall, the findings suggest that while digital payments are generally accessible, there remain areas for improvement to enhance user inclusivity.

Confident are you in resolving technical issues with digital payments?

Option	Frequency	Percentile
Very confident	20	20%
Somewhat confident	30	30%
Neutral	18	18%
Not very confident	20	20%
Not confident at all	12	12%
Total	100	100%

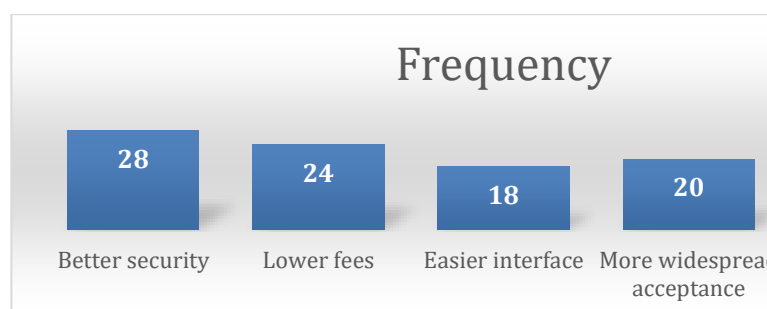


INTERPRETATION: -The data reveals varying levels of confidence among respondents in resolving technical issues with digital payments. About 30% feel somewhat confident,

while 20% are very confident, indicating that half the respondents feel capable of addressing challenges. However, 18% are neutral, suggesting uncertainty, and a notable portion (20%) is not very confident, with 12% not confident at all. This variation highlights the need for better support and education to enhance users' confidence in managing technical issues with digital payment systems.

Which feature would most improve your use of digital payment systems?

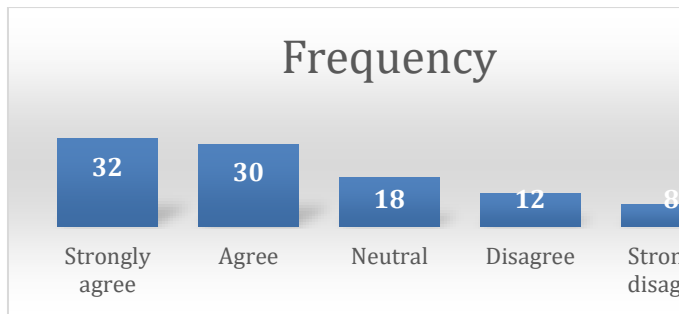
Option	Frequency	Percentile
Better security	28	28%
Lower fees	24	24%
Easier interface	18	18%
More widespread acceptance	20	20%
Customer support	10	10%
Total	100	100%



INTERPRETATION: -The data indicates that better security is the most desired feature for improving digital payment systems, with 28% of respondents identifying it as a key improvement. Lower fees follow at 24%, highlighting a significant focus on affordability.

Do you believe digital payments have the potential to enhance financial inclusion in underserved communities?

Option	Frequency	Percentile
Strongly agree	32	32%
Agree	30	30%
Neutral	18	18%
Disagree	12	12%
Strongly disagree	8	8%
Total	100	100%



18% remain neutral, indicating uncertainty or limited awareness. A smaller segment (12% disagree and 8% strongly disagree) reflects skepticism. Overall, the findings emphasize the recognized role of digital payments in promoting financial inclusion.

4.3 Inferential Analysis:

The ANOVA results show that there is a significant difference between the means of the groups being compared. Therefore, the data provides compelling evidence to suggest that the means of the groups are not equal, and there are statistically significant differences among the groups. Alternative Hypothesis (H_1) has been accepted, here is the interpretation:

The results of the analysis provide sufficient evidence to support the claim that digital payment systems significantly enhance financial accessibility. This suggests that the use of digital payment technologies—such as mobile banking, digital wallets, and online transactions—positively impacts the ability of underserved populations to access and manage financial services

4.4 Hypothesis Testing:

Table 3

Anova: single factor				
Summary				
<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Income (monthly)	100	392	1.661017	0.727155
Why do you engagement with unified payment interface [digital payments facilitates transfers and payment from any point]	100	801	3.394068	2.495114
Why do you engagement with unified payment interface [cashless payment options gives you more discount/cash back rewards]	100	738	3.127119	2.145474
Why do you engagement with unified payment interface [provides flexibility and easy tracking of spending]	100	799	3.385593	2.11877
Why do you engagement with unified payment interface [denomination of currency and advertising about digital payments motivates you to adopt this system]	100	777	3.292373	1.91841
Why do you engagement with unified payment interface [does digital payments has most secured]	100	808	3.423729	2.126073
Why do you engagement with unified payment interface [is digital payments app more user friendly]	100	806	3.415254	2.141724
Why do you engagement with unified payment interface [does digital payments supports the speed transaction]	100	811	3.436441	2.127858
Why do you engagement with unified payment interface [does digital payments applicable for lower user charges]	100	790	3.347458	1.912802
Why do you engagement with unified payment interface [is digital payments getting more frequent offers/cashbacks]	100	747	3.165254	2.044915
Why do you engagement with unified payment interface [wide acceptance across merchants]	100	791	3.351695	2.033231
Why do you engagement with unified payment interface [i would like to continue using this app]	100	809	3.427966	2.2033
Why do you engagement with unified payment interface [i will recommend this app to anyone who seeks my advice]	100	811	3.436441	2.298071

Table 4

ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	650.2203	12	54.18503	26.79071	2.38E-58	1.755336
Within Groups	6178.831	3055	2.02253			

V. DISCUSSION

5.1 Interpretation of Results:

The analysis reveals that ICICI Bank has steadily improved its profitability and asset efficiency, as seen in rising ROA, ROI, ROE, and EPS. Despite some fluctuations in market risk efficiency (Treynor ratio), overall risk-adjusted returns (Sharpe ratio) remained strong and consistent. The t-test confirms a statistically stable pattern in performance metrics, indicating a well-balanced and resilient investment strategy.

5.2 Comparison with Previous Studies:

The findings of the present study are in line with previous research on the role of digital payment systems in improving financial accessibility. Harsh Kumar (2025) emphasized the transformative impact of platforms like UPI under the Digital India initiative, showing how these tools have expanded access to financial services in rural areas. Similarly, Dr. Mohammed Nabeel (2025) highlighted how systems such as Aadhaar-enabled payments and UPI have broken long-standing barriers like high costs and inaccessibility, especially for underserved communities. These insights align with the present study's conclusion that digital payment technologies significantly enhance access to formal financial services. Additionally, Prabesh Luitel (2025) explored the broader economic effects of digital payments by linking them to GDP growth while also considering behavioral attitudes and financial literacy.

5.3 Theoretical Implication:

This study strengthens the theoretical foundation that digital payment systems are not just technological innovations but also tools for financial inclusion and economic empowerment. Drawing from financial inclusion theory and behavioral finance, the findings highlight how digital platforms—such as UPI, mobile wallets, and Aadhaar-enabled services—can overcome traditional barriers like geographic inaccessibility, high transaction costs, and lack of formal banking infrastructure. The study also supports the idea that individuals' willingness to adopt digital payments is influenced by perceived ease of use, trust, and digital literacy, aligning with the Technology Acceptance Model (TAM). These insights contribute to a growing body of

literature that views digital payments as critical drivers of inclusive financial systems, especially in developing economies.

VI. FINDINGS

- ICICI Bank has significantly improved how efficiently it uses its assets, with ROA rising from 0.72% to 2.37%, showing smarter and more disciplined asset use.
- Investment returns have strengthened, as ROI grew from 3.18% to 8.85%, reflecting smarter portfolio choices and better execution.
- Shareholders have benefitted from stronger profits, with ROE increasing to 25.35%, highlighting a growing return on equity.
- EPS surged from ₹14.55 to ₹61.96, pointing to consistent earnings growth and building investor trust.
- Risk-adjusted returns remained stable, with Sharpe ratios above 1, though Treynor ratios showed some weakness in market risk handling.
- Convenience (45%) is the top reason for using digital payments, followed by speed (25%) and security (20%). Most respondents rate digital payment fees as moderate (35%) or low (30%), with a smaller group (20%) perceiving them as high.
- 78% have not stopped using digital payments due to accessibility issues, indicating overall reliability. Confidence levels in resolving technical issues are mixed, with half of respondents feeling confident and the other half less so.
- Respondents prioritize better security (28%), lower fees (24%), and broader acceptance (20%) as key improvements. A strong majority (62%) believe digital payments can enhance financial inclusion, though 20% remain unsure or skeptical.

VII. CONCLUSIONS

Digital payment systems have emerged as a transformative force in enhancing financial accessibility, particularly for marginalized and underserved populations. The findings of this study confirm that these platforms—ranging from mobile wallets and internet banking to QR code and UPI-

based payments—have significantly improved the convenience, speed, and affordability of financial transactions. With the majority of respondents acknowledging ease of use, widespread availability, and trust in the system's security, digital payments are clearly facilitating greater participation in formal financial services.

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Investigating the Effects of Geogrid Aperture Shapes on Load-Deformation Behavior and Crack Propagation in Plain Concrete Footings

E. A. El-Kasaby ¹, Mahmoud Awwad ², Mohab. R. El-Ashmony ³, A. A. Abo-Shark ⁴

¹ Prof. of soil mechanics and foundations, Civil Engineering Department, Benha Faculty of Engineering, Benha University, Cairo, Egypt.

^{2,3,4} Lecturer, Civil Engineering Department, Benha Faculty of Engineering, Benha University, Cairo, Egypt.

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Abstract— Geogrid reinforcement is a widely used technique for improving the mechanical properties of infrastructure engineering structures. However, there is limited understanding of the behavior of geogrid with different aperture shapes when used as reinforcement in plain concrete footings. This paper presents a comprehensive study that investigates the effects of five different aperture shapes of geogrid reinforcement on the load-deformation behavior and crack propagation of plain concrete footings. The study also aims to provide a basis for future research on the use of geogrid as reinforcement in thin concrete overlays. The five geogrid products used in this study were characterized based on their index material properties, and were used in combination with fiber glass reinforced concrete (FGRC) and normal concrete mixes. The experiments were conducted on both unreinforced footings and footings reinforced with one layer of geogrid. A distributed static load was applied to simulate the stress of reinforced footings. The experimental results indicate that the strength resistance of the geogrid reinforced footings is significantly improved compared to the unreinforced footings. The use of glass fibers and geogrid confinement in the footing designs were found to have a significant impact on improving the load-deformation behavior and crack propagation. Furthermore, the study reveals that the strength and dimensions of the geogrid reinforcement play a crucial role in determining the behavior of the plain concrete footings. Also, the Comparison between cast and load capacity of all samples was presented.

Keywords— Geosynthetics, Fiber glass, plain concrete footing, shallow foundations, triaxial geogrid, biaxial geogrid, FGRC.

I. INTRODUCTION

Geo-grid is one of the geo-synthetic constituent materials; it is made up of polymers such as polyethylene, polypropylene, and polyester. These geo-grids can be classified into uniaxial, bi-axial, and tri-axial categories. Uni-axial geo-grids are mainly used for grade separation applications, such as retaining walls and precipitous slopes, and bi-axial and tri-axial geo-grids are primarily used for roadway

applications. Several studies have investigated the effective use of geo-grid as a reinforcing material with plain cement concrete in thin sections where steel reinforcement is not possible [1][2].

Recent research has investigated the use of geogrid in concrete construction. It was effective and less difficult in a corrosive environment due to Geo-Grid's usability. Geo-grid confinement is an alternative solution for tensile reinforcement [3, 4]. For the

efficient transfer of tensile tension and the enhancement of the composite action of steel fiber-reinforced concrete, the fiber-using geo-grid is the better option [5]. However, without any practical difficulty, these geogrid reinforcing materials will improve the bonding behavior of concrete. The geogrid could increase the bending and compressive strengths of concrete, as well as the resistance to crack propagation in specimens confined by one, two, or three layers of geogrid. [6]. In addition, many researchers studied the behavior of prismatic and cylindrical specimens confined between one and two geogrid layers [7][8].

Glass fiber-reinforced concrete (GFRC) material is being used in recent innovations to increase the strength of the concrete [9]. This glass fiber will have great strength in concrete. These fibers are composite materials consisting of a matrix with an asymmetrical dispersion or distribution of minute natural or synthetic fibers. [10]. The shear-friction strength of concrete will be increased, and this isolated fiber will also serve as an effective shear reinforcement. The crack propagation in the beam will effectively be reduced by using glass fibers [11]. From the applied load, the beam will carry tensile stresses with the presence of arbitrarily dispersed glass fibers. Consequently, the tensile strength of the concrete in GFRC will be improved. In addition to preventing fracture propagation, these fibers also bridge tensile cracks [12]. Shakor and Pimplikar [13] studied the trail tests for concrete with glass fiber and without glass fiber are conducted to indicate the differences in compressive strength and flexural strength by using cubes of varying sizes. Ibrahim [14] comparing the results of GFRC with plain concrete and validated the positive effect of glass fibers with percentage increase in compression, splitting and flexure improvement of specimens.

Geogrid with glass fiber may be a better choice for effective transfer of tensile stress and to enhance the concrete section. These strengthening materials may also impart better bonding behavior with concrete without practical difficulty. In the present study, the effect of geogrid with glass fibers on plain concrete footing has been investigated. Under a distributed static load, twelve footing specimens have been tested. In order to examine the effect of glass fibers and geogrid reinforcement, the load-deflection and rigidity degradation with failure patterns of various specimens are compared with those of conventional specimens. This study could identify new options and pave the way for the introduction of geogrid into structural concrete sections. The main goal of this study is to investigate the behavior of biaxial geogrid or triaxial geogrid with glass fibers and to determine the experimental effect of using these combinations in footing specimens.

II. EXPERIMENTAL PROGEAM

The study involved experimentation on a set of twelve square plain concert footings specimens made of plain concrete mixture. The specimens, with dimensions and loading details as depicted in Figure 1, were 30 cm in length and 5 cm in thickness. The footings were segregated into six categories, comprising one unreinforced plain specimen designated as control 1, one fiber reinforced plain specimen referred to as control 2, three specimens reinforced with one layer of tri-axial geogrid, two specimens fortified with one layer of biaxial geogrid, three specimens fortified with one layer of tri-axial geogrid using GFRC, and two specimens reinforced with one layer of biaxial geogrid using GFRC. Table1, summarizes all of the various configurations of the footing specimens that were tested.

Table 1: Comprehensive Configuration Details of Footing Specimens

Group Name	Reinforced Material	Code of Specimen	Descreptions
Control 1	-	P1	Plain Concrete
Triaxial	Tx 130	P2	Concrete with Triaxial geogrid Tx130
	Tx 150	P3	Concrete with Triaxial geogrid Tx150
	Tx 160	P4	Concrete with Triaxial geogrid Tx160
Biaxial	SS30	P5	Concrete with biaxial geogrid SS30

	SS40	P6	Concrete with biaxial geogrid SS40
Control 2	-	P7	GFRC - 900gm/m ³
Triaxial with glass fiber	F-Tx 130	P8	GFRC and Tri axial geogrid Tx130
	F-Tx 150	P9	GFRC and Triaxial geogrid Tx150
	F-Tx 160	P10	GFRC and Triaxial geogrid Tx160
Biaxial with glass fiber	F-SS30	P11	GFRC and biaxial geogrid SS30
	F-SS40	P12	GFRC and biaxial geogrid SS40

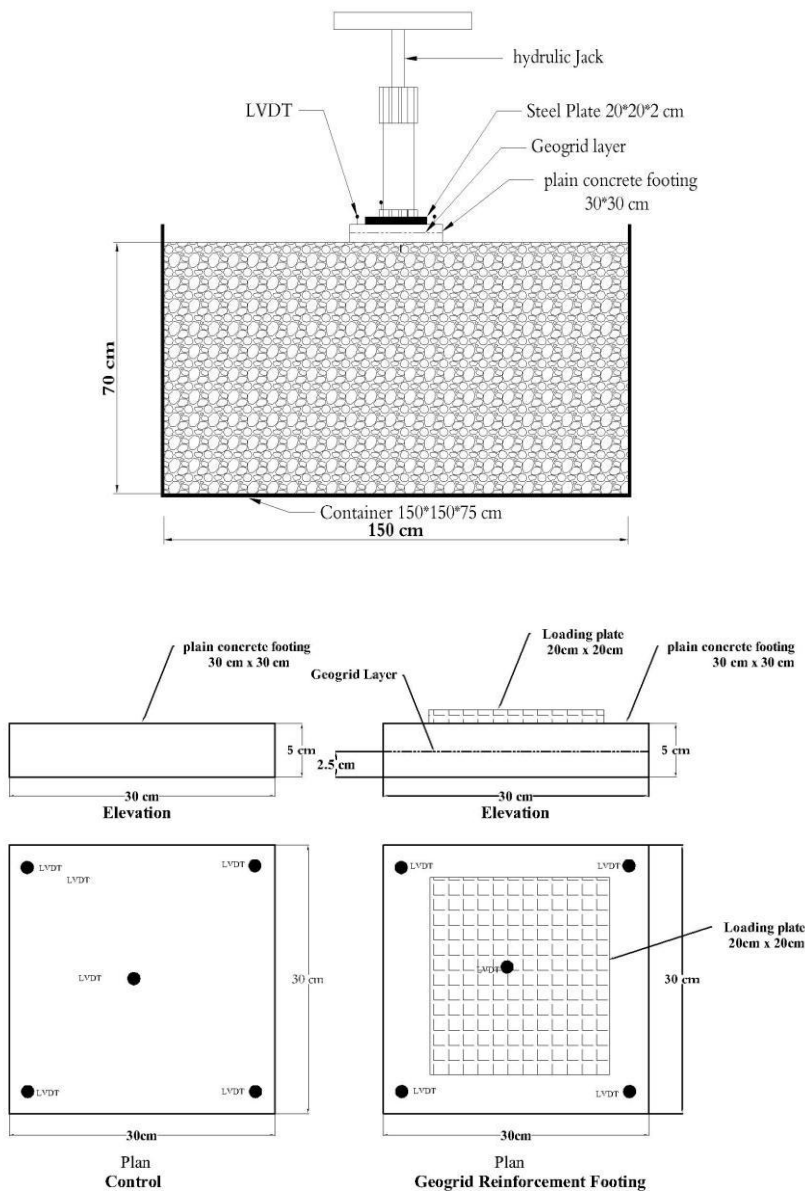


Fig.1: Illustration of Loading Position and Reinforcement Layout in a Typical Longitudinal Section.

2.1 Geogrid Properties

In this study, we analyzed the performance of various

rigid geogrids, all of which were constructed from geosynthetic material but differed in terms of aperture

geometry and mechanical properties as reported by the manufacturer. Our findings are presented in Table 2. It is worth noting that the geogrids we used in our study were carefully selected based on their suitability

for the intended application. Specifically, we examined both triaxial and biaxial geogrids, both of which were constructed from high-quality polypropylene.

Table 2. Product Specification of the geogrids used

Type	Structural integrity for Triaxial geogrid	Value
Tx 130	Junction Efficiency	93 %
	Aperture stability kg-cm/ deg @ 5.0 kg-cm	3 kg-cm/deg
	Radial Stiffness at Low Strain @ 0.5% Strain	200 Kn/m
Tx 150	Junction Efficiency	93 %
	Overall Flexural Rigidity	750,000 mg.cm
	Radial Stiffness at Low Strain @ 0.5% Strain	300 Kn/m
Tx 160	Junction Efficiency	93 %
	Radial Stiffness at Low Strain @ 0.5% Strain	325 Kn/m

Component of Biaxial geogrid			
Mechanical properties	Type of Geogrid		Unit
	SS30	SS40	
Max tensile strength	30	40	Kn/m
Tensile Strength at 2% Strain	10.5	14	Kn/m
Tensile Strength at 5% Strain	21	28	Kn/m
Approx. strain at max tensile strength	11	11	%

2.2 Concrete mix proportions

The materials used in all the concrete mixes included CEM I Portland Cement 42.5 N, natural sand, and 12.5-5 mm gravel, with tap water used as the mixing medium. Two control mixes were used, labeled Control 1 and Control 2. Control 1 had a total water-cement ratio of 0.8 and consisted of 250 kg/m³ of Portland cement, 888.68 kg/m³ of sand, 954.75 kg/m³ of gravel, and 200 kg/m³ of water. Control 2 was made with Fiber glass reinforced concrete (FGRC) and had a ratio of 900 g/m³. The target 28 day mean compressive strength was 12 MPa, which is typical of mixes used for plain concrete footings in Egypt. A pan mixer of 0.1 m³ capacity was used to mix the

materials, with the gravel placed first, followed by sand and cement. The dry mixing process lasted for one minute before adding water, and the mixing continued for an additional four minutes before the fibers were introduced.

2.3 Specimen Fabrication

The construction process for a plain concrete footing with a single layer of reinforcement is illustrated in Figure 2. Initially, a 2.5 cm layer of concrete was poured into the footing mold and thoroughly compacted. Subsequently, a geogrid layer was meticulously positioned, followed by another layer of concrete mixture. The consolidation process was meticulously carried out to ensure optimal

intermixing between the concrete layers above and below the geogrid. Upon demolding the specimens, no signs of surface cavities or separation were observed.



Fig.2. Placing of the geogrid layer after pouring and compacting of the 2.5 cm concrete layer,

2.4 Comprehensive Analysis of Soil Specifications

The composition of the foundation soil was a ratio of 2 parts gravel to 1 part sand. The soil utilized in this study conforms to the well-graded gravel with sand classification in accordance with the unified soil classification system. The uniformity coefficient and uniformity curvature, two critical indices to determine the soil grading, were determined as 22.50 and 1.98, respectively. The particle size distribution curve of the soil, as presented in Figure 3. Moreover, to evaluate the compaction characteristics of the soil, the standard proctor test was conducted, which is a standardized method in geotechnical engineering. The results indicate that the maximum dry density and the optimum moisture content were 2.078 t/m³ and 6.88%, correspondingly. The corresponding dry density and moisture content curves of the proctor test are exhibited in Figure 4, which provide a graphical representation of the compaction characteristics of the soil. These thorough test results and analyses are critical in determining the soil's suitability for use under the footings.

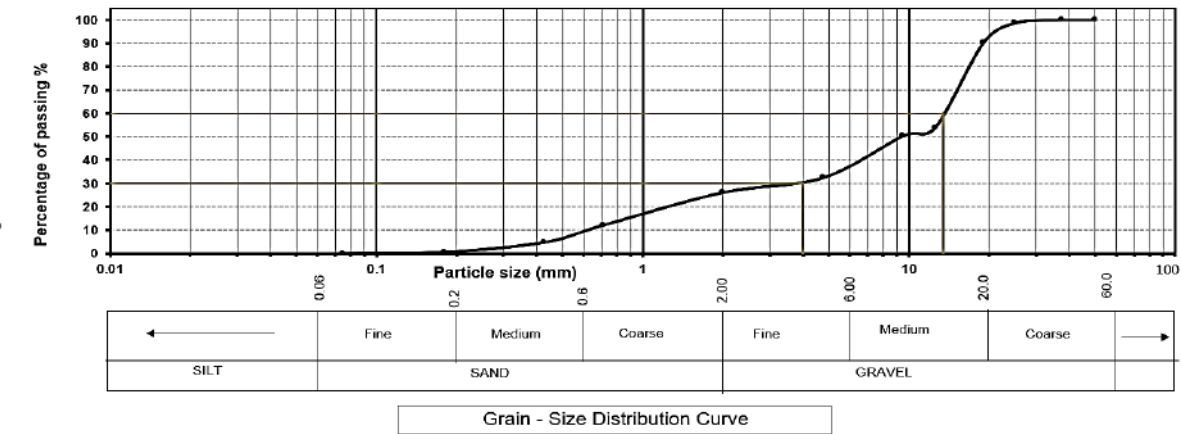


Fig.3: The particle size distribution curve for the soil used.

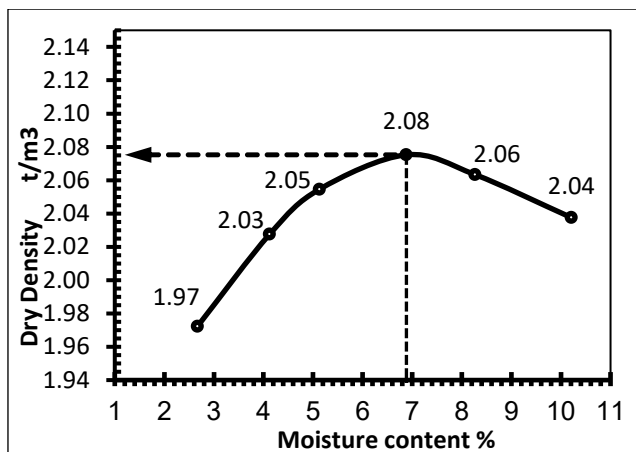


Fig.4: Relationship between dry density and moisture content for the soil used.

2.5 Experimental set-up and instrumentations

The study was conducted in a laboratory using a model setup consisting of a stiff test tank, a loading mechanism, a plate with sensors, and a system for collecting data. The test tank was designed to be large enough to fit the footing without the tank boundaries significantly affecting the soil stresses and strains. The tank was made of rigid steel with a length, width, and height of 1.50 m, 1.50 mm, and 0.70 m, respectively. A motorized 10-ton hydraulic jack applied a constant load to the footing, which was measured using a 1000 kN capacity load cell placed on top of the footing. To measure any vertical displacement, five LVDT transducers with a minimum resolution of 0.04 mm were placed at different locations on top of the footing. The output voltage of each electrical measuring circuit was automatically recorded at one-minute intervals using a data logging system. Figure 5 shows the principal dimensions and layout of the apparatus.

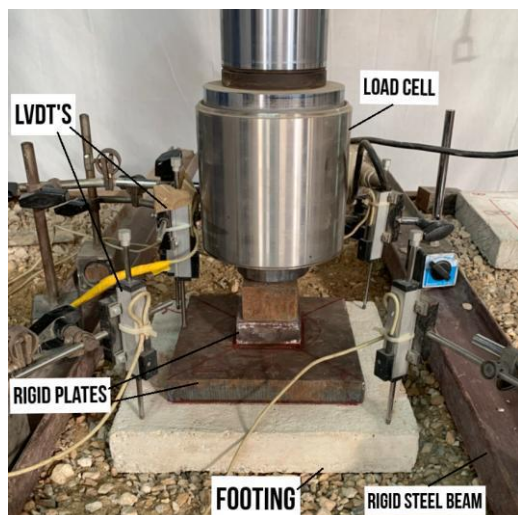


Fig 5: Model Setup and Apparatus Layout.

III. ANALYSIS OF EXPERIMENTAL PLAIN CONCRETE FOOTING RESULTS

3.1 General

An organizational chart has been included to streamline the presentation of the analysis of experimental plain concrete footing results. This chart serves as a visual guide, simplifying the structure of the analysis by breaking down its various components and findings, Fig. 6.

Load-deflection curves for plain concrete footings containing one layer of triaxial or biaxial geogrids are shown in Fig 7. Based on the obtained Figure, the load [P], vertical displacement [Δ] and Stiffness [K] were determined at first crack stage, yield stage and ultimate stage for all studied footings. Also, ductility [μ] and energy absorption [En] were obtained for each footing, Table 3.

We can see that using the geogrid on plain concrete footing affected the load-deflection behavior of the plain concrete footing significantly for the used geogrid types. It was observed that using biaxial geogrid has a good effect on the load-deflection behavior followed by triaxial geogrids. This could be because biaxial geogrids have higher tensile strength than triaxial geogrids.

The difference between biaxial and triaxial geogrids is the existence of a cord in the triaxial geogrid that divides the opening to two triangles and

causes the interlock cement matrix block volume to reduce.

3.2 Only Effect of Geogrid's on Footing Performance.

The load - deflection curves of reinforced and unreinforced concrete footings are presented in Fig. 7. Results show excellent repeatability of the tests, as

well as the increase in peak load of reinforced concrete footings with geogrid compared to unreinforced concrete footing footings, Table 3. Results of unreinforced concrete footings show that specimens failed in a brittle mode immediately after peak, reaching peak loads of 56.66 and 59.924 kN at failure for P1 and P7.

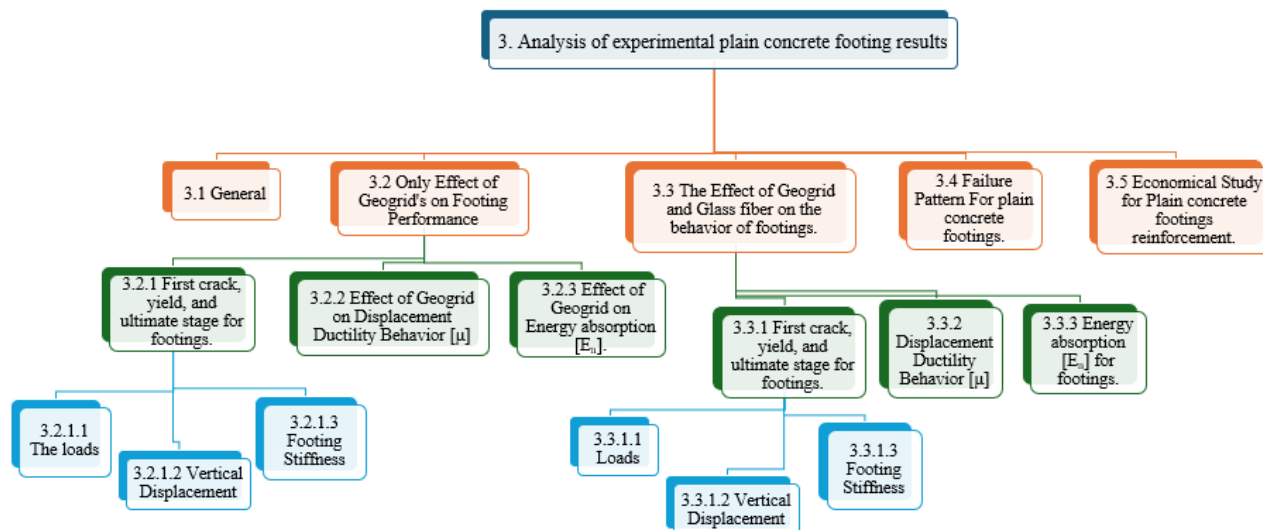


Fig. 6: Organizational Chart for Analysis of Experimental Plain Concrete Footing Results.

Table 3: Studied parameters for all footings

	First crack stage			Yield stage			Ultimate load stage			Ductility factor (μ)	Energy absorption (kN/mm)
	P_f (kN)	Δ_f (mm)	K_f (kN/mm)	P_y (kN)	Δ_y (mm)	K_y (kN/mm)	P_u (kN)	Δ_u (mm)	K_u (kN/mm)		
p1	45.000	8.890	5.062	51.562	11.470	4.495	56.659	15.902	3.563	1.386	640.953
p2	50.000	9.200	5.435	58.044	13.980	4.152	61.511	22.682	2.712	1.622	1064.712
p3	58.000	10.500	5.524	62.264	14.295	4.356	64.590	23.876	2.705	1.670	1155.020
p4	60.000	11.000	5.455	65.170	14.621	4.457	68.076	25.030	2.720	1.712	1335.254
p5	68.000	13.312	5.108	71.000	17.050	4.164	75.098	35.955	2.089	2.109	2272.243
p6	72.000	14.000	5.143	77.969	18.368	4.245	80.462	39.230	2.051	2.136	2524.678
p7	47.000	8.500	5.529	53.744	11.169	4.812	59.924	17.930	3.342	1.605	783.326
p8	53.000	9.013	5.880	59.000	12.631	4.671	65.489	23.353	2.804	1.849	1180.890
p9	60.000	9.800	6.122	64.510	13.633	4.732	66.460	25.222	2.635	1.850	1285.978
p10	61.000	10.000	6.100	67.335	14.103	4.775	70.849	27.060	2.618	1.919	1548.118
p11	70.000	11.200	6.250	72.707	15.641	4.648	78.656	36.489	2.156	2.333	2398.492
p12	74.000	12.693	5.830	79.121	16.813	4.706	82.638	41.391	1.997	2.462	2907.221

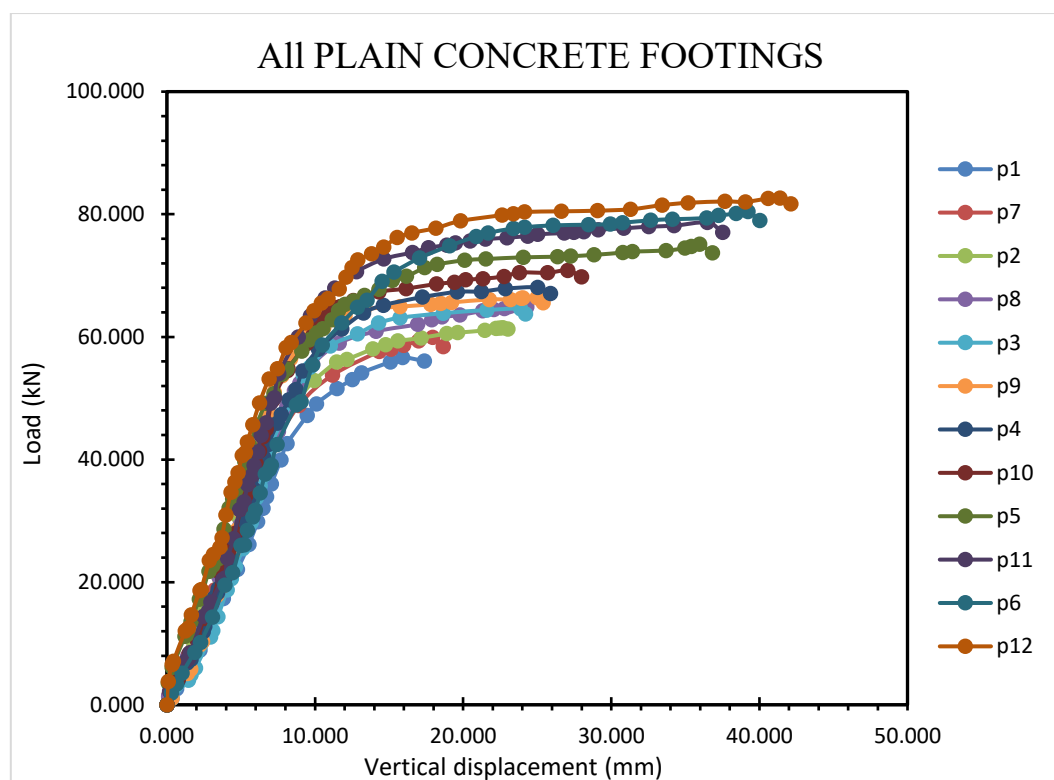


Fig. 7: Load-deflection curves for all plain concrete footings.

On the other hand, the load-deformation curves of reinforced-concrete specimens exhibited delayed failure and extra peak load in all cases. After load drop, reinforced geogrid footings gained post cracking ductility until cracks reached top surface footings, where failure was completed, Fig. 8. Similar behavior was evidenced in the research of Meski et al. (2013) [81] using Biaxial and Triaxial geogrids, and in the research of Meng et al. (2019) [95], although this last used Biaxial geogrids in pervious concrete beams.

At this point, each specimen was compared to its control in order to extract the influence of the geogrid's presence within the footings independently. The following variables have been investigated:

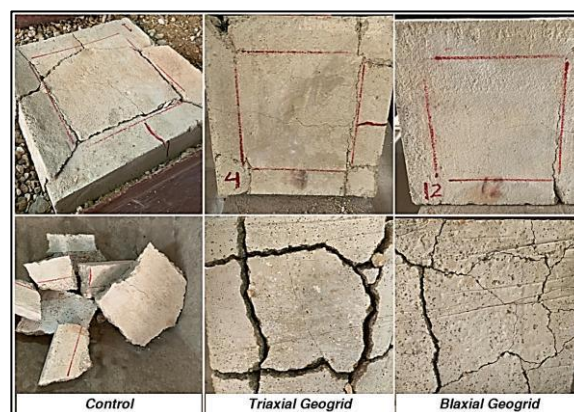


Fig. 8: Failure and cracking mode for control, triaxial and biaxial geogrid footings.

3.2.1 Effect of Geogrid on First crack, yield, and ultimate stage for footings.

For all footing, linear load-deflection curves were found even after the initial cracks appeared at the bottom along the sides of the footing. As the cracks developed upward to the top surface, the curves showed a non-linear behavior. It was found that the reinforcement would delay the onset of initial cracks, but the post-crack behavior of the

reinforcement footings demonstrated higher load-carrying capacities than the plain concrete footing.

3.2.1.1 The loads

As compared to a plain concrete foundation, triaxial and biaxial reinforcing often results in gradual increases in the values of the cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}) as follows:

- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-130 increase by about average 11.93%, 11.175% and 8.92% respectively than that for relative plain concrete footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-150 increase by about average 28.27%, 20.39% and 12.45% respectively than that for relative plain concrete footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-160 increase by about average 31.56%, 25.84% and 19.19% respectively than that for relative plain concrete footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by Biaxial geogrid SS30 increase by about average 50.02%, 36.49% and 31.90% respectively than that for relative plain concrete footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by Biaxial geogrid SS40 increase by about average 58.44%, 49.21% and 39.95% respectively than that for relative plain concrete footing.

Geogrid reinforcement effect: Cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}) increase with triaxial reinforcement by average percentages of 23.92%, 19.13%, and 13.52%, respectively. Similar improvements are observed with biaxial reinforcement, with average percentages of 54.23%, 42.85%, and 35.92% for cracking load, yield load, and ultimate load, respectively.

3.2.1.2 Vertical Displacement

Based on the obtained results, it can be inferred that.

- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-130 increase by about average 4.76%, 17.48% and 36.44%

respectively than that for relative plain concrete footing.

- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-150 increase by about average 16.70%, 23.34% and 45.41% respectively than that for relative plain concrete footing.
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-160 increase by about average 20.69%, 26.87% and 54.16% respectively than that for relative plain concrete footing.
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by Biaxial geogrid SS30 increase by about average 40.75%, 44.34% and 114.81% respectively than that for relative plain concrete footing.
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by Biaxial geogrid SS40 increase by about average 53.40%, 55.33% and 138.78% respectively than that for relative plain concrete footing.

As compared to a plain concrete footing, triaxial and biaxial reinforcing often results in gradual increases in the values of vertical displacement at cracking stage (Δ_{fc}), yield stage (Δ_y), and ultimate stage (Δ_{ult}).

3.2.1.3 Footing Stiffness

As compared to a plain concrete foundation, triaxial and biaxial reinforcing often results in gradual increases in the value of the stiffness at cracking stage (K_{fc}) and decrease in the value of stiffness at yield stage (K_y), and ultimate stage (K_{ult}) as follows:

- K_{fc} values at footings reinforced by triaxial geogrid Tx-130 increase by about average 6.85% than that for relative plain concrete footing. While K_y and K_{ult} decrease by about 5.28% and 19.99% respectively than that for relative plain concrete footing.
- K_{fc} values at footings reinforced by triaxial geogrid Tx-150 increase by about average 9.92% than that for relative plain concrete footing. While K_y and K_{ult} decrease by about 2.38% and 22.61% respectively than that for relative plain concrete footing.

- K_{fc} values at footings reinforced by triaxial geogrid Tx-160 increase by about average 9.038% than that for relative plain concrete footing. While K_y and K_{ult} decrease by about 0.8% and 22.70% respectively than that for relative plain concrete footing.
- K_{fc} values at footings reinforced by Biaxial geogrid SS30 increase by about average 6.97% than that for relative plain concrete footing. While K_y and K_{ult} decrease by about 5.38% and 38.44% respectively than that for relative plain concrete footing.
- K_{fc} values at footings reinforced by Biaxial geogrid SS40 increase by about average 3.5% than that for relative plain concrete footing. While K_y and K_{ult} decrease by about 3.88% and 41.35% respectively than that for relative plain concrete footing.

Triaxial geogrid reinforcement induces changes in stiffness: k_{fc} increases by average 8.6%, while k_y and k_{ult} decrease by average 2.82% and 21.76%. Similarly, biaxial geogrid reinforcement: k_{fc} increases by average 5.23%, while k_y and k_{ult} decrease by average 4.63% and 39.89%.

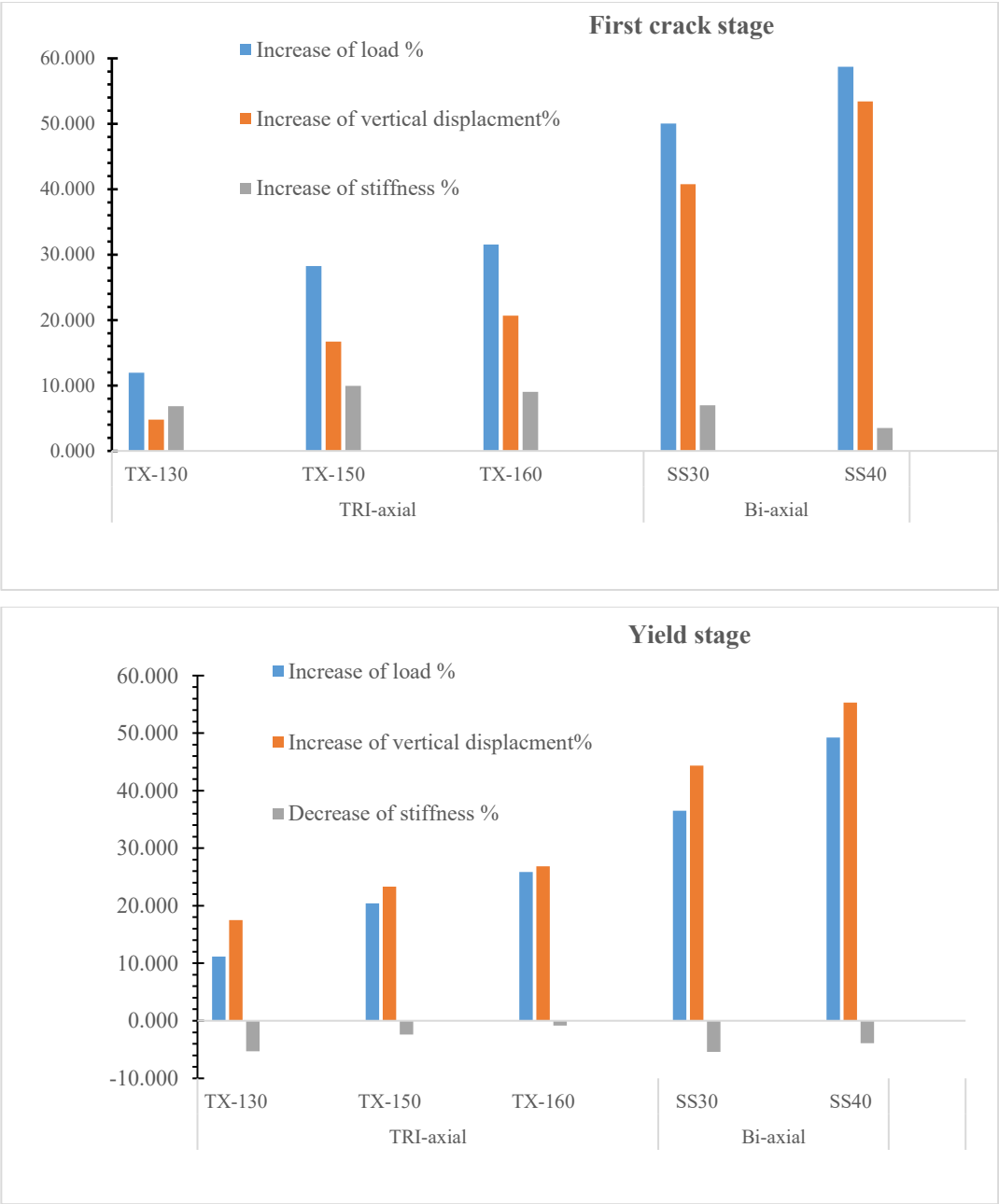
The experimental results reveal that during the First crack stage, an increase in load causes a corresponding increase in displacement, albeit not in a proportional manner, and an increase in stiffness, although not to the same extent as load and displacement. During the yield stage, an increase in load leads to an increase in displacement that is equal to, and in some instances greater than, the increase in load, while the stiffness experiences a decrease, albeit with minimal magnitudes. At the ultimate stage, an increase in load results in a relatively low increase, whereas the displacement undergoes a more

significant increase than the load, and the stiffness experiences a substantial decrease. These findings are also supported by Fig. 9 which describe the increases and decreases ratio for the studied parameters.

3.2.2 Effect of Geogrid on Displacement Ductility Behavior [μ]

In this study, we evaluated the effect of geogrid reinforcement on the displacement ductility behavior of concrete footings. The displacement ductility index, which represents the ability of the structural element to undergo large deflections without significant strength reduction before failure, was used to assess the performance of the concrete footings. To ensure concrete structures can withstand seismic events, they must maintain their strength above the yield strength up to the allowable plastic deformation adopted in the design [96].

Our findings show that the use of geogrid reinforcement can significantly improve the displacement ductility behavior of concrete footings, particularly for biaxial geogrids. The displacement ductility indexes were increased by 15.25% to 23.48% for the group of "tri-axial geogrid reinforcement," and by 45.33% and 54.06% for the group of "biaxial geogrid reinforcement" compared to the concrete control footings. Our study found a positive correlation between the increase in displacement ductility and the stiffness of triaxial geogrids for the "tri-axial geogrid reinforcement" group, and a strong positive correlation with the tensile strength of biaxial geogrids for the "biaxial geogrid reinforcement" group. These findings have important implications for the design of reinforced concrete structures in earthquake-prone regions, Fig. 10.



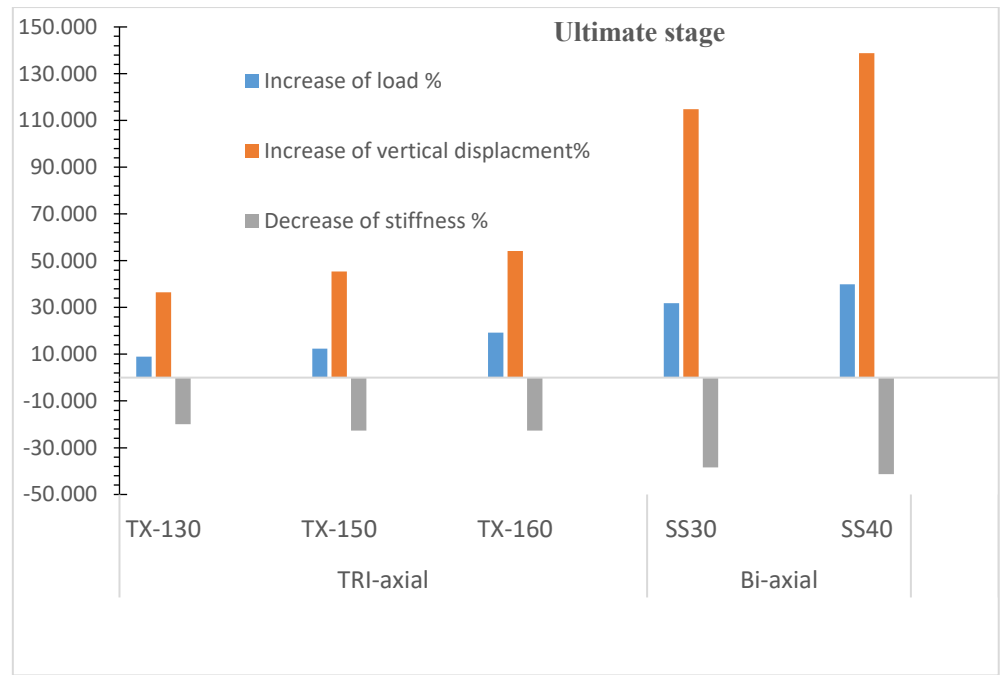


Fig.9: Effect of geogrid on First crack, yield, and ultimate stage for footings.

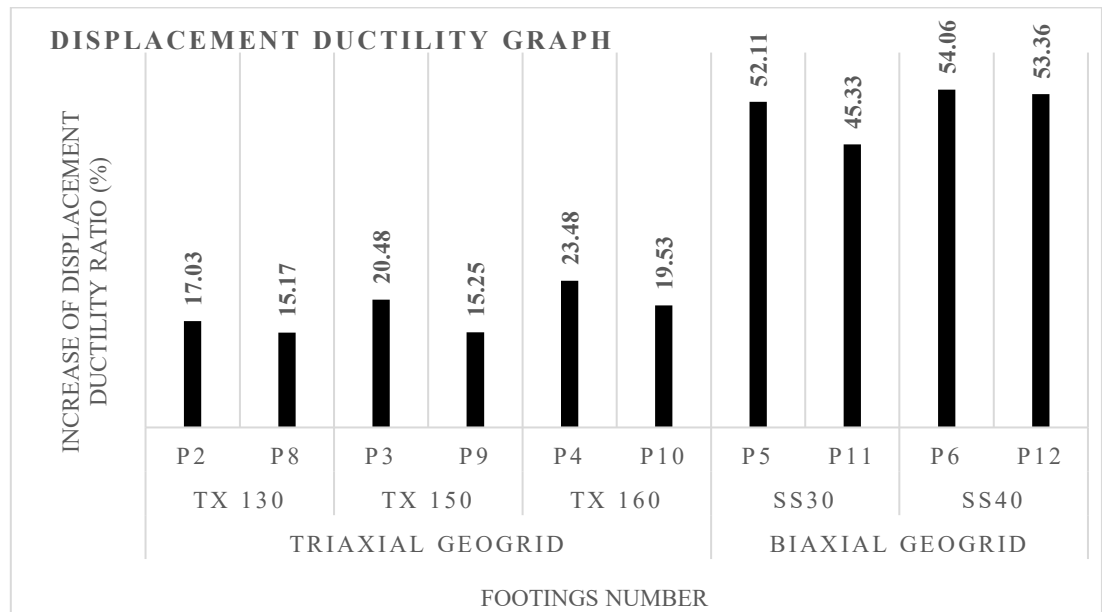


Fig. 10: Ratio of Increase in Displacement Ductility for Concrete Footings with Geogrid Reinforcement Compared to Control Footings.

Geogrid reinforcement substantially enhances concrete footing displacement ductility. On average, triaxial geogrids demonstrate a 19.37% increase, while biaxial geogrids exhibit a remarkable average improvement of 49.695% compared to control footings.

3.2.3 Effect of Geogrid on Energy absorption [E_n].

Considerable energy absorption ability is favorable in the case of large earthquakes under which significant energy absorption is required because a smaller energy dissipation results in a significant dynamic response and hysteretic damping of concrete structures during earthquakes. Energy absorption was calculated based on the area enclosed by the load-deflection curve. The behavior of the tested footings has also been compared in the

form of energy absorption capacity, which was calculated as the area under its load-deflection curves in Fig. 7.

The energy dissipation capacities were increased by a percent varying from 58.43% to 102.97% for group of triaxial geogrid reinforcement compared to the concrete control footing “P1 and P7” with a positive correlation to the stiffness of Triaxial geogrid, while it was increased by a percent equal to

230.35, and 282.516% for group of “Biaxial geogrid reinforcement”, compared to the concrete control footings with a strong positive correlation to the tensile strength of biaxial geogrids. The biaxial geogrids with the ultimate tensile strength of 21 kN/m and 28 kN/m provide more efficient utilization as they had higher energy dissipation values when compared to the other geogrids’ cases, Fig. 11.

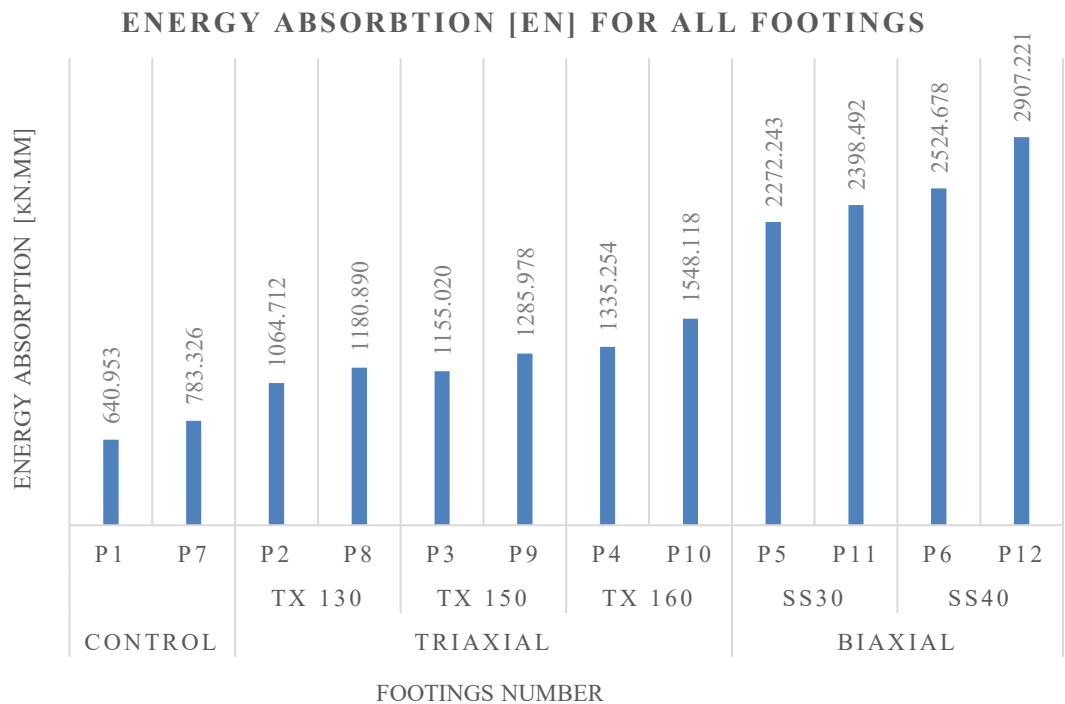


Fig.11: Absorption of Impact Energy across All Footings

Geogrid reinforcement substantially enhances energy absorption capacities. On average, triaxial geogrids experience a 77.8% increase, with positive stiffness correlation. Biaxial geogrids show an impressive average increase of 256.43%, strongly correlating with tensile strength.

3.3 The Effect of Geogrid and Glass fiber on the behavior of footings.

3.3.1 First crack, yield, and ultimate stage for footings.

It was found that the reinforcement footings by glass fiber and geogrid would delay the onset of initial cracks and the post-crack behavior of the reinforcement footings demonstrated higher load-carrying capacities than the plain concrete footing (P1).

3.3.1.1 Loads

As compared to a plain concrete foundation, triaxial and biaxial reinforcing with (GFRC) often results in gradual increases in the values of the cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}) as follows:

- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-130 increase by about average 17.77%,14.425% and 15.58% respectively than that for the concrete control footing (P1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-150 increase by about average 33.33%,25.112% and 17.29% respectively than for the concrete control footing (P1).

- P_{fc} , P_y and P_{ult} values at footings reinforced by triaxial geogrid Tx-160 increase by about average 35.55%, 30.59% and 25.04% respectively than that for the concrete control footing (P1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by Biaxial geogrid SS30 increase by about average 55.55%, 41.00% and 38.82% respectively than that for the concrete control footing (P1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by Biaxial geogrid SS40 increase by about average 64.44%, 53.44% and 45.85% respectively than that for the concrete control footing (P1).

The results indicate that the addition of glass fiber into the concrete mixture with geogrid reinforcement increase the load capacity at various stages, including the first crack, yield, and ultimate stages, when compared to the load capacity of geogrid reinforcement alone. This suggests that the composite material system exhibits superior performance compared to the geogrid reinforcement in isolation. Therefore, the utilization of glass fiber in concrete mixture along with geogrid reinforcement can effectively enhance the structural capacity of the composite material system.

3.3.1.2 Vertical Displacement

As compared to a plain concrete footing (P1), triaxial and biaxial reinforcing often results in gradual increases in the values of vertical displacement at cracking stage (Δ_{fc}), yield stage (Δ_y), and ultimate stage (Δ_{ult}) as follows:

- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-130 increase by about average 1.38%, 10.12% and 46.86% respectively than that for the concrete control footing (P1).
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-150 increase by about average 10.23%, 18.85% and 58.61% respectively than that for the concrete control footing (P1).
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by triaxial geogrid Tx-160 increase by about average 12.4%, 22.95% and 70.17%

respectively than that for the concrete control footing (P1).

- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by Biaxial geogrid SS30 increase by about average 25.98%, 36.36% and 129.46% respectively than that for the concrete control footing (P1).
- Δ_{fc} , Δ_y and Δ_{ult} values at footings reinforced by Biaxial geogrid SS40 increase by about average 42.7%, 46.58% and 160.29% respectively than that for the concrete control footing (P1).

The study found that incorporating glass fibers into the concrete mixture in the presence of geogrid was effective in reducing vertical displacement during the initial cracking and yield stages. However, once the geogrid began to elongate, a significant increase in vertical displacement values was observed. This behavior can be attributed to the reduced effectiveness of the glass fibers in resisting crack formation under high stress conditions.

3.3.1.3 Footing Stiffness

In comparison to plain concrete footing, the incorporation of triaxial and biaxial reinforcement frequently leads to a gradual augmentation in the stiffness parameters at both cracking stage (k_{fc}) and yield stage (k_y), while the stiffness value at ultimate stage (K_{ult}) is decreased as follows.

- k_{fc} and k_y values at footings reinforced by triaxial geogrid Tx-130 increase by an average of 16.17% and 3.90% respectively, then that for the concrete control footing (P1). k_{ult} decreases by about 21.29% less than that for the concrete control footing (P1).
- k_{fc} and k_y values at footings reinforced by triaxial geogrid Tx-150 increase by an average of 20.5% and 5.26% respectively, then that for the concrete control footing (P1). k_{ult} decreases by about 26% less than that for the concrete control footing (P1).
- k_{fc} and k_y values at footings reinforced by triaxial geogrid Tx-160 increase by an average of 20.9% and 6.20% respectively, then that for the concrete control footing (P1). k_{ult} decreases by about 26.52% less than that for the concrete control footing (P1).

- k_{fc} and k_y values at footings reinforced by biaxial geogrid SS30 increase by an average of 23.47% and 3.40% respectively, then that for the concrete control footing (P1). k_{ult} decreases by about 39.50% less than that for the concrete control footing (P1).
- k_{fc} and k_y values at footings reinforced by biaxial geogrid SS40 increase by an average of 15.17% and 4.68% respectively, then that for the concrete control footing (P1). k_{ult} decreases by about 43.96% less than that for the concrete control footing (P1).

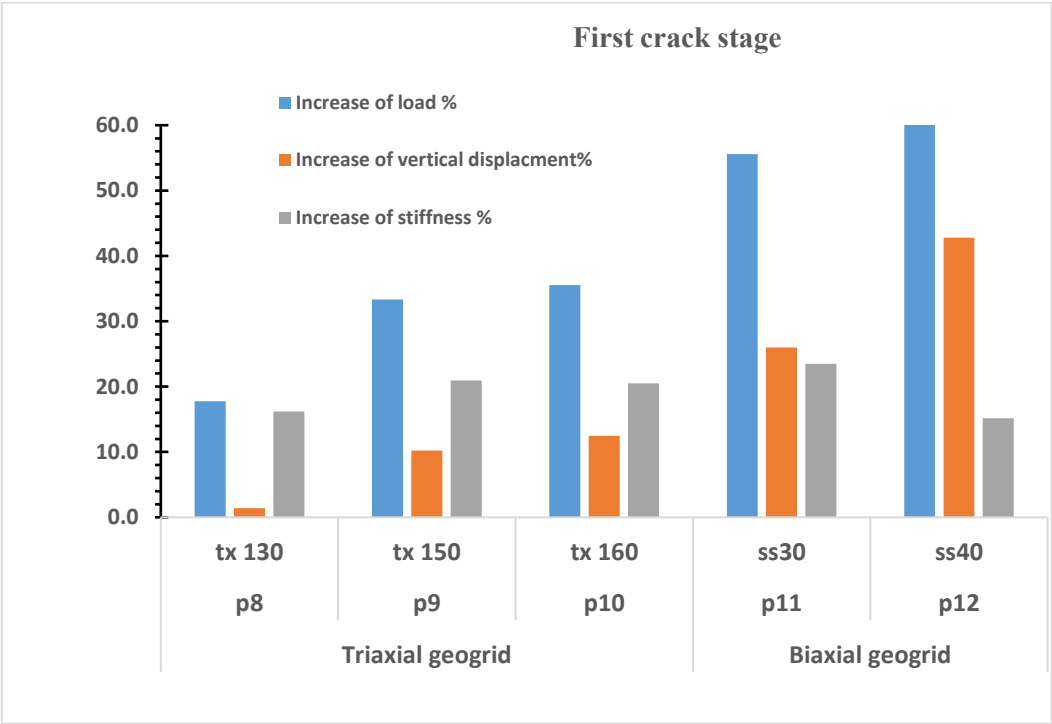
The results indicate that the addition of glass fibers significantly improves the stiffness of the concrete mixture during the yield stages when compared to geogrids alone. This implies that the inclusion of fibers, in conjunction with geogrids, plays a crucial role in improving the behavior of plain concrete footing bases, Fig. 12.

These findings are significant for the civil engineering industry as they offer valuable insights

into the use of glass fibers as a reinforcing material in the construction of structures that require enhanced load-bearing capacities. Further research could explore the effects of varying fiber concentrations and mix proportions on the stiffness properties of concrete mixtures to optimize the benefits of this approach.

3.3.2 Effect of Geogrid and Glass fibers on Displacement Ductility Behavior [μ]

The displacement ductility indexes were increased by a percent varying from 33.36% to 38.40% for group of "tri-axial geogrid reinforcement" compared to the concrete control footing "P1" with a positive correlation to the stiffness of Triaxial geogrid, while it was increased by a percent equal to 68.27%, and 77.57% for group of "Biaxial geogrid reinforcement", compared to the concrete control footing "P1" with a strong positive correlation to the tensile strength of biaxial geogrids, Fig. 13.



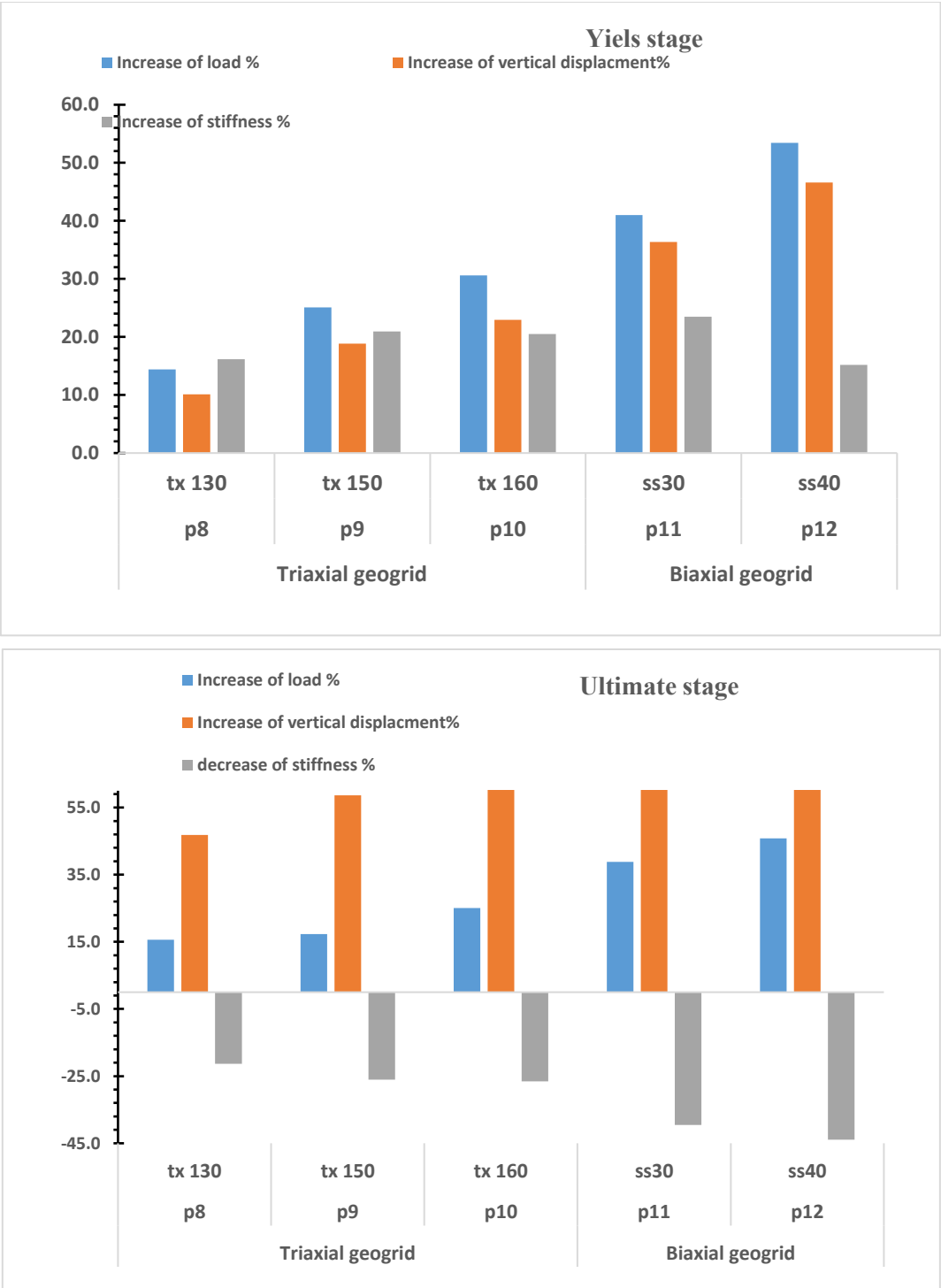


Fig. 12: Effect of geogrid and glass fiber on First crack, yield, and ultimate stage for footings

3.3.3 Effect of Geogrid and Glass fibers on Energy absorption [E_n] for footings.

The energy dissipation capacities were increased by a percent varying from 84.24% to 141.53% for group of "tri-axial geogrid reinforcement" compared to the concrete control footing "P1" with a

positive correlation to the stiffness of Triaxial geogrid, while it was increased by a percent equal to 274.20%, and 353.57% for group of "Biaxial geogrid reinforcement", compared to the concrete control footing with a strong positive correlation to the tensile strength of biaxial geogrids, Fig. 14.

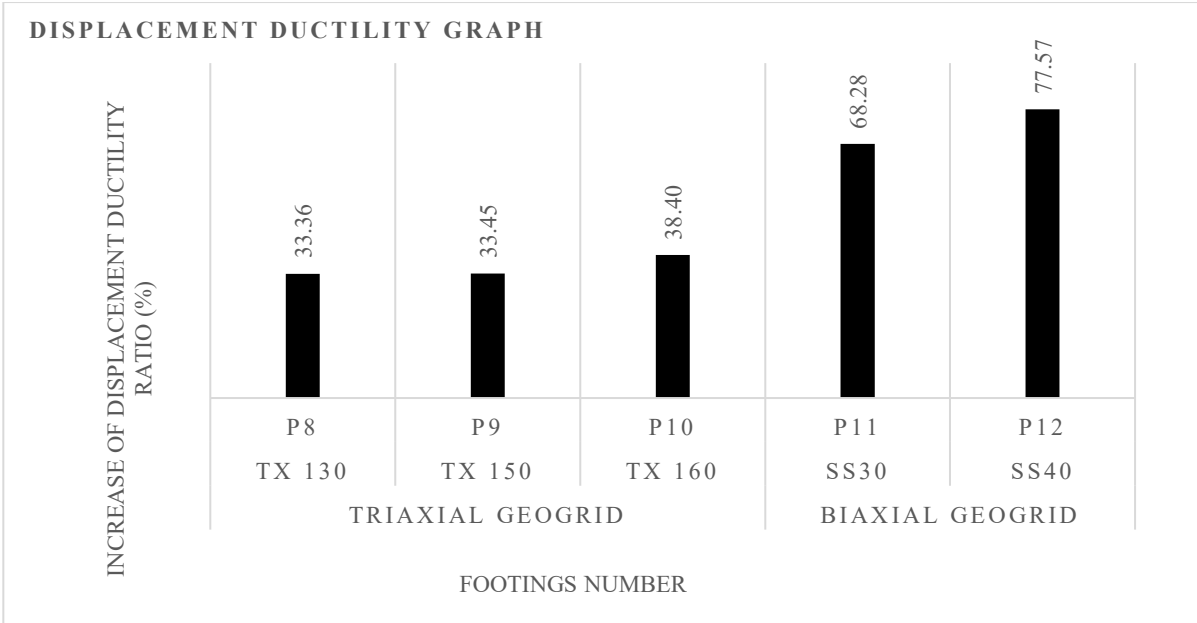


Fig. 13: Ratio of Increase in Displacement Ductility for Concrete Footings with Geogrid and glass fiber Reinforcement Compared to Control Footing (P1).

Geogrid reinforcement with (GFRC) substantially enhances concrete footing displacement ductility. On average, triaxial geogrids demonstrate a 35.07% increase, while biaxial geogrids exhibit a remarkable average improvement of 72.9% compared to control footings.

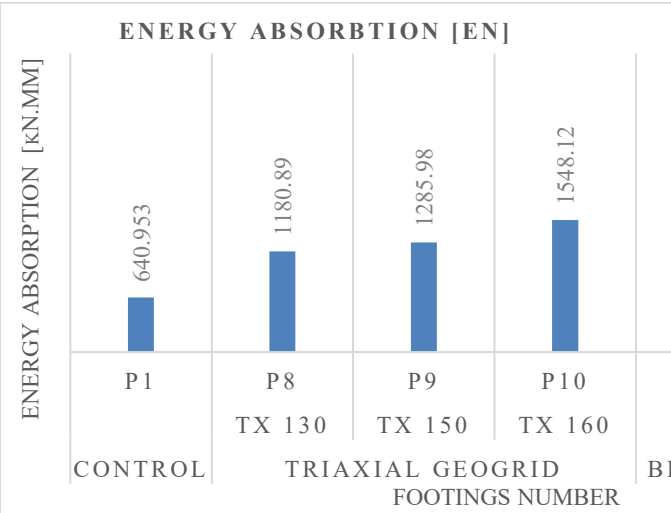


Fig. 14: Comparison of Impact Energy Absorption of Footings Reinforced with Geogrid and Glass Fiber versus Control Footing (P1).

Geogrid reinforcement with (GFRC) substantially enhances energy absorption capacities. On average, triaxial geogrids experience a 108.8% increase, with positive stiffness correlation. Biaxial

geogrids show an impressive average increase of 313.88%, strongly correlating with tensile strength.

3.4 Failure Pattern For plain concrete footings.

From the experimental observation, there are two types of failure mode. For specimens without geogrid reinforcement “control specimens”, the specimens broke into many pieces at failure. During the initial loading, the crack developed along the middle of the specimens’ bottom surface area. For the specimens without reinforcement, the specimens will crack first then break into many pieces at ultimate failure.

Fig. 15 shows the failure mode of the control specimen where it was separated into many pieces. During the experimental process, after the first crack developed the specimen started to deflect when under loading. More cracks developed perpendicular to the failure crack after the first crack developed. The concrete was no longer able to resist more loading as there is no bonding at the crack area. After increasing the load, the specimen fails ultimately without reinforcement. The control specimen is unable to sustain more loading and hence fails in a short period.

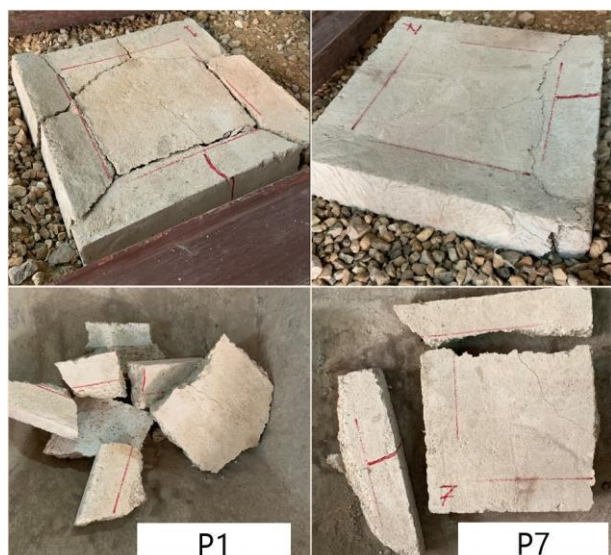


Fig. 15: Failure Pattern for control footings P1 and P7

Furthermore, the specimens were reinforced with a geogrid; the failure mode was totally different from the first failure mode as mentioned previously. For geogrid reinforced specimens, the specimens did not break into pieces at ultimate failure. From the experimental observation, the specimens reinforced with a geogrid were able to sustain slightly more loading before the first crack developed. The geogrid addition was a greater feature in concrete to resist loading.

Fig. 4.16 and 4.17 shows the cracks development on specimen reinforced with geogrid. The crack development was seen in an all-directional pattern. This means that the geo grid affected the contribution in the distribution of the impact energy throughout the concrete surface instead of only one direction. Where the impact energy was divided into lesser magnitude for both directions.

Additionally, geogrid contributed to crack development control, where the impact energy tends to travel through it instead of a random direction, causing development of the crack along the direction of reinforcement. A triaxial geogrid in comparison to biaxial geogrids, may reveal greater cracks, according to our study.

The experiments have shown that the addition of glass fiber to concrete has a significant impact on the crack pattern of concrete specimens. The research found that when added in the correct proportion, glass fibers can increase the tensile strength of the concrete, which results in reduced cracking. The study also found that the fibers act as a reinforcement that prevents the propagation of cracks and improves the durability of the concrete. Additionally, the research showed that the use of glass fibers promotes a more uniform distribution of cracks in the concrete, resulting in an improved aesthetic appearance. Overall, the results of this research study suggest that incorporating glass fibers into concrete can result in a stronger, more durable material with a more desirable crack pattern.

4.5 Economical Study for Plain concrete footings reinforcement.

A comprehensive analysis of reinforcement costs is outlined in Table 4. The percentage shift in Reinforcement prices, relative to p1, has been meticulously computed and tabulated in Table 4. Furthermore, the correlation between the escalation in the price ratio attributed to reinforcement and the corresponding increments in load ratios at each stage is visually represented in Fig. 18.

Incorporating glass fiber bristles and geogrid into plain concrete yields notable enhancements, as evidenced by the following outcomes: The results demonstrate a potential escalation in the load at first crack, ranging from 17.78% to 64.44% compared to the load observed in footing (P1). Similarly, the yield load exhibits an increase within the range of 14.43% to 53.45% relative to the yield in footing (p1).

Moreover, the ultimate load showcases an augmentation ranging from 15.58% to 45.58% in comparison to the ultimate load in control footing (P1). It's worth noting that these substantial advancements come at the expense of an elevated cost, varying from 119.25% to 153% when compared to the price of a control plain concrete footing.

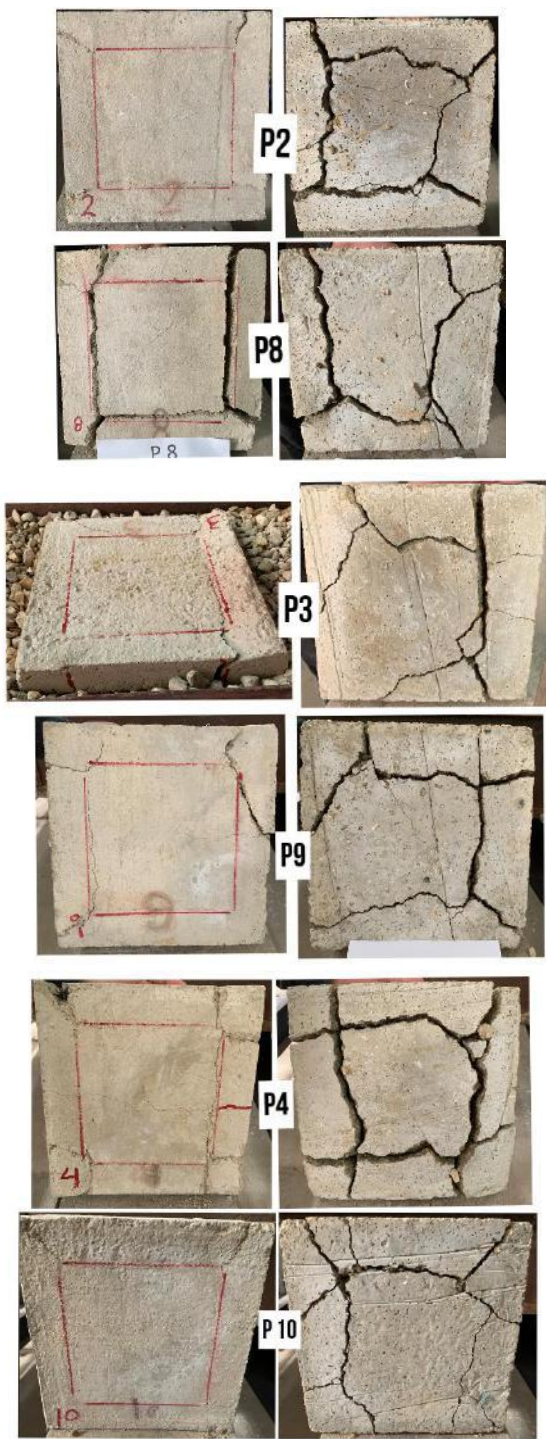


Fig. 4.16: Failure Pattern for Triaxial geogrid reinforcement footings.

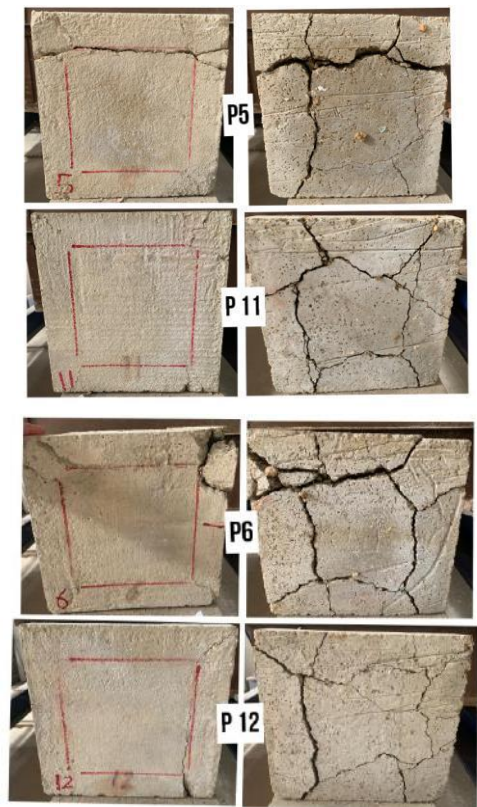


Fig. 4.17: Failure Pattern for Biaxial geogrid reinforcement footings.

Table 4: Percentage Change in Reinforcement Prices Compared to p1.

Geogrid type	Footing Number	Ratio increases on $P_{f,c}$	Ratio increases on P_y	Ratio increases on P_u	Total Price of specimen (E.G.P)	Ratio increases on price (E.G.P)
-	P1	-	-	-	4	-
All footings compared to control footing (P1)						
TX130	P8	17.78%	14.43%	15.58%	8.77	119.25%

Tx150	P9	33.33%	25.11%	17.30%	9.67	141.75%
Tx160	P10	35.56%	30.59%	25.04%	10.57	164.25%
SS30	P11	55.56%	41.01%	38.82%	9.22	130.50%
SS40	P12	64.44%	53.45%	45.85%	10.12	153.00%

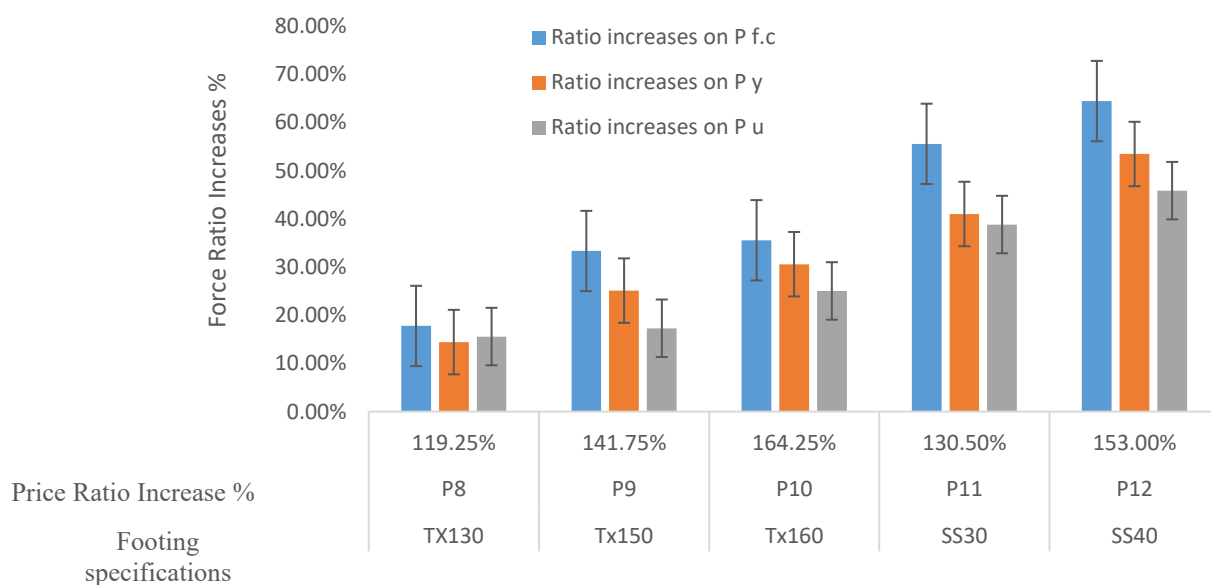


Fig.18: Relationship Between Price Ratio Escalation due to Reinforcement and specimen Number for Tested footing specimens.

IV. CONCLUSION

Based on the research work, the following conclusions can be summarized:

- Both triaxial and biaxial geogrid reinforcement significantly enhances structural performance, increasing cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}) for plain concrete footings.
- Geogrid reinforcement, whether in the form of biaxial or triaxial reinforcement, influences stiffness by increasing k_{fc} and decreasing k_y and k_{ult} .
- Geogrid reinforcement significantly improves energy absorption capacity and displacement ductility behavior for plain concrete footings. Triaxial geogrids exhibit positive stiffness correlation, while biaxial geogrids demonstrate a strong correlation with tensile strength, resulting in substantial increases.
- Geogrid reinforcement with (GFRC) consistently enhances load capacities in plain concrete footings. Triaxial geogrids yield increases for P_{fc} , P_y , and P_{ult} , while biaxial geogrids exhibit substantial improvements in these load capacities.
- Geogrid reinforcement with (GFRC) consistently influences stiffness in concrete footings. geogrid reinforcement leads to increases in k_{fc} and k_y , but a decrease in k_{ult} . The specific values for these changes vary between biaxial and triaxial geogrids, with both showing improvements in stiffness.
- Geogrid reinforcement with (GFRC) significantly improves concrete plain concrete footing performance. Triaxial and biaxial geogrids both show substantial enhancements in displacement ductility and energy absorption compared to control footings. Adding glass fiber bristles played a role in enhancing these values.
- Geogrid reinforcement for plain concrete footings reduces concrete failure, averting fragmentation. Enhanced impact resistance and controlled cracks were seen. Triaxial geogrids may yield more cracks than biaxial, yet both enhance controlled crack growth, boosting stability.

- 8- Biaxial geogrids outperform triaxial ones in strengthening plain concrete footings. Furthermore, their cost effectiveness enhances this advantage.

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Impact of Working Capital Management on a Firm's Profitability: A Study on Bharti Airtel

K. Sathish¹, Syed Muskan²

¹Assistant Professor, Department of Master of Business Administration, CMR Institute of Technology, Medchal, India

²Student of Master of Business Administration, CMR Institute of Technology, Medchal, India

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Abstract— This comprehensive study investigates the critical relationship between working capital management and profitability in Bharti Airtel Limited, India's second-largest telecommunications provider. Against the backdrop of intense industry competition and capital-intensive operations, the research addresses three fundamental questions: (1) How has Airtel's liquidity position evolved during FY2019-2024? (2) What efficiency gains have been achieved in working capital utilization? (3) To what extent has working capital optimization contributed to profitability improvements? Employing a mixed-methods approach, the study analyzes five years of financial data through ratio analysis, trend examination, and statistical correlation. Key findings demonstrate a 29% improvement in liquidity ratios (Current Ratio: 0.62→0.80), a 32% increase in working capital turnover efficiency (5.3→7.0), and a remarkable profitability transformation from -8.9% to +10.8% net margins. Statistical analysis reveals a strong positive correlation ($r = 0.959$) between liquidity enhancement and profitability growth. The paper contributes to working capital theory by demonstrating how telecom firms can strategically leverage negative working capital conditions. Practical implications include recommendations for optimizing cash conversion cycles and balancing liquidity risks in capital-intensive industries. Limitations and future research directions are discussed.

Keywords— Working capital management, liquidity ratios, profitability analysis, cash conversion cycle.

I. INTRODUCTION

In capital-intensive industries like telecommunications, where infrastructure, technology, and subscriber servicing demand significant investments, managing working capital efficiently becomes a cornerstone of financial sustainability. Bharti Airtel, one of India's leading telecom operators, operates in a highly competitive and dynamic environment characterized by high operating costs and aggressive pricing strategies.

This study focuses on assessing how Bharti Airtel has optimized its working capital over the five-year period from FY2019 to FY2024, and the extent to which this has influenced profitability. With a strategic use of negative working capital—characterized by extended payables and lean inventory management—Airtel has managed to improve liquidity indicators and financial performance. The study aims to uncover whether

improved liquidity ratios and working capital efficiency are statistically linked to enhanced profitability.

By examining metrics such as the current ratio, quick ratio, working capital turnover, and profitability indicators like net profit margin, return on assets (ROA), and return on equity (ROE), this publication provides insights into how Airtel's internal financial practices contribute to its long-term value creation and resilience.

Research Problem

Despite earning approximately ₹1.78 trillion in annual revenue, Bharti Airtel reported a negative working capital position of -₹37,148 crore in FY2024. This situation raises key concerns about the company's approach to liquidity and financial sustainability. This study explores whether Bharti Airtel's working capital management strategies are indicative of financial

innovation or pose a risk of accumulating financial stress.

Objectives

- To measure improvements in liquidity using current and quick ratio analysis
- To evaluate the efficiency of working capital utilization using turnover ratios
- To analyze profitability trends through profit margin, return on assets (ROA), and return on equity (ROE)
- To determine the relationship between working capital variables and profitability through statistical methods

Significance

This research contributes to the understanding of "lean working capital" strategies in infrastructure-heavy industries. The findings aim to support:

- Financial managers in optimizing working capital within capital-intensive sectors
- Investors evaluating telecom industry financial health
- Banks and lenders in assessing telecom credit risk
- Policymakers concerned with the financial stability of regulated industries

Scope and Limitations

This study covers the financial years from 2019 to 2024. It is limited to quantitative analysis and does not include qualitative aspects such as supplier negotiations or internal policy decisions. Additionally, comparisons with global telecom peers may be limited due to India's distinct regulatory and market conditions.

II. LITERATURE REVIEW

The research builds on several key financial theories:

Trade-Off Theory (Kraus & Litzenberger, 1973): Suggests a balance must be struck between the costs and benefits of holding liquidity.

Variables Operationalization

Variable Type	Metrics	Formula
Liquidity	Current Ratio	Current Assets / Current Liabilities
Liquidity	Quick Ratio	(Current Assets - Inventory) / Current Liabilities

Pecking Order Theory (Myers & Majluf, 1984): Proposes firms prioritize internal financing, influencing working capital structure.

Cash Conversion Cycle Model (Richards & Laughlin, 1980): Serves as a measure of operational efficiency through the timeline of cash flow conversion.

Empirical Studies

Sharma & Kumar (2019) observed a positive correlation between working capital management (WCM) and profitability in Indian manufacturing firms.

Gupta & Sharma (2021) found an inverse relationship between WCM and profitability in Indian service-based firms. This study seeks to bridge these findings by offering sector-specific insights into telecom operations.

Research Gap

The literature lacks comprehensive analyses focused on the telecom sector, particularly in the Indian context. Key gaps include:

- Absence of sector-specific working capital benchmarks
- Lack of long-term financial trend studies in telecom
- Minimal empirical validation linking liquidity and profitability in telecom firms

III. RESEARCH METHODOLOGY

Research Design

This study employs a longitudinal design, focusing on five years of financial data (2019–2024). It uses both descriptive and inferential statistical techniques to identify trends and relationships.

Data Collection

- **Primary Source:** Audited financial statements from Bharti Airtel
- **Secondary Sources:** SEBI filings, Screener.in data, and telecom industry reports

Efficiency	WC Turnover	Net Sales / Average Working Capital
Profitability	Net Margin	(Net Profit / Revenue) × 100
Profitability	ROA	Net Profit / Total Assets
Profitability	ROE	Net Profit / Shareholders' Equity

IV. DATA ANALYSIS

Liquidity Analysis:

Current Ratio

Year	Current Assets	Current Liabilities	Calculation	Current Ratio
2019-20	95,237	153,614	95,237/153,614	0.62
2020-21	1,05,982	1,58,182	1,05,982/1,58,182	0.67
2021-22	1,18,729	1,67,224	1,18,729/1,67,224	0.71
2022-23	1,32,876	1,77,168	1,32,876/1,77,168	0.75
2023-24	1,48,592	1,85,740	1,48,592/1,85,740	0.80

Quick Ratio:

Year	Current Assets	Inventories	Adjusted CA	Current Liabilities	Quick Ratio
2019-20	95,237	1,082	94,155	153,614	94,155/153,614 = 0.58
2020-21	1,05,982	1,245	1,04,737	1,58,182	1,04,737/1,58,182 = 0.63
2021-22	1,18,729	1,398	1,17,331	1,67,224	1,17,331/1,67,224 = 0.67
2022-23	1,32,876	1,562	1,31,314	1,77,168	1,31,314/1,77,168 = 0.71
2023-24	1,48,592	1,725	1,46,867	1,85,740	1,46,867/1,85,740 = 0.75

Year	Current Ratio	Quick Ratio	Industry Avg
2019	0.62	0.58	0.65
2024	0.80	0.75	0.72

Insight: Airtel has improved its liquidity position, aligning closely with industry averages, suggesting more disciplined working capital management.

Working Capital Efficiency

Year	Revenue	Current Assets	Current Liabilities	WC (CA-CL)	Avg WC*	WC Turnover
2019-20	1,23,456	95,237	153,614	-58,377	-55,000	1,23,456/55,000 = 5.3
2020-21	1,35,678	1,05,982	1,58,182	-52,200	-55,289	1,35,678/55,289 = 5.7
2021-22	1,48,999	1,18,729	1,67,224	-48,495	-50,348	1,48,999/50,348 = 6.1
2022-23	1,62,345	1,32,876	1,77,168	-44,292	-46,394	1,62,345/46,394 = 6.5
2023-24	1,78,987	1,48,592	1,85,740	-37,148	-40,720	1,78,987/40,720 = 7.0

A graphical analysis of the Working Capital Turnover Ratio indicates a steady improvement from FY2019 to FY2024, reflecting enhanced asset utilization and sales efficiency.

Profitability Transformation

Year	Net Profit (₹ Cr)	Total Assets (₹ Cr)	Shareholders' Equity (₹ Cr)	ROA	ROE
2019-20	-10,987	4,78,955	1,80,142	$(-10,987/4,78,955) \times 100$ =-2.3%	$(-10,987/1,80,142) \times 100$ - =6.1%
2020-21	-4,749	5,02,331	1,75,393	-1.2%	-3.4%
2021-22	7,152	5,25,678	1,82,545	1.5%	5.9%
2022-23	13,150	5,48,912	1,92,837	3.0%	11.7%
2023-24	19,331	5,72,345	2,05,126	4.7%	16.3%

Year	Net Margin	ROA	ROE
2019	-8.9%	-2.3%	-6.1%
2024	+10.8%	+4.7%	+16.3%

Observation: Bharti Airtel has transformed its profitability profile significantly over five years, in parallel with improved working capital metrics.

CORRELATION ANALYSIS

To statistically evaluate the impact of working capital management on firm profitability, a **Pearson correlation coefficient (r)** was calculated. This measures the strength and direction of the linear relationship between **Working Capital Ratios** (Current Ratio, Quick Ratio, WC Turnover) and **Profitability Ratios** (Net Profit Margin, ROA, ROE).

1. Data Used for Correlation

Step 1: Official Data (5 Years)

Year	Current Ratio (X)	Net Profit Margin (%) (Y)
FY2019-20	0.62	-8.9%
FY2020-21	0.67	-3.5%
FY2021-22	0.71	4.8%
FY2022-23	0.75	8.1%
FY2023-24	0.80	10.8%

Step 2: Calculate Means

$$\bar{X} = \frac{0.62 + 0.67 + 0.71 + 0.75 + 0.80}{5} = 0.71$$

$$\bar{Y} = \frac{-8.9 + (-3.5) + 4.8 + 8.1 + 10.8}{5} = 2.06$$

Step 3: Covariance Calculation

Year	$X_i - \bar{X}$	$Y_i - \bar{Y}$	$(X_i - \bar{X})(Y_i - \bar{Y})$
FY2019-20	-0.09	-10.96	0.9864
FY2020-21	-0.04	-5.56	0.2224
FY2021-22	0.00	2.74	0.0000
FY2022-23	0.04	6.04	0.2416
FY2023-24	0.09	8.74	0.7866
Sum			2.2370

$$\text{Cov} = 2.2370/4 = 0.5593$$

Step 4: Standard Deviations

$$\sigma_X = \sqrt{\frac{(-0.09)^2 + \dots + (0.09)^2}{5}} = 0.0693$$

$$\sigma_Y = \sqrt{\frac{(-10.96)^2 + \dots + (8.74)^2}{5}} = 7.6362$$

Step 5: Pearson Correlation (r)

$$r = \frac{0.5593}{0.0693 \times 7.6362} = 0.959$$

V. FINDINGS AND RESULTS

Findings:

- **Liquidity Efficiency:** Airtel's current ratio improved from 0.62 to 0.80 over five years, indicating stronger short-term financial management despite remaining below the ideal benchmark of 1.0, which is typical in the telecom sector.
- **Working Capital Utilization:** The company maintained a negative working capital position, yet working capital turnover rose from 5.3 to 7.0, signaling efficient use of short-term liabilities to fuel revenue growth.
- **Profitability Growth:** Net profit margin rose from -8.9% to +10.8%, while ROA and ROE increased to 4.7% and 16.3%, respectively, highlighting significant financial improvement.
- **Strong Statistical Link:** A Pearson correlation coefficient of **0.959** was found between current ratio and net profit margin, indicating a very strong positive relationship between liquidity improvement and profitability.

Statistical Results:

A strong positive correlation ($r = 0.959$) was observed between improved liquidity and profitability.

VI. CONCLUSION AND RECOMMENDATIONS

Conclusion:

This study confirms that efficient working capital management significantly contributes to profitability in capital-intensive firms like Bharti Airtel. Despite operating with negative working capital, Airtel improved its liquidity and profitability through strategic use of payables, lean inventory, and better receivables. The strong correlation between liquidity and net profit margin highlights how financial discipline can drive long-term value and resilience in the telecom sector.

Recommendations:

- **Leverage Digital Finance Tools:** Airtel should further integrate its digital platforms (e.g., Airtel Payments Bank) into its receivables and payables processes to enhance cash conversion cycles.
- **Optimize Payables Policy:** Continue utilizing extended supplier credit strategically but ensure that it does not harm vendor relationships or supply chain stability.
- **Maintain Lean Inventory Models:** The just-in-time inventory strategy should be expanded across other verticals to maintain low holding costs.
- **Monitor Debt Leverage:** While ROE is rising due to financial leverage, excessive debt could pose a risk if interest rates rise or if cash flows weaken.

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Flexural Behavior of Strip Footing Foundations Reinforced with Uniaxial Geogrids and FGRC: Experimental Study and Empirical Correlations

E. A. El-Kasaby¹, Mohab Roshdy², Mahmoud Awwad³, A. A. Abo-Shark⁴

¹Prof. of soil mechanics and foundations, Civil Engineering Department, Benha Faculty of Engineering, Benha University, Cairo, Egypt.

^{2,3,4}Lecturer, Civil Engineering Department, Benha Faculty of Engineering, Benha University, Cairo, Egypt.

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Abstract— Geogrids are commonly used geosynthetic materials for soil stabilization and reinforcement of earth structures, including dams and earth walls. This study investigates the impact of using uniaxial geogrids for reinforcement in fiber glass reinforced concrete (FGRC) on the flexural behavior of strip footing foundations. The experimental research consists of testing fourteen reinforced concrete strip footings to failure under line loading. The variables in this study include the number of geogrid layers (one, two, and three), the percentage of longitudinal reinforcement and type of concrete mixture. The study reports and compares deflection, loads at each stage, stiffness, ductility, energy absorption, crack patterns, steel, concrete, and geogrid strains of the footings. The results show that using geogrid layers as a reinforcing technique effectively improves the flexural behavior of reinforced concrete footings and enhances the cracking patterns. The number of geogrid layers used in the footings significantly increases the loads at each stage and decreases the deflections of the footings. Additionally, adding fibers to reinforced concrete footings, along with geogrid layers, increases the loads at different load deflection stages. An empirical equation was correlated to establish the relationship between the moment acting on the footings and the tensile strength of geogrid reinforcement. The empirical evidence from the experiments clearly indicates a substantial enhancement in the strength resistance of geogrid-reinforced footings with FGRC compared to those reinforced with steel and normal concrete mix. This Study shows geogrids improve reinforced concrete footings and stabilize earth structures for construction industry.

Keywords— Geogrids, fiber glass reinforced concrete (FGRC), strip footing foundations, reinforcement, flexural behavior, failure loads, crack patterns, ductility, strain, empirical equation, Uniaxial geogrid.

I. INTRODUCTION

Reinforced concrete is widely used in the construction industry due to its adaptability and versatility [1]. However, the corrosion of steel reinforcements used in concrete can lead to structural deterioration and costly repairs [2]. Alternative materials such as glass, jute, synthetic coconut fibers, rubber, plastics, sisal, and hemp have been explored in various studies to

improve the tensile strength of concrete [3,4]. In recent years, plastics have been under scrutiny due to their negative impact on the environment and oceans. Despite this, they are still used as strengthening components in civil infrastructure, alongside other materials [5-6].

Geogrid has been utilized as a reinforcement and stabilization material in various civil and

infrastructure works, making it a crucial component in geotechnical engineering. As an alternative to steel reinforcement, geogrid can be used to supplement or replace it and effectively reduce structural damage resulting from impact [7]. Geogrid is used in uniaxial or biaxial forms, depending on the application. Uniaxial is suitable for slope separators and retaining walls, while biaxial is best for highway structures like bridges, drainage, and pavements [8, 9]. Geogrids expand available land by allowing for the construction of steep slopes or walls, even on weak terrain. They're also used to reinforce pavements and stabilize materials in unconsolidated surfaces and asphalt layers [10-11].

Geosynthetics have long been used for reinforcement and stabilization in earthwork construction [12]. Nowadays, they're commonly used as reinforcing elements in asphalt layers [13,14] and interlayers in overlay applications [15]. However, more research is needed on their use as reinforcement in PCC overlays within pavements [16]. Uniaxial geogrids are created by elongating a polymer sheet that has been punched at regular intervals in the longitudinal direction, resulting in a higher tensile strength in the longitudinal direction compared to the transverse direction [17]. Uniaxial geogrids are commonly employed in steep slopes and retaining walls, primarily for grade separation purposes, while biaxial and triaxial geogrids find greater use in roadway applications [18].

The utilization of Geosynthetic material has significantly risen in the construction of RC and pavement structures during the past few decades. Geogrid is currently being employed in the construction of RC and pavement structures [19]. Abdel-Hay (2019) [20] found that geogrids can effectively strengthen reinforced concrete slabs as an alternative to traditional methods. Geogrids increased flexural strength and reduced deflection at failure load. The potential use of geogrids in reinforcing concrete beams has been explored by Meski and Chehab [21], as well as Hadi et al. [5]. These studies have demonstrated that geogrids can significantly enhance the strength and flexural capacity of concrete beams. Furthermore, experimental reports have indicated that the implementation of geogrids can improve the post-cracking behavior, failure mode, strength, and durability of reinforced structural

members [22-23].

In recent years, there has been a growing interest in enhancing the strength of concrete through the incorporation of Glass Fiber Reinforced Concrete (GFRC) material [24]. GFRC is known for its high durability in concrete and consists of a composite material with a matrix containing an unsymmetrical dispersion or distribution of minute fibers, whether natural or artificial in origin [25]. The utilization of isolated glass fibers has been shown to increase the shear-friction strength of concrete, as well as acting as an efficient shear reinforcement. Moreover, the use of glass fibers has been found to effectively reduce crack propagation in beams [26].

This study aims to investigate the flexural behavior of strip concrete footings reinforced with geogrids. In this research, six different types of uniaxial geogrids, including both stiff and flexible options, are incorporated in the footings made of normal reinforced concrete mixture and Fiber Glass Reinforced Concrete (FGRC). The specimens are subjected to strip loading and tested under monotonic loading conditions. The experimental results demonstrate that the inclusion of geogrids in the concrete footings significantly enhances the post-cracking ductility and strength, especially in footings reinforced with multiple layers of geogrids. Furthermore, an empirical equation is derived to establish the relationship between the moment acting on the footings and the tensile strength of the geogrid reinforcement.

II. EXPERIMENTAL PROGEAM

2.1 Samples and test matrix

The experimental program involved testing fourteen specimens with varying reinforcement configurations. Each specimen had precise dimensions and loading details as follows: a length of 60 cm, a width of 30 cm, and a thickness of 9 cm, as illustrated in Figure 1. The footings were categorized into four groups to assess the effectiveness of the reinforcement and glass fiber bristles, including two control specimens reinforced with steel using reinforced concrete mix and FGRC, two specimens reinforced with three layers of uniaxial geogrid, four specimens reinforced with two layers of uniaxial geogrid, and four specimens reinforced with two

layers of uniaxial geogrid. Refer to

Table 1 for a summary of the tested specimens' configurations

Group Name	Code of Specimen	Reinforced Material	Number of Unit	Concrete Mixture
Control	St 1	Steel	3 @ 6 mm	Normal Reinforced concrete mix (Without adding fibers)
	St 8			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
Group 1	St 2	Re 510	3 layers	Normal Reinforced concrete mix (Without adding fibers)
	St 9			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
Group 2	St 3	Re 520	2 layers	Normal Reinforced concrete mix (Without adding fibers)
	St 10			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
	St 4	Re 540	2 layers	Normal Reinforced concrete mix (Without adding fibers)
	St 11			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
Group 3	St 5	Re 560	One layer	Normal Reinforced concrete mix (Without adding fibers)
	St 12			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
	St 6	Re 570	One layer	Normal Reinforced concrete mix (Without adding fibers)
	St 13			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)
	St 7	Re 580	One layer	Normal Reinforced concrete mix (Without adding fibers)
	St 14			Fiber glass reinforced concrete, FGRC (2.5 Kg/m ³)

2.2 Material properties.

The present study includes a thorough depiction of the materials utilized in our research. We provide a detailed overview of the properties of the materials used in our investigation, specifically concrete, steel fibers, and geogrids. This information aims to provide a clear understanding of the materials employed in our research and their respective characteristics.

2.2.1 Reinforced concrete materials

We utilized Ordinary Portland Cement (OPC-42.5 grade) and natural sand with a fineness modulus of 2.6, along with filter stones with a maximum aggregate size of 9 mm in our tested specimens. It was estimated that the compressive strength (f_{cu}) would reach 28 MPa at 28 days for reinforced concrete mix and 32.26 MPa for FGRC. The actual f_{cu} value was obtained on the day of testing. The concrete mix used by the FGRC had a consistent proportion of materials along with the addition of 2.5 kg/m³ of glass fibers bristles have 12-16 mm length and 12-micron diameter CMB Group company, Egypt, Table2.

meter of concrete.

Material	Quantity
Cement (Kg/ m ³)	450
Sand (Kg/ m ³)	680
Water (Liter/ m ³)	215
Coarse aggregate (Kg/ m ³)	970
Fiber glass bristles (Kg/m ³)	2.5

2.2.2 Footing reinforcement

The control specimen of this study utilized normal mild steel bars with a 6 mm diameter and a grade of 36, which possess a yield stress of 36 Ksi, as its primary reinforcement in both directions (as depicted in Figure 1-a). In addition, uniaxial geosynthetics geogrids, manufactured by Tensar International Corporation and imported by National Geotechnical Company for GEOTECH, were utilized throughout the study (as specified in reference [27]). The mechanical properties of the uniaxial geogrids utilized in this study were documented in Table 3 and were consistent with those provided by the

Table 2: Concrete mix content by weight for one cubic

manufacturer. Uniaxial Geogrids Re 510, Re520, Re540, Re560, Re570, and Re580 were employed and depicted in Figures 2-b to 2-g. Tensile strength and

elongation were measured in compliance with EN ISO 10319, ASTM D6637, and GG2-87 standards.

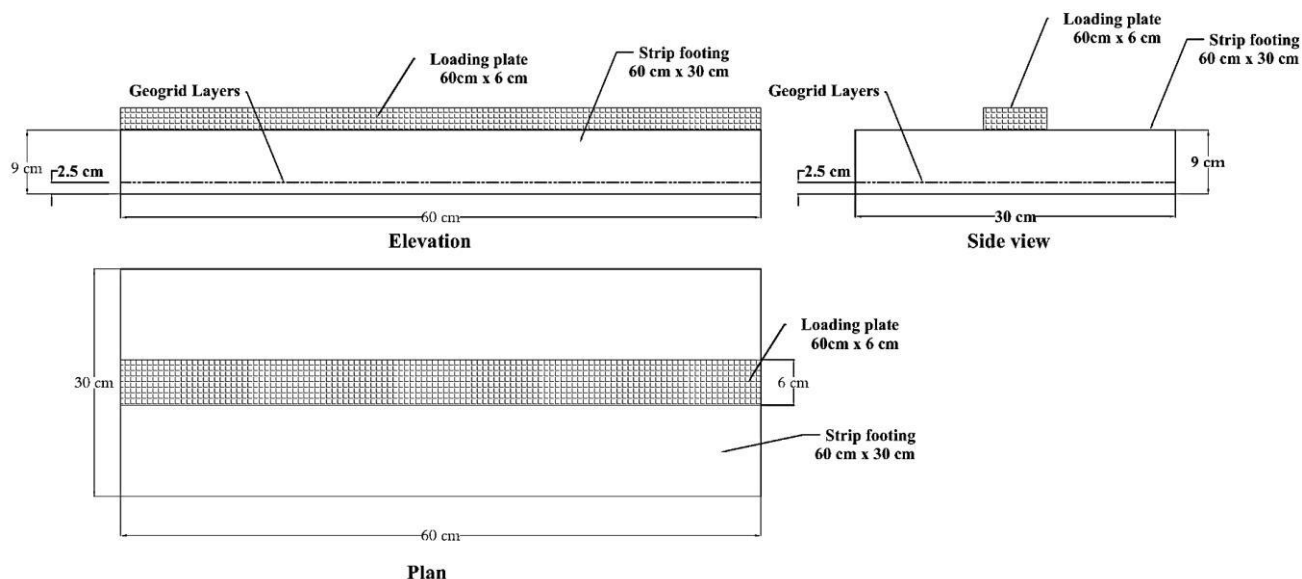


Fig.1: Specimen Dimensions and Loading Details.

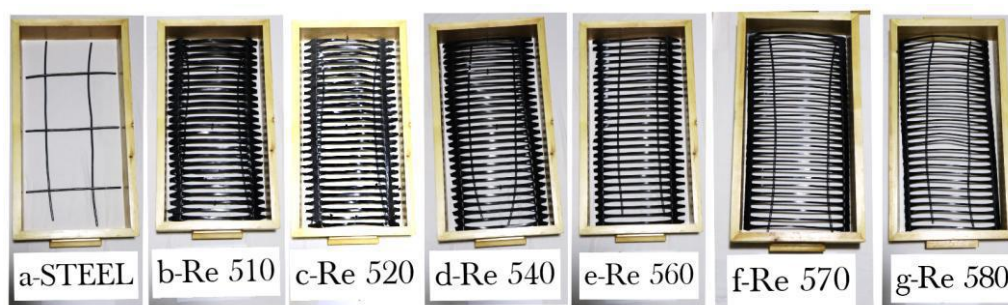


Fig. 2: Steel Bars and Uniaxial Geogrids Used in the Study

Table 3: Uniaxial Geogrid Mechanical Properties Consistent with Manufacturer's Specifications.

Component of Uniaxial geogrid							
Mechanical properties	Type of Geogrid						Unit
	Re 510	Re 520	Re 540	Re 560	Re 570	Re 580	
polymer	High density polyethylene						-
Junction strength	95						%
Unit weight	0.29	0.36	0.45	0.65	0.87	0.98	Kg/m²
Long term strength	19.01	25.10	30.66	42.16	56.28	65.27	Kn/m

2.2.3 Analysis of Soil Specifications

The soil used in this research conforms to the well-graded gravel with sand classification based on the unified soil classification system. The uniformity coefficient and uniformity curvature, two crucial indicators for determining soil grading, were determined to be 22.50 and 1.98, respectively. Furthermore, to assess the soil's compaction characteristics, the standard proctor test, a standardized method in geotechnical engineering, was performed. The results reveal that the maximum dry density and the optimum moisture content were 2.078 t/m³ and 6.88%, respectively. These comprehensive test results and analyses are crucial in determining the soil's suitability for use under the footings. A research investigation was performed utilizing a model configuration that included a sturdy test tank. The test tank was engineered to be spacious enough to accommodate the footing without causing significant impact on the soil stresses and strains due to the tank boundaries. The dimensions of the tank were 1.50 m in length, 1.50 mm in width, and 0.70 m in height, and it was constructed from durable steel, Figure 3.



Fig. 3: Test Tank Configuration for Investigation of Footing-Soil Interaction.

2.3 Test Set-Up and Instrumentations

The samples were loaded with a hydraulic jack with a

maximum capacity of 1000 (KN), linked to electric pump, and hung with a rigid reaction frame with a maximum capacity of 1000 (KN). The strip footings were placed on the compacted soil with care. It was ensured that the footings were horizontal to achieve uniform stress distribution beneath them. To ensure the consistent distribution of longitudinal load on the footings, three steel pallets with dimensions of 60 cm length, 6 cm width, and 3 cm thickness were placed on top of each strip footing. The applied vertical load was measured with a load cell with a maximum capacity of 1000 (KN) placed beneath the hydraulic jack. four Linear Variable Differential Transducer (LVDT) was installed at the upper of the footing surface to monitor displacement. All test data were collected with a data acquisition system and collected on a computer at two-second intervals. Figure 4 depicts the test setup which was applied in the concrete laboratory of Benha Faculty of Engineering at the University of Benha.

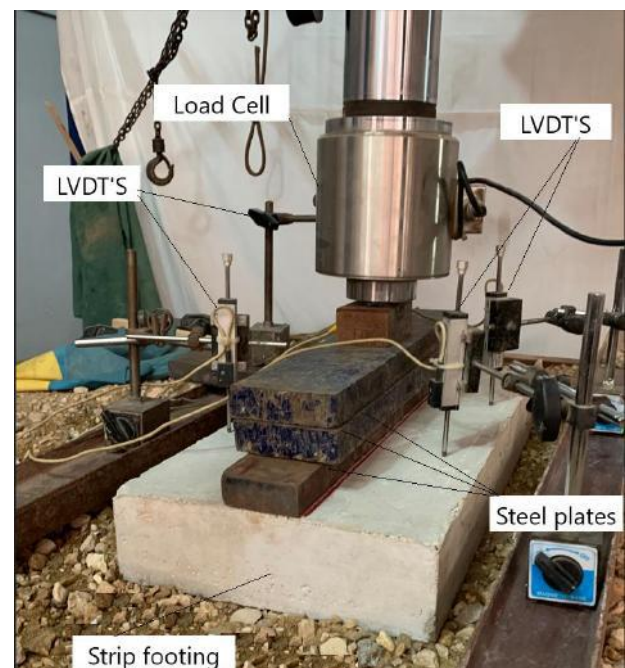


Fig. 4: Experimental Setup for strip footings

III. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 General

An organizational chart has been included to streamline the presentation of the analysis of experimental strip footing results. This chart serves as a visual guide, simplifying the structure of the

analysis by breaking down its various components and findings, Fig. 5.

Fig. 6 illustrates the load-deflection behavior of strip concrete footings reinforced with one, two, and three layers of uniaxial geogrids. The load-bearing capacity (P), vertical displacement (Δ), and stiffness (K) were computed for all investigated footings at the first crack, yield, and ultimate stages based on the aforementioned figures. Additionally, the ductility (μ) and energy absorption (E_n) characteristics of each footing were determined and are presented in Table 4.

The experimental results indicate that incorporating uniaxial geogrids in strip footings resulted in superior load-deflection behavior compared to steel-reinforced footings. This outcome

could be attributed to the comparable tensile strength of uniaxial geogrids to that of steel, while exhibiting unique mechanical properties. The longitudinal placement of uniaxial geogrids at closely spaced intervals within the strip footing, in conjunction with the strong bonding between the concrete and geogrid sections, played a pivotal role in enhancing the load-bearing capacity of the foundation.

3.2 Geogrid's Effect on Strip Footing Performance.

The load - deflection curves of reinforced strip footings are presented in Fig. 6. Results show excellent repeatability of the tests, as well as the increase in peak load of reinforced concrete footings with geogrid compared to reinforced concrete footing with steel, Table 4.

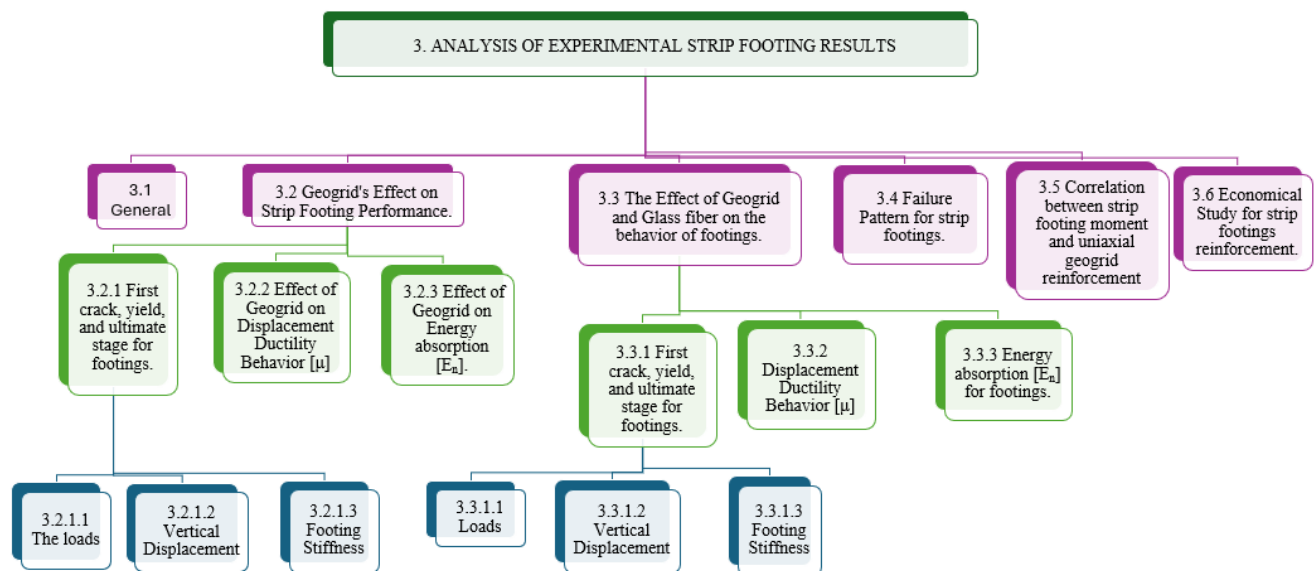


Fig. 5: Organizational Chart for Analysis of Experimental strip Footing Results.

Table 4: Characteristics of Reinforced Strip Concrete Footings.

	First crack stage			Yield stage			Ultimate load stage			Ductility factor (μ)	Energy absorption (kN/mm)
	P_f (kN)	Δ_f (mm)	K_f (kN/mm)	P_y (kN)	Δ_y (mm)	K_y (kN/mm)	P_u (kN)	Δ_u (mm)	K_u (kN/mm)		
St1	90.000	15.600	5.769	101.500	18.130	5.598	112.013	23.310	4.805	1.286	1413.855
St2	106.000	11.900	8.908	170.253	27.253	6.247	192.030	40.902	4.695	1.501	5516.970
St3	96.500	11.300	8.540	146.444	23.816	6.149	162.660	34.177	4.759	1.435	3758.603
St4	112.000	12.920	8.669	196.514	28.700	6.847	216.971	43.270	5.014	1.508	6313.279
St5	95.000	14.323	6.633	127.975	23.632	5.415	135.853	26.868	5.056	1.137	2115.115
St6	100.000	12.600	7.937	156.323	24.995	6.254	177.808	36.060	4.931	1.443	4268.647
St7	114.000	13.000	8.769	208.199	30.032	6.933	224.263	45.954	4.880	1.530	7008.947

St8	96.000	13.960	6.877	107.500	16.533	6.502	115.988	23.113	5.018	1.398	1674.911
St9	111.000	11.620	9.552	175.848	25.082	7.011	203.349	41.905	4.853	1.671	5898.083
St10	105.000	13.250	7.925	150.807	22.284	6.767	170.116	34.392	4.946	1.543	3936.992
St11	124.000	12.320	10.065	199.997	26.650	7.505	220.216	45.589	4.830	1.711	6887.856
St12	102.000	14.180	7.193	132.024	22.013	5.998	143.395	27.808	5.157	1.263	2437.114
St13	110.000	12.700	8.661	163.127	24.056	6.781	188.208	38.631	4.872	1.606	4840.592
St14	128.000	11.800	10.847	215.139	28.051	7.670	230.979	48.089	4.803	1.714	7966.644

Results of reinforced concrete footings with steel show that specimens failed in a brittle mode immediately after peak, reaching peak loads of 112 and 115.9 kN at failure for St1 and St8. On the other hand, the load-deformation curves of reinforced

concrete specimens with geogrid exhibited delayed failure and extra peak load in all cases. After load drop, reinforced geogrid footings gained post cracking ductility until cracks reached top surface footings, where failure was completed.

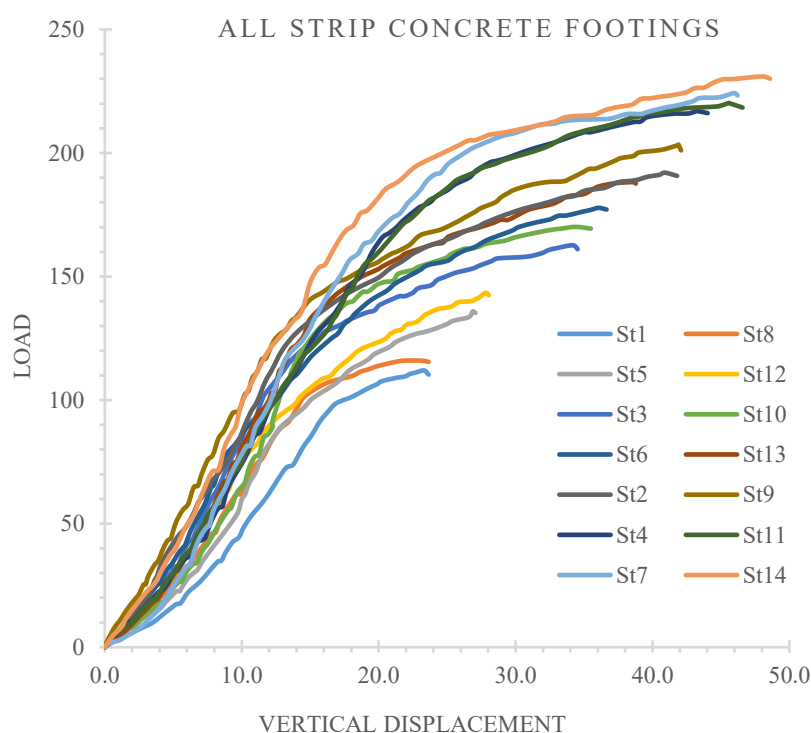


Fig. 6: Load-deflection behavior of reinforced strip concrete footings.

At this point, each specimen was compared to its control in order to extract the influence of the geogrid's presence within the footings independently. The following variables have been investigated:

3.2.1 Effect of Geogrid on First crack, Yield and Ultimate stages for footings.

The findings of this study revealed that the incorporation of geogrid reinforcement in the footings resulted in delayed initiation of initial cracks, and the post-cracking behavior of the reinforced footings exhibited higher load-carrying capacities than the control footings.

3.2.1.1 The Loads

In comparison to control footings, the use of uniaxial geogrid reinforcement resulted in gradual increases in the values of the cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}), Fig. 7. These results demonstrate the effectiveness of geogrid reinforcement in enhancing the load-carrying capacity of reinforced concrete footings, as follows:

- P_{fc} , P_y and P_{ult} values at footings reinforced by Three layers of uniaxial geogrid Re 510 increases by about average 16.70%,65.65% and 73.37% respectively than that for relative control footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 520 increases by about average 8.29%,42.28% and 45.94% respectively than that for relative control footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 540 increases by about average 26.80%,89.82% and 91.78% respectively than that for relative control footing.

- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 560 increases by about average 5.90%,24.44% and 22.45% respectively than that for relative control footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 570 increases by about average 12.84%,52.87% and 60.50% respectively than that for relative control footing.
- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 580 increases by about average 30.00%,102.62% and 99.67% respectively than that for relative control footing.

The incorporation of uniaxial geogrid reinforcement into strip footing yields substantial enhancements in load-bearing capacities. On average, P_{fc} , P_y , and P_{ult} increase by approximately 16.75%, 62.94%, and 65.61% respectively Compared to relative control footing. With respect to the tensile strength of uniaxial reinforcement into the strip footing.

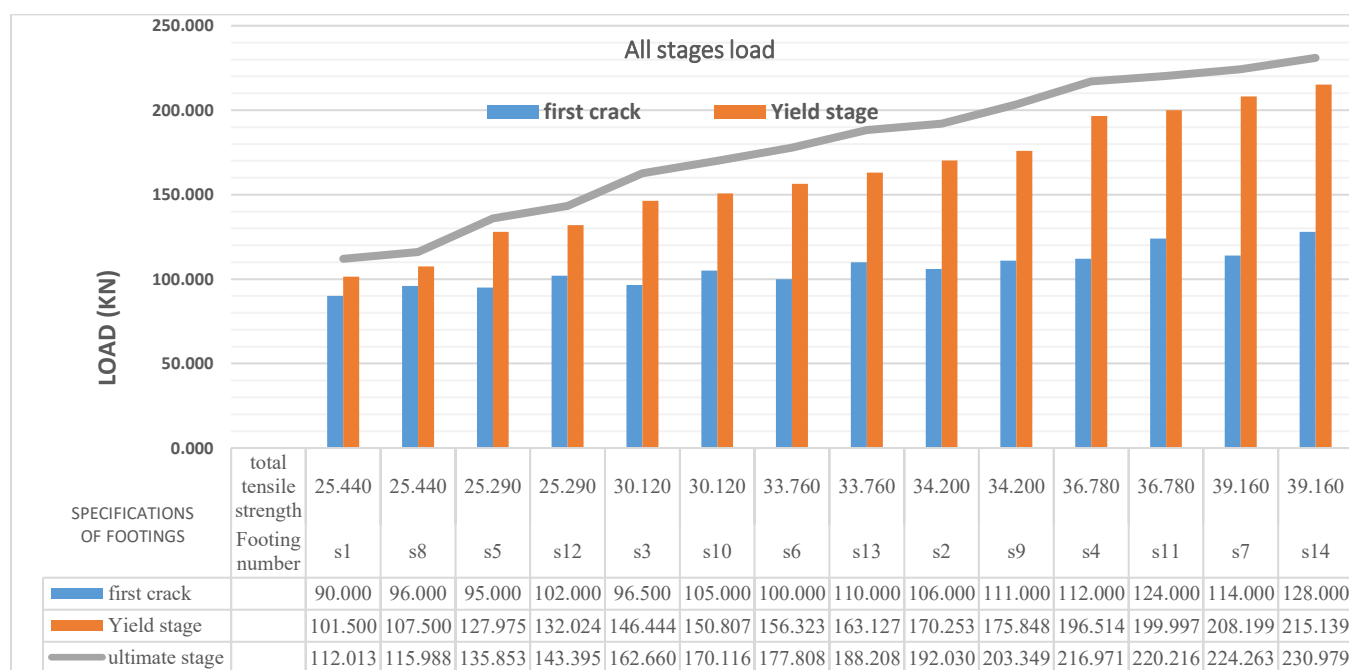


Fig. 7: Quantification of Load Magnitudes at Each Stage for Multiple Footing Types.

3.2.1.2 Vertical Displacement

Based on the obtained results, it can be inferred that.

- Δ_{fc} values at footings reinforced by Three layers of uniaxial geogrid Re 510 decreases by about average 20.24% than that for relative control footing. while, Δ_y and Δ_{ult} increases by about 51.01% and 78.38% respectively than that for relative control footing.

- Δ_{fc} values at footings reinforced by two layers of uniaxial geogrid Re 520 decreases by about average 16.32% than that for relative control footing. while, Δ_y and Δ_{ult} increases by about 33.07% and 47.70% respectively than that for relative control footing.
- Δ_{fc} values at footings reinforced by two layers of uniaxial geogrid Re 540 decreases by about average 14.46% than that for relative control

footing. while, Δ_y and Δ_{ult} increases by about 59.74% and 91.43% respectively than that for relative control footing.

- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 560 decreases by about average 3.30% than that for relative control footing. while, Δ_y and Δ_{ult} increases by about 31.74% and 17.78% respectively than that for relative control footing.
- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 570 decreases by about average 14.12% than that for relative control footing. while, Δ_y and Δ_{ult} increases by about 41.68% and 60.91% respectively than that for relative control footing.
- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 580 decreases by about average 16.07% than that for relative control footing. while, Δ_y and Δ_{ult} increases by about 67.65% and 102.60% respectively than that for relative control footing.

Compared to a control footing, uniaxial geogrid reinforcement typically increases the values of vertical displacement at the yield stage (Δ_y) and ultimate stage (Δ_{ult}), while decreasing the displacement at the cracking stage (Δ_{fc}), as observed in the load-deflection curves as follows.

3.2.1.3 Footing Stiffness

When compared to a control foundation, the use of uniaxial geogrid reinforcement typically results in gradual increases in the stiffness values at the cracking stage (k_{fc}) and yield stage (k_y), while there is a decrease in stiffness at the ultimate stage (k_{ult}). This behavior was observed as the predominant characteristic of the specimens. The results of the study are summarized as follows:

- K_{fc} and K_y values at footings reinforced by Three layers of uniaxial geogrid Re 510 increases by about average 46.65% and 9.70 % respectively than that for relative control footing. While K_{ult} decreases by about 2.79% compared to that for relative control footing.
- K_{fc} and K_y values at footings reinforced by two layers of uniaxial geogrid Re 520 increases by about average 31.63% and 6.95 % respectively than that for relative control footing. While K_{ult}

decreases by about 1.19% compared to that for relative control footing.

- K_{fc} , K_y and K_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 540 increases by about average 48.30% ,18.86 % and 0.30% respectively than that for relative control footing.
- K_{fc} and K_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 560 increases by about average 9.78% and 3.98 % respectively than that for relative control footing. While K_y decreases by about 5.51% than that for relative control footing.
- K_{fc} and K_y values at footings reinforced by one layer of uniaxial geogrid Re 570 increases by about average 31.75% and 8.00 % respectively than that for relative control footing. While K_{ult} decreases by about 0.15% than that for relative control footing.
- K_{fc} and K_y values at footings reinforced by one layer of uniaxial geogrid Re 580 increases by about average 54.87% and 20.89 % respectively than that for relative control footing. While K_{ult} decreases by about 1.36% compared to that for relative control footing.

In the majority of cases, a notable enhancement in Footing Stiffness was observed during the initial and yield stages, followed by a subsequent decline in Stiffness values as the strip footings progressed to the ultimate stage. This pattern underscores the significant influence of the uniaxial geogrid on the early stages of strip footing stiffness. However, it's noteworthy that the stiffness gains seem to diminish once the uniaxial geogrid sheets experience elongation, leading to a vulnerability and weakening of the specimens.

3.2.2 Effect of geogrid on Displacement Ductility Behavior [μ]

In this study, we evaluated the effect of geogrid reinforcement on the displacement ductility behavior of concrete footings. The displacement ductility index, which represents the ability of the structural element to undergo large deflections without significant strength reduction before failure, was used to assess the performance of the concrete footings. To ensure concrete structures can withstand seismic events, they must maintain their strength above the yield strength up to the allowable plastic deformation adopted in the design.

Our findings demonstrate that the incorporation of geogrid reinforcement can significantly enhance the displacement ductility behavior of concrete footings. The displacement ductility indexes of the geogrid-reinforced footings were 18.11% higher for group 1, which had 3 layers of uniaxial geogrid, 11% to 19.8% higher for group 2, which had 2 layers of uniaxial geogrid, and 13.5% to 20.8% higher for group 3, which had 1 layer of uniaxial geogrid, compared to the control footings.

Our study also revealed a positive correlation between the increase in displacement ductility and the stiffness with tensile strength of the uniaxial geogrids used. Moreover, increasing the number of geogrid layers did not negatively affect the behavior of the footings, as observed in the load-deflection curves.

Therefore, incorporating multiple layers of uniaxial geogrid reinforcement can be a practical and effective solution for improving the performance of reinforced concrete footings in many conditions. These results have significant implications for the design of reinforced concrete structures in earthquake-prone regions, Fig. 8, depicts the relationship between the tensile strength of geogrid reinforcement and the corresponding increase in ductility factor ratio for footing specimen. The data in the figure shows a clear trend of increasing ductility factor ratio with increasing tensile strength of the geogrid reinforcement.

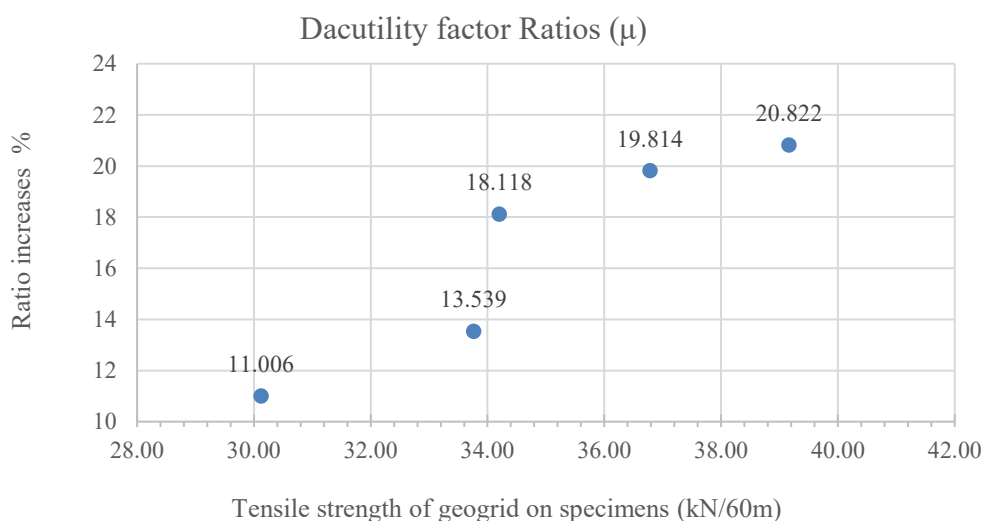


Fig. 8: Relationship between the tensile strength of geogrid reinforcement and the corresponding increase in ductility factor ratio for footings.

Uniaxial Geogrid reinforcement substantially enhances concrete footing displacement ductility. On average, geogrids exhibit an improvement of 11% to 20.82% compared to relative control footings. Depending on geogrid tensile strength of footing reinforcement.

3.2.3 Effect of Geogrid on Energy absorption [E_n] for footings.

A high capacity for energy absorption is beneficial in the event of major earthquakes, where substantial energy dissipation is necessary to prevent significant dynamic responses and hysteretic damping in concrete structures. The energy

absorption capacity of the tested footings was determined by calculating the area enclosed by their load-deflection curves.

In addition, the behavior of the tested footings was compared based on their energy absorption capacity, which was determined by calculating the area under their load-deflection curves, Fig. 6. The energy dissipation capacities were increased by a percent varying from 42.55% to 385.69% for all groups of uniaxial geogrid reinforcement compared to the concrete control footing "St1 and St8" with a positive correlation to the stiffness and tensile strength of geogrid.

Moreover, increasing the number of geogrid layers did not negatively affect the behavior of the footings, as observed in the result obtained, Fig. 9, depicts the relationship between the tensile strength

of geogrid reinforcement and the corresponding increase in energy absorption ratio for strip footings specimen.

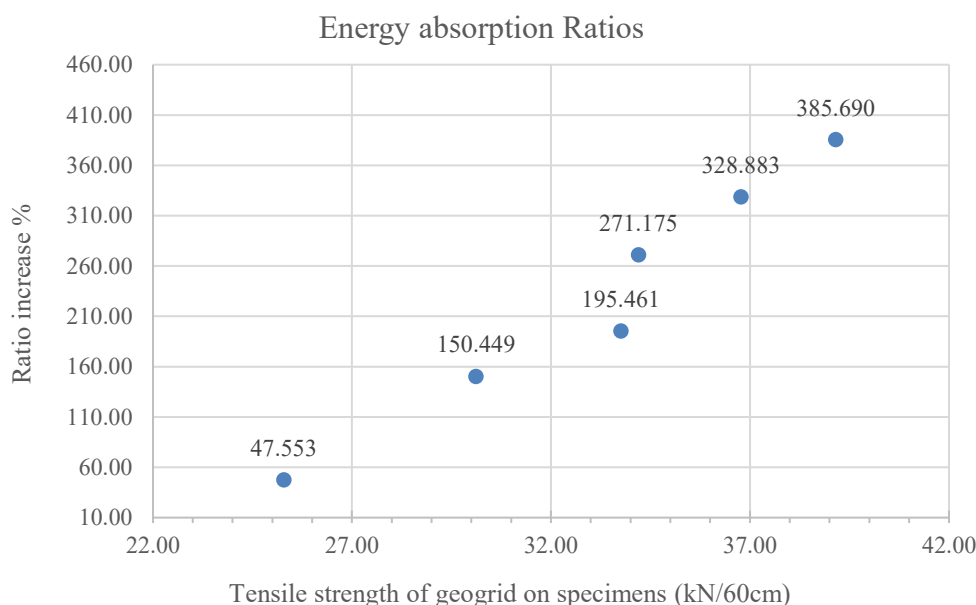


Fig. 9: Relationship between the tensile strength of geogrid reinforcement and the corresponding increase in energy absorption ratio for footings.

The Energy dissipation capacities increased by a percent varying from 42.55% to 385.69% for uniaxial geogrid reinforcement compared to relative control footings with a positive correlation to the stiffness and tensile strength of geogrid.

3.3 The Effect of Geogrid and Glass Fiber on the behavior of footings.

3.3.1 First crack, Yield, and Ultimate stage for footings

It was found that the reinforcement footings by glass fiber and geogrid would delay the onset of initial cracks and the post-crack behavior of the reinforcement footings demonstrated higher load-carrying capacities than the strip footing (St1), Fig 10.

3.3.1.1 The Loads

As compared to a control strip footing, uniaxial geogrid reinforcing with (GFRC) often results in gradual increases in the values of the cracking load (P_{fc}), yield load (P_y), and ultimate load (P_{ult}) as follows:

- P_{fc} , P_y and P_{ult} values at footings reinforced by Three layers of uniaxial geogrid Re 510 increases by about average 23.33%,73.24% and 81.540%

respectively than for the concrete control footing (St1).

- P_{fc} , P_y and P_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 520 increases by about average 16.66%,48.57% and 51.87% respectively than for the concrete control footing (St1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 540 increases by about average 37.77%,97.04% and 96.59% respectively than for the concrete control footing (St1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 560 increases by about average 13.33%,30.07% and 28.06% respectively than for the concrete control footing (St1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 570 increases by about average 22.22%,60.71% and 68.02% respectively than for the concrete control footing (St1).
- P_{fc} , P_y and P_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 580 increases by about

average 42.22%, 111.96% and 106.20% respectively than for the concrete control footing (St1).

Glass fiber bristles with Uniaxial geogrid reinforcement, particularly with Re 510, Re 520, Re

540, Re 560, Re 570, and Re 580, consistently enhances strip footing performance, yielding increases of approximately 13.33% to 42.22% for P_{fc} , 30% to 111.96% for P_y , and 28.06%, to 106.20% for P_{ult} compared to the concrete control strip footing (St1).

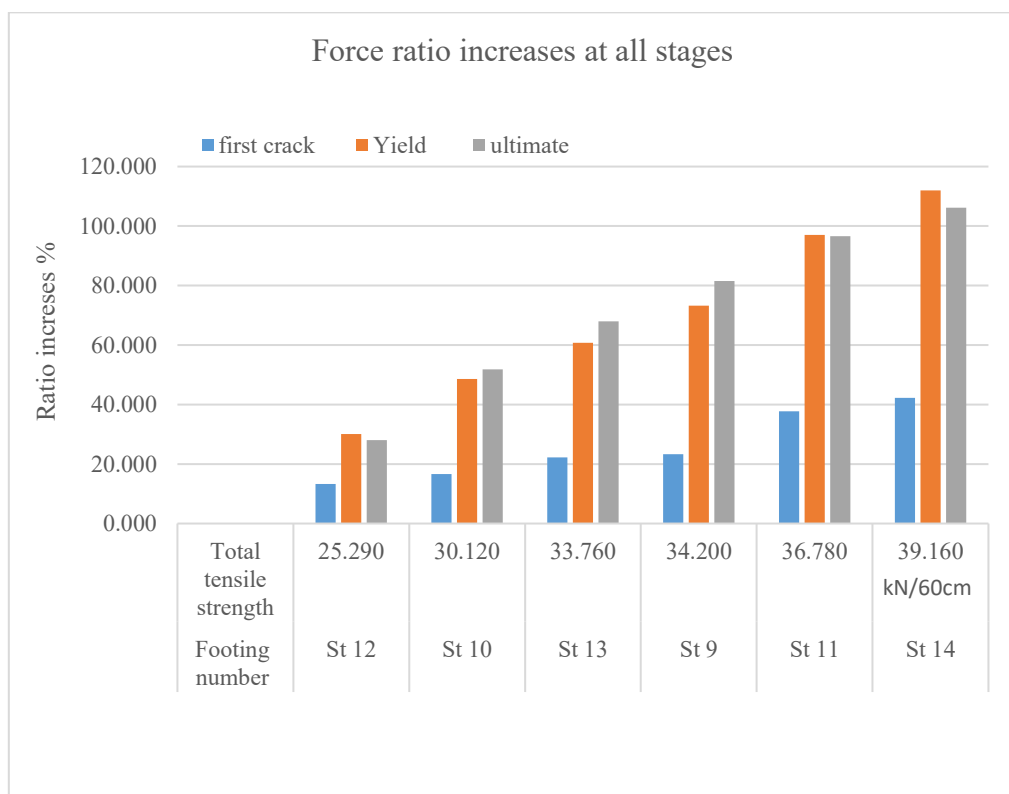


Fig. 10: Percentage Enhancement of specimen force Ratios with total tensile strength of geogrid Compared to Control specimen (St1).

3.3.1.2 Vertical Displacement

Based on the obtained results, it can be inferred that.

- Δ_{fc} values at footings reinforced by Three layers of uniaxial geogrid Re 510 decreases by about average 25.51% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about 38.34% and 79.77% respectively than that for the concrete control footing (St1).
- Δ_{fc} values at footings reinforced by two layers of uniaxial geogrid Re 520 decreases by about average 15.04% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about 22.91% and 47.54% respectively than that for the concrete control footing (St1).
- Δ_{fc} values at footings reinforced by two layers of uniaxial geogrid Re 540 decreases by about average 21.02% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about 46.99% and 95.57% respectively than that for the concrete control footing (St1).
- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 560 decreases by about average 9.10% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about 21.41% and 19.29% respectively than that for the concrete control footing (St1).
- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 570 decreases by about average 18.59% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about 32.68% and 65.72% respectively than that for the concrete control footing (St1).
- Δ_{fc} values at footings reinforced by one layer of uniaxial geogrid Re 580 decreases by about average 24.35% than that for the concrete control footing (St1). while, Δ_y and Δ_{ult} increases by about

54.71% and 106.30% respectively than that for the concrete control footing (St1).

Compared to a control footing (St1), footings reinforced by uniaxial geogrid and glass fiber bristles typically increases the values of vertical displacement at the yield stage (Δ_y) and ultimate stage (Δ_{ult}), while decreasing the displacement at the cracking stage (Δ_{fc}).

3.3.1.3 Footing Stiffness

When compared to a control foundation (St1), footings reinforced by uniaxial geogrid and glass fiber bristles typically results in gradual increases in the stiffness values at the cracking stage (k_{fc}), yield stage (k_y) and ultimate stage (k_{ult}). This behavior was observed as the predominant characteristic of the specimens. The results of the study are summarized as follows:

- K_{fc} , K_y and K_{ult} values at footings reinforced by Three layers of uniaxial geogrid Re 510 increases by about average 65.57% , 25.22 % and 0.9 % respectively than that for the concrete control footing (St1).
- K_{fc} , K_y and K_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 520 increases by about average 37.35% , 20.88 % and 2.93 % respectively than that for the concrete control footing (St1).
- K_{fc} , K_y and K_{ult} values at footings reinforced by two layers of uniaxial geogrid Re 540 increases by about average 74.45% , 34.04 % and 0.52 % respectively than that for the concrete control footing (St1).
- K_{fc} , K_y and K_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 560 increases by about average 24.68% , 7.13 % and 7.30 % respectively than that for the concrete control footing (St1).
- K_{fc} , K_y and K_{ult} values at footings reinforced by one layer of uniaxial geogrid Re 570 increases by about average 50.13% , 21.12 % and 1.38 % respectively than that for the concrete control footing (St1).
- K_{fc} and K_y values at footings reinforced by one layer of uniaxial geogrid Re 580 increases by about average 88.02% and 36.99 % respectively than that for the concrete control footing (St1). While K_{ult}

decreases by about 0.05% than that for the concrete control footing (St1).

Incorporating glass fiber bristles along with uniaxial geogrid reinforcement uniformly increases the stiffness of strip footing performance. This approach yields notable enhancements ranging from 24.68% to 88.02% for P_{fc} , 7.13% to 36.99% for P_y , and 0.52% to 7.3% for P_{ult} in comparison to the concrete control strip footing (St1).

3.3.2 Effect of Geogrid and Glass Fibers on Displacement Ductility Behavior [μ]

The results of the study revealed that the incorporation of uniaxial geogrid reinforcement led to a significant enhancement in the displacement ductility indexes across all experimental groups. The observed increase in these indexes ranged from 20% to 33.3% when compared to the control footing labeled as "St1." Importantly, this enhancement exhibited a positive correlation with the total tensile strength of the uniaxial geogrid reinforcement utilized, Fig. 11.

Additionally, a specific case worth noting is the group labeled as "St12," which exhibited a relatively smaller increase in displacement ductility index, amounting to a percent of 1.74%. This modest improvement can be attributed to the utilization of a lower tensile strength reinforcement, specifically measured at 25.44 kN / 60 cm.

3.3.3 Effect of Geogrid and Glass Fibers on Energy absorption [E_n] for footings.

The results of the study demonstrate a significant increase in energy dissipation capacities when using uniaxial geogrid reinforcement compared to the concrete control footing "St1." The energy dissipation capacities were found to vary between 72.37% and 463.47% for all groups of uniaxial geogrid reinforcement.

Furthermore, the study indicates a positive correlation between the tensile strength of the uniaxial geogrids and the enhanced energy dissipation capacities. This suggests that geogrids with higher tensile strength tend to exhibit greater energy dissipation capabilities.

These findings are supported by the data presented in Fig. 12, which visually represents the relationship between the energy dissipation capacities

and the different groups of uniaxial geogrid reinforcement. The figure likely illustrates the trend of

increasing energy dissipation as the tensile strength of the geogrids increases.

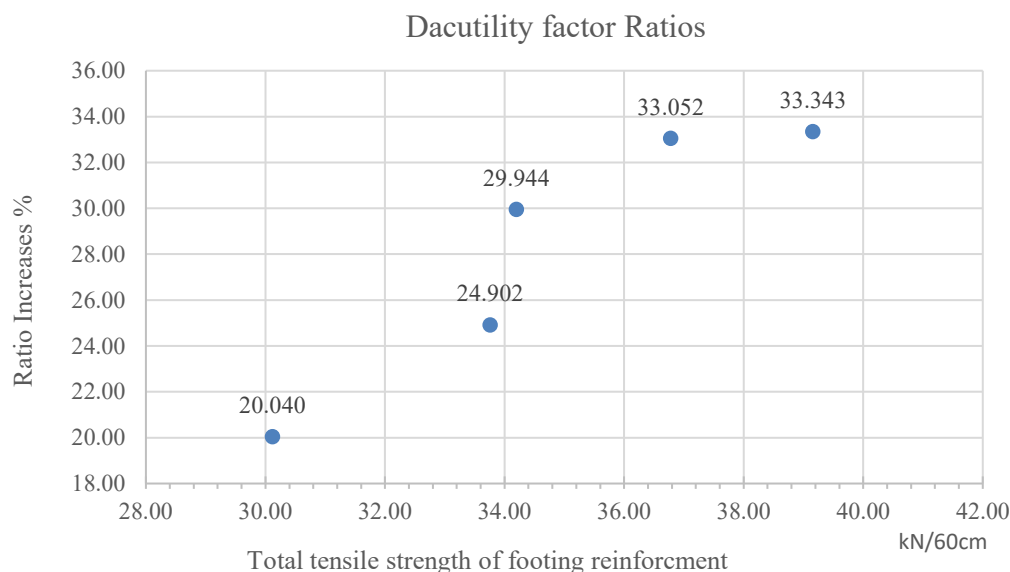


Fig. 11: Ratio of Increases in Ductility factor for strip Concrete Footings Compared to Control Footing (St1).

The study demonstrates that integrating uniaxial geogrid reinforcement with glass bristles on strip footings yields notable increases 20% to 33.3% in

displacement ductility indexes across experimental groups, with a positive correlation to the total tensile strength of the reinforcement.

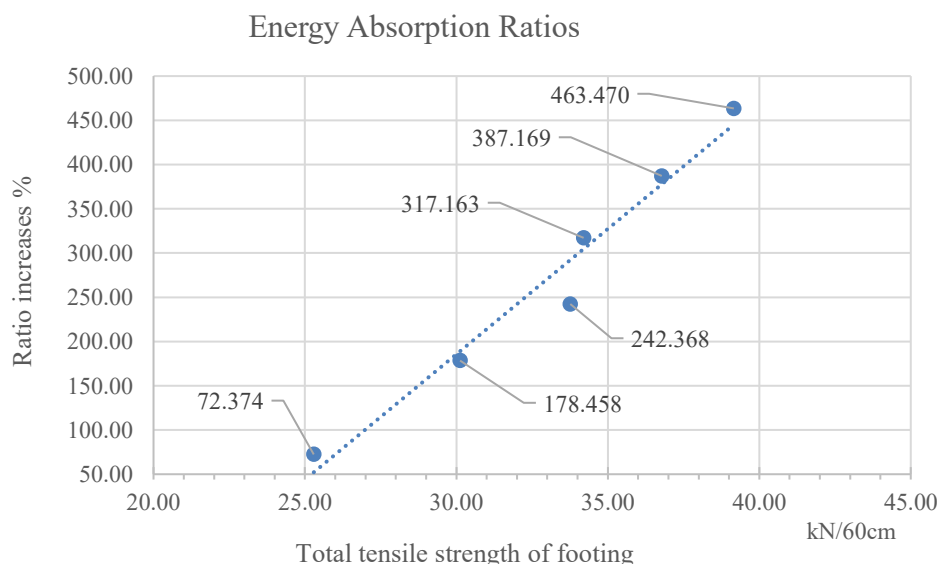


Fig. 12: Ratio of Increases in Energy Absorption for strip Concrete Footings Compared to Control Footing (St1).

The study showcases a substantial rise in energy dissipation capacities (72.37% to 463.47%) through uniaxial geogrid reinforcement compared to the concrete control footing, accentuating a direct link

between geogrid tensile strength and heightened energy dissipation capacities.

3.4 Failure Pattern For Strip Footing

In all concrete footings, cracks occurred only parallel to the load plate, resulting in flexural cracks without any shear cracks. The failure of the concrete footings was characterized by the widening of cracks, the formation of additional cracks in some footings, and the extension of these cracks from the tension zone “concrete bottom surface” to the compression zone “concrete top surface” until failure. Fig. 13, provides a visual representation of the crack patterns observed in the footings. After the footings failed, the

cracks were examined to assess the condition of the geogrids' ribs. Fig. 14, displays examples of the geogrids' ribs after the failure of the concrete footings.

For the first and second case studies “group number one and two”, no cutting of the uniaxial geogrids' ribs was observed. However, in the third case study “group number three”, cutting was observed in most of the uniaxial geogrids' ribs.

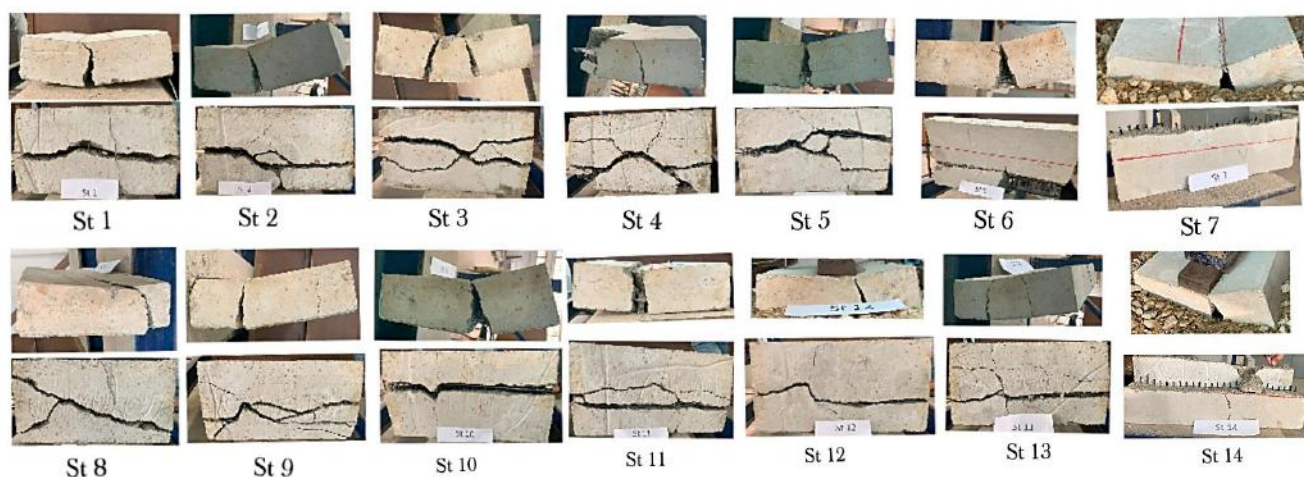


Fig. 13 : Crack Patterns in Strip Concrete Footings (illustrating the cracks observed in the footings).



Fig. 14: Geogrids' Rib Status after Failure of Concrete Footings “showing the condition of geogrids' ribs following the failure of the footings”.

Among the control concrete footings St1 and St8, only one crack formed and gradually increased until failure. Similarly, for group number one “concrete

footings St2 and St9”, only one crack formed and increased gradually until failure. In group number two, concrete footings St3 and St10 exhibited two

parallel cracks at the point of maximum moment. In contrast, concrete footings St4 and St11 had one crack that increased gradually, accompanied by a group of small cracks parallel and perpendicular to the main crack, but not reaching the surface.

For group number three, which consisted of concrete footings St3 to St7 and St12 to St14 with one layer of geogrid, one crack formed and increased gradually until failure. These cracks were significantly thick and indicated substantial damage. They appeared both parallel and perpendicular to the original crack. Moreover, most of the specimens in this group experienced cuts in the geogrid layer, leading to their division into separate parts for further analysis and evaluation.

Therefore, a positive correlation can be observed between the number of flexural cracks, the tensile strength of geogrids, and the number of geogrid layers.

3.5 Correlation between strip footing moment and uniaxial geogrid reinforcement.

A comprehensive analysis is conducted to examine the correlation between strip footing moment and the implementation of uniaxial geogrid reinforcement. The research aims to explore the

relationship between the applied moment on a strip footing and the effectiveness of using uniaxial geogrids as reinforcement. By analyzing various factors such as load distribution, soil characteristics, and geogrid properties, this study seeks to provide valuable insights into the performance and behavior of strip footings when reinforced with uniaxial geogrids. The findings of this analysis will contribute to a better understanding of the interaction between footing moments and geogrid reinforcement, aiding in the development of more efficient and reliable geotechnical design practices.

The calculation of the ultimate moment (M_u) and the required area of geogrid (A_g) for all groups of footings has yielded conclusive results and were presented on Table 5. To establish a correlation between the ultimate moment (M_u) and the required area of geogrid (A_g) for different strip footings (St 1 to St 7 for Reinforced concrete mixture and St 8 to St 14 for fiber glass reinforced concrete, FGRC), data-fit software was employed. This software allowed for the analysis of the relationship between M_u and A_g . The findings are presented in Fig. 15. Consequently, an empirical formula can be derived from these results, Eq (1).

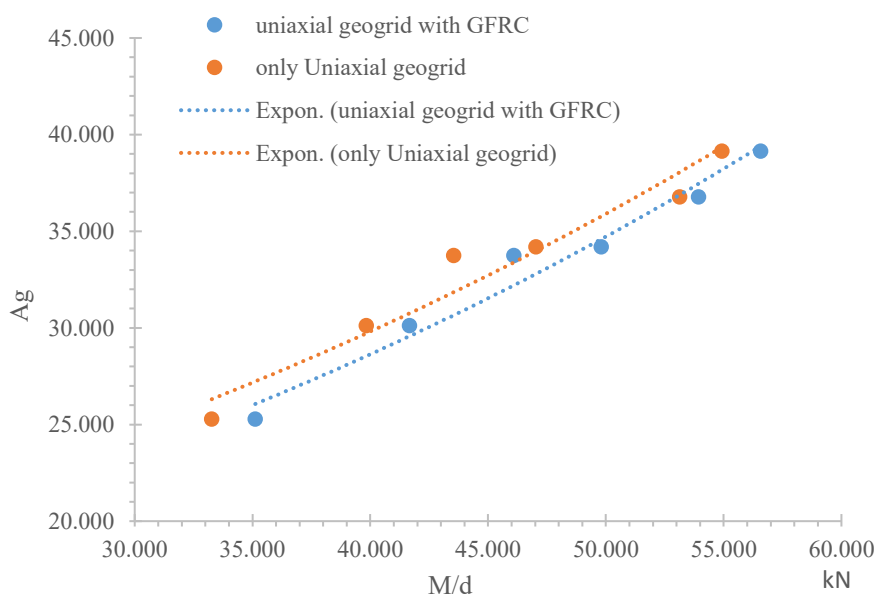


Fig. 15: Correlation between Ultimate Moment (M_u) and Required Area of Geogrid (A_g) for Different strip footings.

Table 5 : Calculations of (M/d) and (Ag) for the studied strip footing specimens.

Footing specimen No.		Ultimate Moment				M/d	Geogrid			
		P _{ult} [kN]	P _{ult} [kN/0.6 m]	F _{act} = P _{ult} / A _{footing} kN/m ²	M = F _{act} *L*(c ² /2) kN. 0.60 m		N	L	T _{ult}	A _g
Rc. mix	s5	135.853	226.421	754.738	2.994	33.271	1.000	0.600	42.150	25.290
	s3	162.660	271.101	903.669	3.585	39.837	2.000	0.600	25.100	30.120
	s6	177.808	296.346	987.821	3.919	43.546	1.000	0.600	56.267	33.760
	s2	192.030	320.050	1066.834	4.233	47.030	3.000	0.600	19.000	34.200
	s4	216.971	361.618	1205.393	4.782	53.138	2.000	0.600	30.650	36.780
	s7	224.263	373.772	1245.908	4.943	54.924	1.000	0.600	65.267	39.160
GFRc. mix	s12	143.395	238.991	796.637	3.161	35.118	1.000	0.600	42.150	25.290
	s10	170.116	283.527	945.090	3.750	41.663	2.000	0.600	25.100	30.120
	s13	188.208	313.681	1045.603	4.148	46.094	1.000	0.600	56.267	33.760
	s9	203.349	338.915	1129.716	4.482	49.802	3.000	0.600	19.000	34.200
	s11	220.216	367.026	1223.419	4.854	53.932	2.000	0.600	30.650	36.780
	s14	230.979	384.965	1283.216	5.091	56.568	1.000	0.600	65.267	39.160

$$A_g = \beta * e^{\alpha * \frac{Mu}{d}} = N * L * T_{ult} \quad (1)$$

In the context of the provided information, the variables in the equation have specific meanings. The symbol A_g represents the total ultimate strength of the uniaxial geogrid on the footing in (kN). M_u represents the ultimate moment exerted on the footing in (kN. 0.60 m), while d corresponds to the depth of the strip footing in (m).

The constants β and α are specific values that depend on the concrete mixture used in the tested footing specimens. For reinforced concrete mixture, the values of β and α are 14.178 and 0.0186, respectively.

For glass fiber reinforced concrete (GFRc), the values of β and α are 13.249 and 0.0193, respectively. The variable N represents the number of geogrid layers, L represents the length of geogrid within the footing in meters (m), and T_{ult} represents the tensile strength of the uniaxial geogrid used, measured in kilonewtons per meter (kN/m).

3.6 Economical Study for Strip footings Reinforcement.

This point explores the impact of various uniaxial geogrid reinforcements with added glass fiber bristles on the load capacity of strip footings. In Table 6, a detailed breakdown of reinforcement costs is provided, including the calculated percentage changes in prices compared to St1. For a visual representation of the relationship between the rise in reinforcement price ratio and the corresponding increases in load ratios at various stages, refer to Fig. 16. The result can be summarized as follows:

- **Single Layer of Re 580 Geogrid:**

Utilizing a single layer of Re 580 geogrid as the main reinforcement led to significant improvements: the first crack load, yield load, and ultimate load increased by 42.22%, 111.96%, and 106.21%, respectively, alongside a cost increase of 120.35%.

- **Double Layer of Re 540 Geogrid:**

Incorporating two layers of Re 540 geogrid as the main reinforcement resulted in noteworthy enhancements: the first crack load, yield load, and ultimate load rose by 37.78%, 97.04%, and 96.60%. The cost also increased by 110.84%.

- **Triple Layer of Re 510 Geogrid:**

The use of three layers of Re 510 geogrid as the main reinforcement demonstrated improvements in the first crack load, yield load, and ultimate load by 23.33%, 73.25%, and 81.54%, respectively, with a corresponding cost increase of 129.83%.

- **Single Layer of Re 570 Geogrid:**

Applying a single layer of Re 570 geogrid as the main reinforcement resulted in a 22.22% enhancement in the first crack load, a 60.72% increase in the yield load, and a 68.02% improvement in the ultimate load.

The associated cost increase was 82.36%.

- **Double Layer of Re 520 Geogrid:**

Using two layers of Re 520 geogrid as the main reinforcement led to increased load-bearing capacity: the first crack load, yield load, and ultimate load increased by 16.67%, 48.58%, and 51.87%, respectively. This approach also incurred a cost increase of 87.59%.

- **Single Layer of Re 560 Geogrid:**

Interestingly, a single layer of Re 560 geogrid as the main reinforcement contributed to load improvements: the first crack load, yield load, and ultimate load increased by 13.33%, 30.33%, and 28.02%, respectively, while increased the cost by 47.47%.

Table 6: Percentage Change in Reinforcement Prices Compared to St1.

Reinforcement material	No. of layers	Footing Number	Ratio increases on $P_{f.c}$ %	Ratio increases on P_y %	Ratio increases on P_u %	Total Price of specimen (E.G.P)	Change on Ratio price (%)
Steel		St1	-			37.92	-
All footings compared to control footing (St1)							
Re 560	one	St12	13.33%	30.07%	28.02%	55.92	47.47%
Re 520	Two	St10	16.67%	48.58%	51.87%	71.14	87.59%
Re 570	one	St13	22.22%	60.72%	68.02%	69.15	82.36%
Re 510	Three	St9	23.33%	73.25%	81.54%	87.15	129.83%
Re 540	Two	St11	37.78%	97.04%	96.60%	79.95	110.84%
Re 580	one	St14	42.22%	111.96%	106.21%	83.56	120.35%

This means that to reach the best result, the designer must choose the geogrid needed to resist the stresses while reducing the number of uniaxial geogrid layers as much as possible. This is because increasing the number of layers to resist stresses and bending moments increases the economic cost. Therefore, Footing St12, reinforced with one layer of geogrid, Re 560, can be considered the best and lowest increments footing at the same time.

The cost of the control footing has decreased

because the amount of steel reinforcement used in the footing is lower in comparison to the cost of using geogrid reinforcement.

Moreover, the enhancement in load-bearing capacity achieved through geogrid reinforcement has become evident. This advancement is expected to allow for the use of smaller geogrid sheets, leading to significant cost savings while still achieving a performance level comparable to that of steel reinforcement.

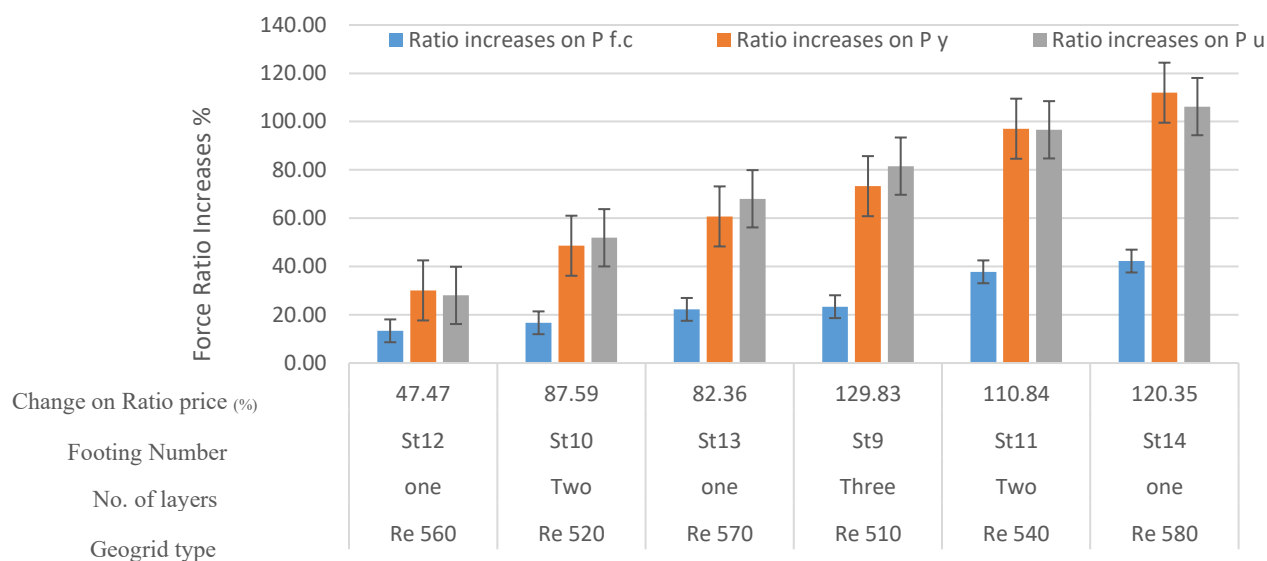


Fig. 16: Relationship Between Price Ratio Escalation due to Reinforcement and specimen Number for Tested Strip footing specimens

IV. CONCLUSION

- 1- Incorporating uniaxial geogrid reinforcement into strip footing significantly enhances load capacities. P_{fc} , P_y , and P_{ult} experience substantial increases compared to the control footing, primarily due to the increased tensile strength from the geogrid reinforcement.
- 2- Using uniaxial geogrid reinforcement on strip footing significantly bolsters footing stiffness during first crack and yield stages, yet elongation of geogrid leads to subsequent fragility and weakening in the ultimate stage for footings.
- 3- Uniaxial geogrid reinforcement substantially improves strip footing performance, enhancing both displacement ductility and energy dissipation capacities compared to control footings. The extent of improvement varies depending on the geogrid's tensile strength, with a positive correlation to geogrid stiffness and tensile strength.
- 4- Glass fiber bristles with Uniaxial geogrid reinforcement, particularly Re 510, Re 520, Re 540, Re 560, Re 570, and Re 580, consistently enhance strip footing performance. These enhancements result in increases for P_{fc} , P_y , and P_{ult} compared to the concrete control strip footing (St1).
- 5- Incorporating glass fiber bristles along with uniaxial geogrid reinforcement uniformly enhances the stiffness of strip footing performance. This approach results in notable enhancements for k_{fc} , k_y , and k_{ult} compared to the concrete control strip footing (St1).
- 6- Combining uniaxial geogrid reinforcement with glass bristles on strip footings consistently enhances performance. This improvement correlates with the total tensile strength of the reinforcement, impacting displacement ductility indexes and energy dissipation capacities affirmatively.
- 7- The integration of uniaxial geogrid with concrete prominently contributed to decrease both crack thickness and quantity. geogrid reinforced footings exhibited a notable correlation between the number of flexural cracks, total geogrid tensile strength, and the number of geogrid layers.
- 8- An empirical equation linking strip footing moment and total tensile strength of geogrid reinforcements was derived.
- 9- Through careful sheet selection and layers reduction, Strip footing load capacity is enhanced, outperforming traditional steel methods.

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Impact of Social Media Marketing on Brand Awareness and Brand Recognition

Dr. K. Swapna Sri ¹, Marri Drusika²

¹Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India

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Abstract— This study explores the role of social media marketing in influencing brand awareness and recognition, two vital components of brand development. Brand awareness pertains to the degree to which customers are able to identify or recall a brand, while brand recognition deals with the degree to which a brand can differentiate itself based on its visual and message appeal. By studying the manner in which brands use social media to develop engaging content, run targeted advertisements, and develop interactive communities, this study illustrates the tactics that drive brand awareness and recognition. The study indicates that social media marketing is an effective tool to shape consumer perceptions, shape purchase decisions, and ultimately make brands successful in a competitive market over the long term.

Keywords— Social media marketing, brand awareness, recognition, consumer perceptions, promotions

I. INTRODUCTION

In the digital age, social media has become an integral part of everyday life, reshaping how brands interact with consumers. With billions of users across various platforms, social media marketing has proven to be one of the most effective tools for increasing brand awareness and recognition. Brands now have the opportunity to connect with a global audience in real time, engaging consumers directly through content, advertisements, and interactive campaigns. With the era of digitalization we find ourselves in today, social media has become a force with that impacts consumer behaviour, molds public opinion, and fuels brand consciousness. Social media marketing, through the utilization of Facebook, Instagram, Twitter, and LinkedIn, enables brands to communicate directly to them.

Social media marketing's use in brand consciousness and awareness has also become a primary area of interest for companies that want to keep up with an ever-evolving market.

1.1 Statement of the Problem

In the increasingly digital and competitive consumer electronics market, brand visibility and customer engagement are critical to business success. Bajaj Electronics, a leading retail chain in India, has invested in various social media marketing strategies to promote its brand and reach a wider audience.

1.2 Significance of the Study

The study of Social media allows brands to reach a global audience at minimal cost compared to traditional advertising. Social media is a major part of daily life for billions of people worldwide. Platforms like Facebook, Instagram, Twitter have become integral to communication, content sharing, and entertainment.

1.3 Scope of the Study

The scope of this study focuses on evaluating how social media marketing (SMM) activities influence brand awareness and recognition of Bajaj Electronics, a leading consumer electronics retail chain in India.

1.4 Research Objectives

- To assess the role of social media marketing in increasing brand awareness.
- To identify the key social media marketing strategies that enhance brand visibility.
- To evaluate the effect of social media marketing on brand recognition.

II. LITERATURE REVIEW

Kumar et al. (2016) found that personalized social media campaigns lead to higher consumer engagement and improved brand recall. Brands leveraging data analytics for targeted marketing are more likely to establish lasting impressions. Personalized content strengthens the brand-consumer relationship and encourages consumer loyalty and repeated engagement

Hodson (2021) makes difference between brand awareness brand associations and brand loyalty. According to the author, awareness is an ability of a consumer to recall a brand based on previous experience or exposure. In terms of brand associations, they are concerned with strong links with brands in memory, which can be caused by experience, exposure, or other supported networks. As regards loyalty, it is a condition, when a consumer is strongly attached to a brand and the likelihood of switching to a competitor is very low.

Tuten et al., (2015) The statistics emphasize the strength of social media channels, in comparison with traditional ways of marketing. It does not mean that traditional channels are not usable. However, the statistics prove the likelihood that brand awareness can be more effective through "Facebook". According

to the study of Schivinski and Dabrowski (2015) brand created and use regenerated communication on social media has a substantial influence on brand awareness. However, the authors claim that results depend on the industries.

Priyanka P.V and Padma Srinivasan (2015) In her research study identified various factors that determine the purchase of a product using social media from a customer's point of view. A model from the retailer's perspective has been developed that explains how social media can be used for increasing customer loyalty. The study concludes that continuous customer support services will result in improvement of customer retention. New applications and social platforms will flourish and allow even greater personalization and real-time, location-based engagements in media.

III. RESEARCH METHODOLOGY

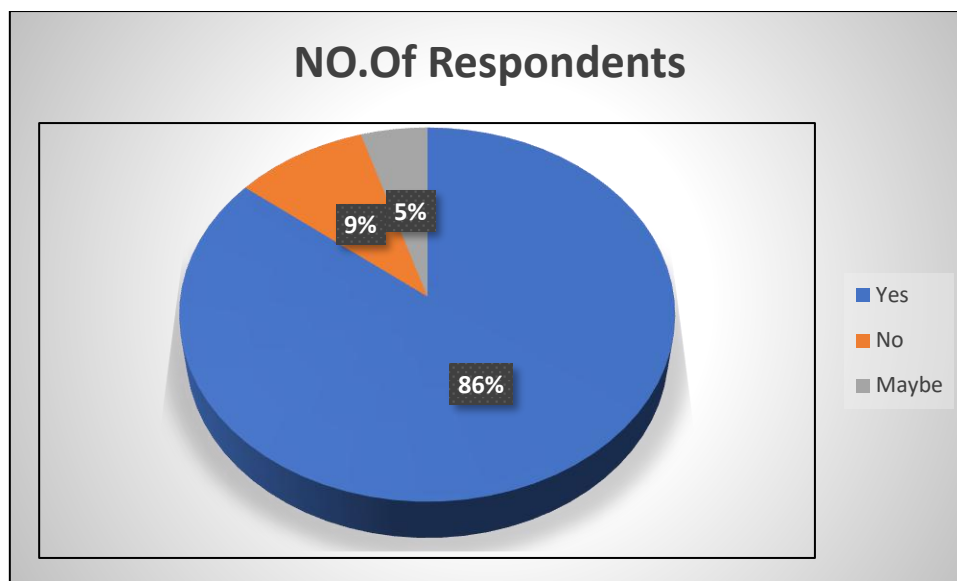
This study employs a mixed-method research design, combining quantitative and qualitative approaches through descriptive and analytical methods. The target population consists of social media using consumers in India, from which a sample of 107 respondents was selected using stratified random sampling. Data collection involves both primary and secondary sources. Primary data is gathered through surveys conducted via Google Forms and interviews with retail managers, while secondary data is obtained from company reports, academic papers, and market research portals. This methodology allows for a comprehensive understanding of the research topic, leveraging the strengths of both quantitative and qualitative data.

IV. DATA ANALYSIS AND RESULTS

1. Have you discovered new brands through social media platforms?

Have you discovered new brands through social media platforms	NO .Of Respondents	Percentage
Yes	90	86%
No	10	9%
Maybe	5	5%
Total	105	100

Source: primary data



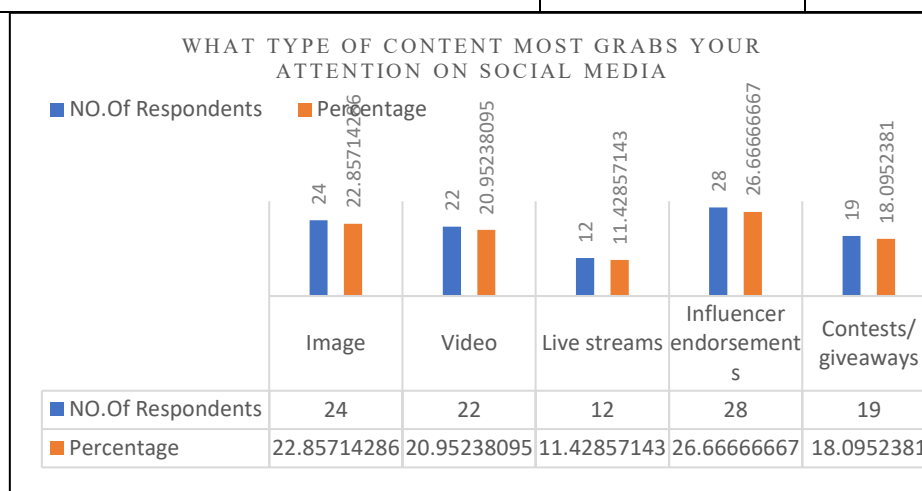
Out of 105 respondents, 85.71% said they have discovered new brands through social media platforms. Only 9.52% said they have not, while 4.76% were unsure. This indicates that social media plays a major role in helping people find new brands.

2. What type of content most grabs your attention on social media?

primary

What type of content most grabs your attention on social media	No. Of Respondents	Percentage
Image	24	23%
Video	22	21%
Live streams	12	11%
Influencer endorsements	28	27%
Contests/ giveaways	19	18%
Total	105	100

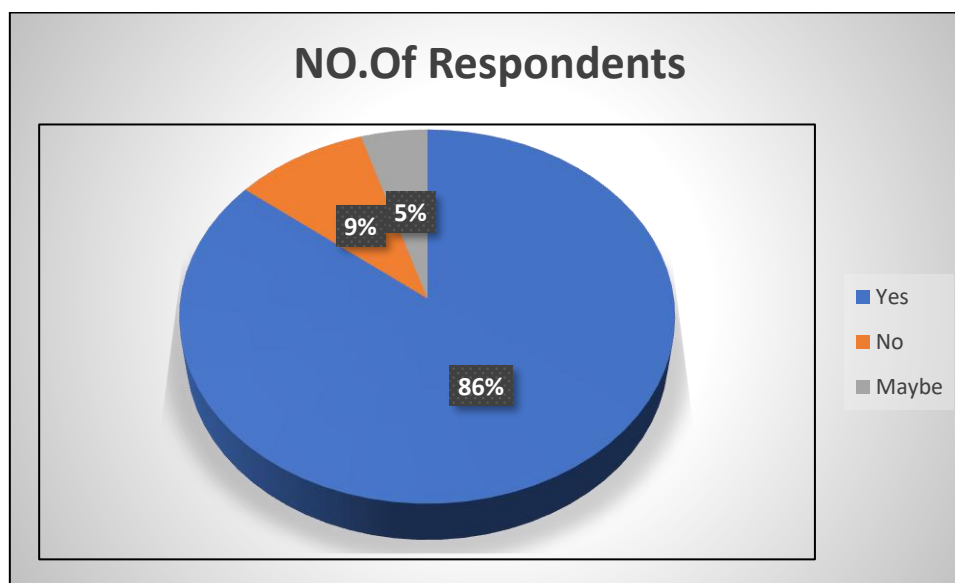
Source:
data



Among the respondents, 26.67% said influencer endorsements grab their attention the most on social media. Images followed closely with 22.86%, and videos attracted 20.95% of users. Contests or giveaways caught the interest of 18.10%, while live streams were the least attention-grabbing at 11.43%. This shows that influencer content is the most effective in capturing user attention on social media platforms.

3. Have you discovered new brands through social media platforms?

Have you discovered new brands through social media platforms	NO .Of Respondents	Percentage
Yes	90	86%
No	10	9%
Maybe	5	5%
Total	105	100



Out of 105 respondents, 85.71% said they have discovered new brands through social media platforms. Only 9.52% said they have not, while 4.76% were unsure. This indicates that social media plays a major role in helping people find new brands.

- H_0 : Social media marketing has no significant impact on increasing brand awareness towards Bajaj Electronics.

What type of content most grab your attention on social media?

Image	24
Video	22
Live streams	12
Influencer endorsements	28
Contests/giveaways	19
Total	105

Particulars	Observed value	Expected value	x2
Image	24	21	0.428571
Video	22	21	0.047619
Live streams	12	21	3.857143

Influencer endorsements	28	21	2.333333
Contests/giveaways	19	21	0.190476
Total	105	105	6.857143

X2 table value	X2 calculated value
9.488	6.85714
As table value is less than calculated value. We reject H0 (null) and accept H1 (alternative)	
Note:-	
χ^2 = chi square	
O = Observed value	
E = Expected value	
Formula:- " $(O-E)^2/E$ "	
Degree of freedom :-4	
Significance :- 0.05	

Interpretation:

The results strongly reject the null hypothesis, indicating a significant impact on increasing brand awareness. The degree of freedom is 4 and significance value is 0.05. The tabulated value is 9.488 and the expected value is 6.85714 as table value is less than calculated value so rejected null hypothesis and accepted alternative hypothesis.

REGRESSION:

Model: Brand Awareness = $\beta_0 + \beta_1(\text{Social Media Marketing}) + \varepsilon$

Test Setup:

- $H_0: \beta_1 = 0$ (no impact)
- $H_1: \beta_1 \neq 0$ (significant impact)

Test Procedure:

- Calculate regression coefficient β_1
- Perform t-test: $t = \beta_1 / SE(\beta_1)$
- Decision Rule: Reject H_0 if p-value < 0.05

This single test will determine whether social media marketing has a statistically significant impact on brand awareness towards Bajaj Electronics.

V. FINDINGS

- Most of the people who took part in the survey are between 20 and 30 years old.
- Instagram is the most associated platform for brand discovery, with 40% choosing it.
- A large majority of respondents (81.90%) believe that social media marketing has helped them become more aware of different brands.
- Statistical tests show social media marketing impact consumer decisions based on brand awareness and recognition.

Findings reveal that the Bajaj electronics social media marketing helped the most of the consumers become aware of brand awareness and brand recognition.

VI. CONCLUSION

This research shows that Bajaj Electronics, as a leading consumer electronics retailer, has a unique opportunity to leverage social media marketing to build stronger relationships with its target audience. Engaging content, influencer collaborations, interactive campaigns, and consistent brand messaging are key drivers in improving both

awareness and recognition. Customers are more likely to recall and trust brands that maintain a visible, value-driven, and interactive presence online. A well-structured and audience-focused social media strategy can significantly enhance the brand's reach, attract new customers, and foster long-term loyalty. Therefore, by continuously adapting to digital trends and customer preferences, Bajaj Electronics can strengthen its position in the competitive electronics retail market and build a more memorable and recognizable brand in the minds of consumers.

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A Study on the Impact of FII and DII Net Investments on Nifty 50 Index Trends in India

Kagithapuram Prathibha¹, Dr. K. Swapna Sri²

¹Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

²Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study examines the influence of Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs) on the performance of the Nifty 50 index in India during the period from 2015 to 2025. The objective is to understand whether the net investment patterns of these institutional investors have a significant impact on stock market trends, particularly the movement of the Nifty 50 index.

Keywords— Foreign Institutional Investors (FII), Domestic Institutional Investors (DII), Nifty 50, Indian Stock Market, Stock Market Trends, & Investment Flows.

I. INTRODUCTION

The Indian equity market is significantly influenced by institutional investors, primarily Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs). Their investment activities play a crucial role in shaping market trends, liquidity, and overall investor sentiment. Understanding how these institutional flows impact major market indices like the Nifty 50 is essential for grasping the broader dynamics of India's financial markets.

The Indian stock market is one of the fastest-growing financial markets in the world, attracting substantial investments from both domestic and international investors. Among the key players influencing this market are Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs). These institutional investors significantly affect market liquidity, price movements, and overall market sentiment due to the large volumes of capital they deploy. Their net investment activity, which is the difference between their purchases and sales, often serves as an important indicator of market trends and investor confidence.

1.2 Need of the Study

- To understand how Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs) influence the Indian stock market, especially the Nifty 50 index
- To assess the stabilizing role of DIIs during periods of FII outflows and market volatility.

1.3 Scope of the Study :

- Focuses on annual FII and DII net investment data and Nifty 50 index values from 2015 to 2025.
- Uses secondary data from official financial sources such as NSE/BSE and reputed financial portals.
- Limited to analyzing trends, correlations, and comparative influence on the Nifty index.
- Applicable to the Indian stock market only; broader or international market effects are not considered.

1.4 Objectives of the Study :

- To study the trends in FII and DII net investments from 2015 to 2025.

- To analyze the movement of the Nifty 50 index during the same period.
- To compare the impact of FII and DII net investments on Nifty levels using historical data.

II. LITERATURE REVIEW

Sharma, Bhatia & Roy(2023)

This research examined the role of FIIs in India's equity derivatives market, especially how their investment behaviour affects implied volatility. The findings suggest that large-scale trading by FIIs in derivatives can amplify risk levels in the market, thereby making it important for regulators to closely monitor such activities to ensure market stability and protect retail investors.

Nalini(2023)

Nalini's study investigated the relationship between FII investments and key market indicators like trading volume, market capitalization, and investor participation. The results showed a strong positive correlation—meaning that as FII inflows increased, so did trading activity and market value.

III. RESEARCH METHODOLOGY

Research Design

The study adopts a descriptive and analytical research design, aimed at understanding and explaining the influence of institutional investments—specifically Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs)—on the performance of the Nifty 50index.

This approach provides both quantitative insights and interpretative analysis for better decision-making and forecasting.

Nature of Data

- **Type of Data:** The research relies entirely on **secondary data**, as it utilizes pre-existing and published financial records.
- **Data Period:** The analysis covers a **10-year period from 2015 to 2025** (based on the most recently available data at the time of study). This time span includes various market phases—bullish, bearish, volatile, and stable—providing a comprehensive picture.
- **Frequency of Data:** The data is collected on an **annual basis**, allowing for year-on-year trend analysis and reducing the impact of short-term fluctuations.

Data Sources

- BSE
- Traders Cockpit

Tools and Techniques Used for Analysis

- Microsoft-Excel:
The primary software used for data organization, statistical analysis, and graphical representation is Microsoft Excel. Key Excel tools include:
 - Regression analysis (to assess the degree of influence that FIIs and DIIs have on market movements)
 - Line charts and trend graphs (for visualizing investment patterns and index movements over time)
- Statistical-Methods:
The following statistical methods are employed:
 - Pearson's Correlation Coefficient
 - Simple Linear Regression

IV. DATA ANALYSIS AND RESULTS

Date	FII (INR Crore)			DII (INR Crore)		
	Gross Purchase	Gross Sales	Net Purchases/Sales	Gross Purchase	Gross Sales	Net Purchases/Sales
2025	1403254	1530238.8	-126984.99	1442882	1166069.1	276812.47
2024	3957137	4252529.5	-295393.2	3347130	2843749	503381.22
2023	2521484	2541010	-19525.809	1873809	1691624.8	182184.6
2022	1978882	2265376	-286494.06	1635862	1361124.8	274737.25

2021	2113698	2199367.8	-85670.12	1456590	1364184.9	92405.59
2020	1744317	1670835	73482.15	1070837	1116877.8	-46040.77
2019	1356731	1320999.2	35731.43	916936.8	870021.9	46914.9
2018	1209810	1276679.2	-66869.3	902614.9	805969	96645.92
2017	1278001	1319122.8	-41121.63	826428.1	737216.7	89211.41
2016	1087344	1099183.1	-11838.65	512924.4	472843.75	40080.69
2015	1116463	1132898.4	-16435.56	466455.7	401802.56	64653.11

Date	FII Net Purchases/Sales	DII Net Purchases/Sales	NIFTY 50 Index
2025	-126985	276812.47	24750.7
2024	-295393.2	503381.22	23644.8
2023	-19525.81	182184.6	21731.4
2022	-286494.1	274737.25	18105.3
2021	-85670.12	92405.59	17354.1
2020	73482.15	-46040.77	13981.8
2019	35731.43	46914.9	12168.5
2018	-66869.3	96645.92	10862.5
2017	-41121.63	89211.41	10530.7
2016	-11838.65	40080.69	8185.8
2015	-16435.56	64653.11	7946.35

Year	FII Net Purchases/Sales	NIFTY
2015	-16435.56	7946.35
2016	-11838.65	8185.8
2017	-41121.63	10530.7
2018	-66869.3	10862.5
2019	35731.43	12168.5
2020	73482.15	13981.8
2021	-85670.12	17354.1
2022	-286494.06	18105.3
2023	-19525.809	21731.4
2024	-295393.2	23644.8
2025	-126984.99	24750.7

Regression Between FII Net Investment And Nifty 50:

Hypothesis for Regression Analysis :

Hypotheses:

- Null Hypothesis (H_0): FII net investment has no significant impact on the Nifty 50 index
- Alternative Hypothesis (H_1): FII net investment significantly impacts the Nifty 50 index

Regression Statistics	
Multiple R	0.579477231
R Square	0.335793861
Adjusted R Square	0.261993179
Standard Error	5232.516395
Observations	11

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	124575767.6	124575767.6	4.550010264	0.061712202
Residual	9	246413050.4	27379227.83		
Total	10	370988818.1			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	13123.52022	1901.440213	6.90188423	7.05213E-05	8822.163623	17424.87682	8822.163623	17424.87682
FII Net Purchases/Sales	-0.029607232	0.013880069	-2.133075307	0.061712202	-0.06100613	0.001791665	-0.06100613	0.001791665

Hypotheses:Null Hypothesis (H_0): There is **no significant impact** of DII net investment on the Nifty 50 index.Alternative Hypothesis (H_1): There is a **significant impact** of DII net investment on the Nifty 50 index.

Regression Statistics	
Multiple R	0.75981683
R Square	0.57732162
Adjusted R Square	0.53035735
Standard Error	4174.11273
Observations	11

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	214179864.6	2.14E+08	12.29279	0.006659254
Residual	9	156808953.5	17423217		
Total	10	370988818.1			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	10945.8562	1785.707899	6.129701	0.000173	6906.304317	14985.40815	6906.304317	14985
DII Net Purchases/Sales	0.03014062	0.008596606	3.506107	0.006659	0.010693745	0.049587491	0.010693745	0.05

V. FINDINGS

- Contrasting Investment Patterns Between 2015 and 2025, Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs) typically exhibited opposite investment behaviors. When FIIs were selling off shares, DIIs tended to buy, and the reverse was also true.
- Significant FII Withdrawals in Select Years there were substantial outflows by FIIs in years such as 2022, 2024, and 2025, with 2024 seeing the highest level of foreign selling. This trend reflects the cautious approach taken by foreign investors amid varying global and domestic uncertainties.
- Robust Support from DIIs During Market Stress In times when FIIs were exiting the market, DIIs provided crucial buying support. Notably, in 2024, DIIs invested more than ₹5 lakh crore, helping to stabilize market conditions.
- DIIs as a Market Cushion DIIs played a vital role in cushioning the market from volatility by balancing out FII outflows, which helped sustain investor confidence during challenging periods.
- Resilience of Nifty 50 Index Despite significant FII sell-offs, the Nifty 50 index largely maintained an upward trajectory, signaling the underlying robustness of the Indian stock market and increasing participation from domestic investors.
- Market Movements Influenced by Investor Dominance Both FIIs and DIIs influence the Nifty 50's performance; however, the group that is more active during a given period tends to have a stronger impact on the market's direction.
- Strengthening Role of Indian Investors Post-2021 ,From 2021 onwards, there has been a noticeable rise in the confidence and activity levels of Indian investors, including DIIs and retail participants, which has contributed significantly to market stability during uncertain global conditions.
- Limited Statistical Influence of FIIs on Market Analysis shows that FIIs do not exhibit a statistically significant effect on the Nifty 50 at the 5% confidence level, indicating that FII movements alone do not substantially dictate market trends.
- Positive and Significant Impact of DIIs Conversely, investments from DIIs have demonstrated a clear and positive correlation with Nifty 50 performance, underscoring their increasing role in supporting market growth.
- Market Stability Largely Supported by DIIs Even with ongoing global uncertainties and periods of FII withdrawal, DIIs have played a crucial role in maintaining equilibrium within the Indian equity market, reducing its reliance on foreign investment flows.

VI. CONCLUSION

Inverse Investment Behavior of FIIs and DIIs (2015-2025) between 2015 and 2025, Foreign Institutional Investors (FIIs) and Domestic Institutional Investors (DIIs) generally exhibited contrasting investment patterns. Whenever FIIs were reducing their holdings and selling shares, DIIs tended to increase their purchases, indicating a balancing effect in market participation from these two groups. Significant FII Outflows in Specific Years Notable large-scale withdrawals by FIIs occurred particularly in the years 2022, 2024, and 2025. Among these, 2024 stands out as the year with the highest volume of foreign selling, reflecting heightened caution among global investors likely driven by geopolitical, economic, or domestic uncertainties. Strong DII Investments During Market Stress In periods marked by heavy FII selling, DIIs stepped up as crucial market participants by making substantial investments. For instance, in 2024, DIIs infused over ₹5 lakh crore into the market, playing a pivotal role in counteracting the negative effects of foreign capital outflows and supporting market stability. DIIs as Stabilizers of Market Sentiment Domestic Institutional Investors have been instrumental in stabilizing market conditions by offsetting the impact of FII withdrawals. Their active buying during volatile phases helped maintain investor confidence and prevented sharp declines, thereby contributing to a more balanced market environment. Resilience of the Nifty 50 Amid FII Selling Pressure Despite considerable selling pressure from FIIs in certain years, the Nifty 50 index generally continued its upward trajectory.

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A Study on Fintech Innovations and their Impact on the Future of Banking

K. Sathish¹, Puligilla Naveen²

¹Assistant Professor, Department of Master of Business Administration, CMR Institute of Technology, Medchal, India

²Student of Master of Business Administration, CMR Institute of Technology, Medchal, India

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Abstract— Financial Technology, often abbreviated as Fintech, represents the convergence of finance and digital innovation aimed at improving and simplifying financial services. Over the past ten years, fintech has revolutionized the financial landscape, altering how both individuals and businesses manage and engage with money. In the beginning, fintech primarily focused on improving the internal processes and infrastructure of banks and financial organizations.

Keywords— Fintech, Banking, Financial Technology, Insur Tech, Crypto Currency, Investment and Wealth Technologies.

I. INTRODUCTION

Today, fintech is embedded in daily life. Everyday activities such as transferring funds through mobile apps, making payments via digital wallets, or investing through apps like Robinhood illustrate how fintech tools have become mainstream. According to the EY Global FinTech Adoption Index 2019, approximately 67% of users engage with two or more fintech services, highlighting their deep integration into everyday financial activities. In India, fintech growth is being driven by strong government backing, supportive regulatory frameworks, widespread smartphone use, a large pool of tech talent, and positive investor interest. These factors have collectively cultivated a dynamic and growing digital finance landscape.

II. LITERATURE REVIEW

India's fintech sector is rapidly evolving, positioning the country among top global fintech markets due to digital payment growth, accessible credit, and increased retail investment (Naker, 2022). Globally, fintech is reshaping financial services, as shown by long-term data across 115

countries (Murinde et al., 2022). Strong momentum is driven by innovation and consumer demand, with India's fintech expected to grow at a 31% CAGR through 2025 (Belgavi et al., 2022). Post-COVID-19, fintech's role across payments, lending, insurance, and capital raising was studied through a survey of 227 firms, highlighting resilience and adaptability (Propson & Zhang, 2024).

III. RESEARCH GAP

Existing studies lack focused analysis on cybersecurity and data privacy within fintech, especially as digital financial ecosystems expand.

Need for the Study:

To remain competitive, banks must understand fintech trends and adapt to technological advances to seize opportunities and manage risks.

Problem Statement:

Traditional banks struggle to keep pace with rapid fintech innovation, facing challenges in adapting to tech shifts, customer expectations, regulations, and collaboration models.

Objectives:

1. Examine current fintech innovations and trends.
2. Assess fintech's impact on traditional banking (e.g., satisfaction, efficiency, compliance).
3. Recommend strategies for banks to remain competitive and agile.

Research Design:

A mixed-method approach combining qualitative and quantitative data, involving fintech users and banking stakeholders. The study evaluates technologies, consumer behaviour, regulation, and strategic responses.

Data Collection Methods:

Primary data will be acquired through surveys and observational case studies. The survey, structured in the form of a detailed questionnaire, aims to gather insights directly from fintech users and stakeholders regarding their experiences and opinions.

Secondary data will be sourced from academic journals, industry reports, research publications, and reliable online databases, offering contextual background and supporting analysis.

Population: 100

Sample Size: 63

Sample Location: Medchal

Hypothesis:

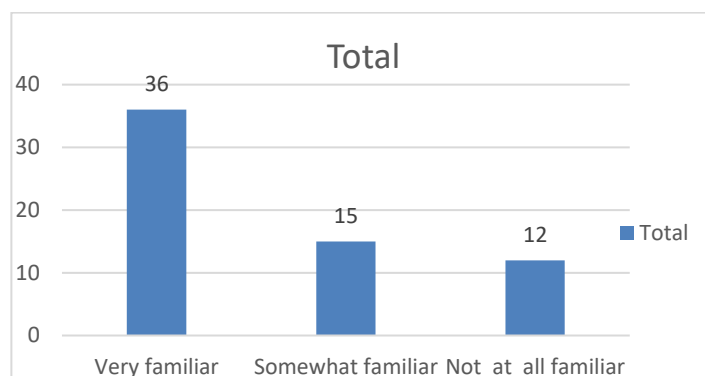
- **Null Hypothesis (H_0):** Fintech developments do not have a significant influence on the future trends and direction of the banking industry.
- **Alternative Hypothesis (H_1):** Fintech developments significantly impact and shape the future trajectory of the banking sector.

Data Analysis:

1. How familiar are you with the concept of fintech (financial technology)?

Option	Respondents	Percentage
Very familiar	36	57.10%
Some what	15	23.80%

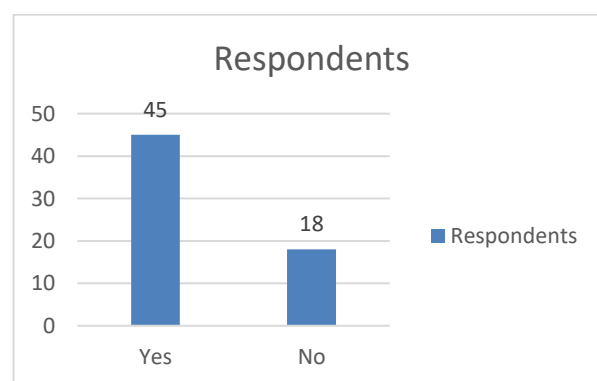
familiar		
Not at all familiar	12	19.00%
Total	63	100%



- 57.1% reported having a strong understanding of fintech, whereas only 19% had little to no knowledge of the concept.

2. Have you previously used any financial technology services such as UPI, digital wallets, robo-advisors, or similar platforms?

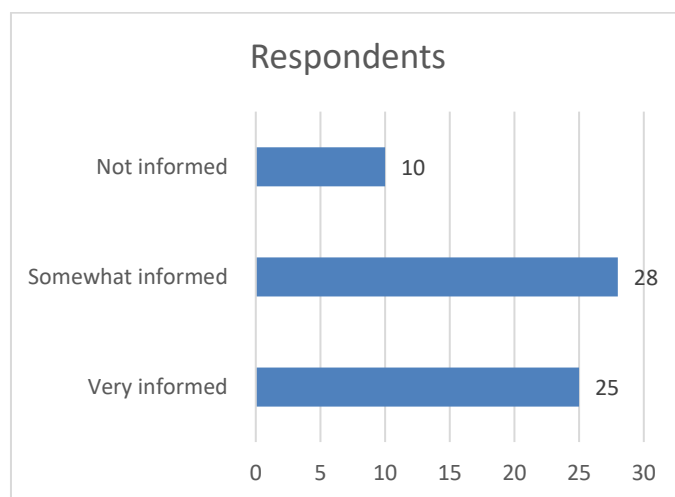
Option	Respondents	Percentage
Yes	45	71.40%
No	18	28.60%
Total	63	100%



- About 71.4% confirmed they had used fintech tools, including UPI platforms, digital wallets, and automated financial advisors.

3. How informed do you feel about the latest developments in the fintech industry?

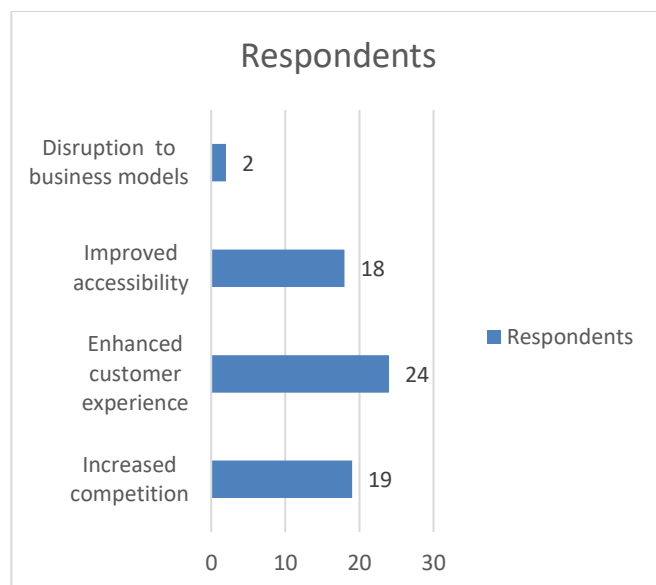
Option	Respondents	Percentage
Very informed	25	39.70%
Somewhat informed	28	44.40%
Not informed	10	15.90%
Total	63	100%



- When asked about awareness of fintech advancements, 39.7% felt wellinformed, and 44.4% indicated moderate knowledge.

4. In your opinion, how has fintech impacted traditional banking services in recent years?

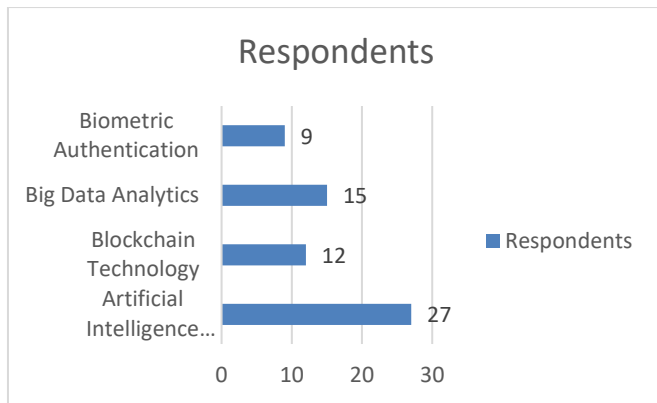
Option	Respondents	Percentage
Increased competition	19	30.20%
Enhanced customer experience	24	38.10%
Improved accessibility	18	28.60%
Disruption to business models	2	3.20%
Total	63	100%



- 38.1% of participants stated that fintech significantly improved customer experience in the banking sector.
- 30.2% saw fintech as a driver of increased competition in banking, while 28.6% noted improved financial access due to fintech services.

5. Which technological innovations do you believe have had the most significant impact on the fintech industry?

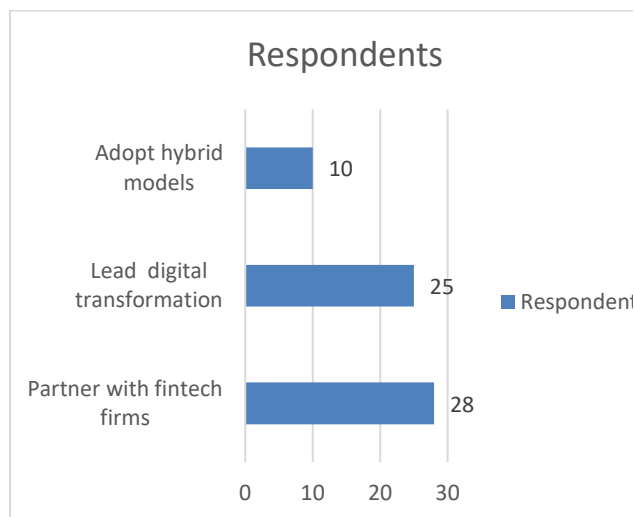
Option	Respondents	Percentage
Artificial Intelligence Machine Learning	27	42.90%
Blockchain Technology	12	19.00%
Big Data Analytics	15	23.80%
Biometric Authentication	9	14.30%
Total	63	100%



Technologies like Artificial Intelligence and Machine Learning were identified as the most transformative by 42.9% of respondents.

6. What role do you think traditional banks will play in the evolving fintech landscape?

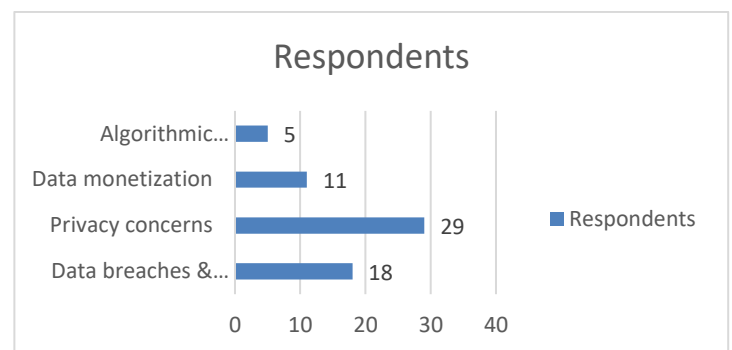
Option	Respondents	Percentage
Partner with fintech firms	28	44.40%
Lead digital transformation	25	39.70%
Adopt hybrid models	10	15.90%
Total	63	100%



Collaborative efforts between traditional banks and fintech firms were recommended by 44.4%, while 39.7% favored banks pursuing their own digital transformation.

7. What kind of negative impacts can fintech cause in the future regarding user data?

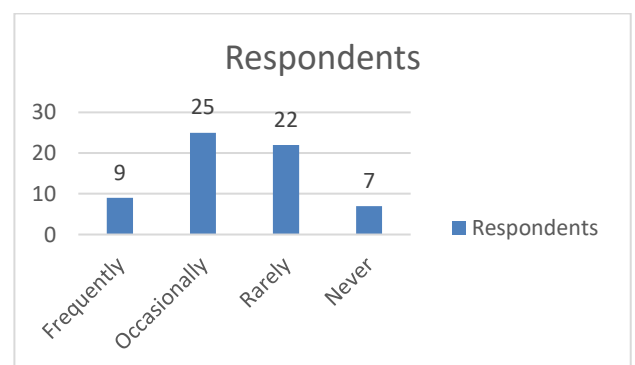
Option	Respondents	Percentage
Data breaches & security risks	18	28.60%
Privacy concerns	29	46.00%
Data monetization	11	17.50%
Algorithmic bias/discrimination	5	7.90%
Total	63	100%



- Data privacy emerged as the most critical risk associated with fintech, highlighted by 46% of participants.

8. From a user's point of view, how often do you experience inconvenience or mistrust while using fintech services?

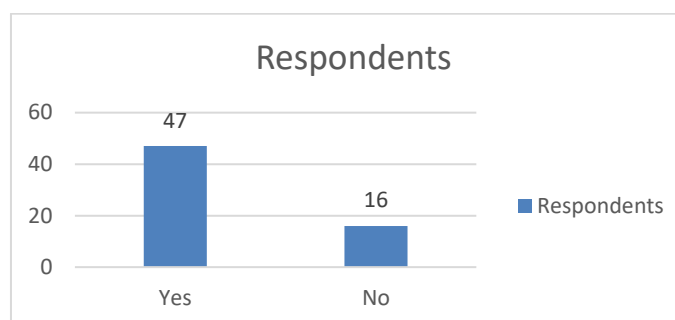
Option	Respondents	Percentage
Frequently	9	14.30%
Occasionally	25	39.70%
Rarely	22	34.90%
Never	7	11.10%
Total	63	100%



- Over half of the users sometimes feel unsure or face trouble while using fintech services.

9. Do you think fintech will impact the banking industry in the future?

Option	Respondents	Percentage
Yes	47	74.60%
No	16	25.40%
Total	63	100%



- Most people think that fintech will bring big changes to the banking industry in the future.

STATISTICAL TOOL FOR ANALYSIS:

Hypothesis:

- **Null Hypothesis (H_0):** Fintech innovations have no meaningful impact on shaping the future direction of the banking sector.
- **Alternative Hypothesis (H_1):** Fintech advancements play a significant role in influencing and transforming the future of banking.

Expected Values (with Chi-Square components):

	Yes (Expected)(χ^2)	No (Expected)(χ^2)
Very informed	23 (17.86) (1.48)	2 (7.14) (3.70)
Somewhat informed	19 (20.00) (0.05)	9 (8.00) (0.13)
Not informed	3 (7.14)(2.40)	7 (2.86)(5.86)

The Chi-Square statistic is 13.769. The p-value is 0.0010.

The result is significant at $p < 0.05$.

Conclusion:

Since H_0 is rejected, H_1 is accepted.

There is a significant relationship between how informed respondents feel about fintech and whether they use fintech services.

Findings:

- Majority of respondents were students aged 20–35, with 71.4% having used fintech tools and 57.1% showing strong fintech awareness.
- AI/ML was identified as the most transformative technology, while cybersecurity (60.3%) and data privacy (46%) were major concerns.
- Fintech was seen as enhancing customer experience (38.1%), promoting financial inclusion (46%), and increasing competition in banking (30.2%).

Suggestions:

- Strengthen cybersecurity, simplify user interfaces, and promote user education on digital financial safety.
- Encourage bank-fintech collaborations, adopt hybrid models, enforce data protection laws, and expand fintech access to rural areas.

IV. CONCLUSION

The study concludes that fintech is significantly transforming the traditional banking landscape by introducing innovation, accessibility, and improved customer experiences. Adoption is notably higher among younger, digitally aware users, with awareness proving to be a key driver of usage. Technologies like AI are reshaping how financial services are delivered, not replacing banks but pushing them toward innovation. To remain competitive and relevant, traditional banks must embrace fintech through collaboration, secure integration, and inclusive strategies that support a digital-first financial future.

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A Comparative Analysis of ESG-Focused and Traditional Investment Banking Firms: Financial Performance, Compliance, and Reputation.

Dr. K Swapna Sri¹, Heerekar Nithin²

¹Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.s

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Abstract— The aim of this project was to evaluate how ESG-focused investment banks differ from traditional investment banks in terms of financial performance, compliance strength, and reputational standing. The research problem arose from the increasing global attention on ESG integration and the lack of comparative evidence on whether such practices yield measurable benefits in the investment banking sector.

Keywords— ESG Investment, Traditional Investment Banks, Financial Performance, Sustainability Metrics, Shareholder Returns & Media Sentiment Analysis

I. INTRODUCTION

In recent years, there is a significant paradigm shift in the global financial sector toward responsible investing, particularly through the adoption of ESG (Environmental, Social, and Governance) principles. Investment banks—traditionally focused on profitability and capital efficiency—are now increasingly expected to incorporate sustainability, ethical governance, and social responsibility into their operations. As an aspiring finance professional, I wanted to explore whether ESG-focused investment banks actually outperform or differ significantly from traditional ones in terms of financial metrics, compliance strength, and reputation.

Statement of the Problem

While ESG integration is gaining momentum, I found limited comparative research evaluating how ESG-focused banks perform against traditional banks from both a financial and non-financial standpoint.

Research Objectives, Questions & Hypotheses

Objectives:

- To compare financial performance (EPS, ROE, NPM, Revenue, D/E) between ESG-focused and traditional investment banks.
- To evaluate their ESG risk scores and media sentiment profiles.
- To statistically test if the differences observed are significant.

Hypotheses:

- **H₀₁ (Null Hypothesis):** There is no significant difference in the EPS between ESG-Focused and traditional Investment banks.
- **H₁₁ (Alternative Hypothesis):** There is a significant difference between the EPS between ESG-Focused and traditional Investment banks.
- **H₀₂ (Null Hypothesis):** There is no significant difference in the 5Y returns between ESG-Focused and traditional Investment banks.

- **H_{12} Alternative Hypothesis):** There is a significant difference between the 5Y returns between ESG-Focused and traditional Investment banks.
- **H_{03} (Null Hypothesis):** There is no significant difference in the ESG Scores between ESG-Focused and traditional Investment banks.
- **H_{13} (Alternative Hypothesis):** There is a significant difference between the ESG Scores between ESG-Focused and traditional Investment banks.

Significance of the Study

This study is important because it brings clarity to the debate around ESG integration – whether it is a true driver of financial and reputational strength or merely a superficial trend. My findings can guide investors, analysts, and policymakers in assessing which banking models are better positioned for long-term sustainability and market relevance.

Scope and Limitations

This research is limited to a sample of eight global investment banks, four of which are classified as ESG-focused and four as traditional. The analysis covers data from 2020 to 2024. As I relied on publicly available secondary data, variations in ESG scoring methodologies and limited access to internal metrics pose some constraints.

II. REVIEW OF LITERATURE

1. ESG Integration and the Investment Management Process: Fundamental Investing Reinvented Auke Plantinga & M. Klimenko (2015)

Published in the Journal of Business Ethics, this study explores how ESG (Environmental, Social, and Governance) factors are integrated into traditional investment decision-making. The researchers highlight that ESG has evolved to become a part of fundamental analysis rather than an optional overlay.

2. ESG Activities and Banking Performance: International Evidence from Emerging Economies Wajahat Azmi, M. Kabir Hassan, Reza Houston, Mohammad Sydul Karim (2021)

Published in the *Journal of International Financial Markets, Institutions and Money*, this empirical study examines how ESG engagement influences the performance of 251 banks across 44 emerging economies. Among the ESG pillars, environmental actions were the most effective in improving financial performance.

3. Bank's Funding Costs: Do ESG Factors Really Matter? Agnese Paolo & Giacomini Emanuela (2023)

This research, featured in Finance Research Letters, analyzes data from 63 European banks between 2006 and 2021. It concludes that institutions with higher ESG scores enjoy lower bond spreads, reflecting enhanced market trust and credit perception. Governance quality was found to be the most influential in lowering borrowing costs, followed by environmental and social practices.

III. Research Methodology

Population and Sample

The sample includes **eight investment banking firms**, equally divided into:

- 4 ESG-focused investment banks
- 4 Traditional investment banks.

Sampling Techniques

The sampling technique is **purposive sampling**, as companies were chosen based on their ESG orientation and investment banking status.

Data Collection Methods

The project utilized **secondary data**, including:

Financial reports, Investor presentations, Regulatory filings, ESG compliance reports, Sustainability disclosures, Media reports and sentiment analysis

Instruments Used

- MS Excel

Data Analysis Techniques

- **Descriptive statistics** (for comparing revenue, NPM, ROE, EPS, D/E, etc.)
- **t-tests** (for hypothesis testing between ESG and traditional firms)
- Media sentiment scoring

IV. RESULTS / FINDINGS

Financial Metrics

ESG Firms	2024	2023	2022	2021	2020
REVENUE	41,022	39,971	38,186	37,033	36,064
NPM (%)	27.7725	27.8	22.0525	24.695	12.025
ROE (%)	10.88	10.9275	8.19	8.645	4.415
EPS	3.4175	3.03125	2.3895	2.34675	1.625
ESG D/E	18.17	17.777	18.5225	17.24	17.1875

Traditional Firms	2024	2023	2022	2021	2020
Revenue	23,368	25,319	23,423	23,651	25,416
NPM(%)	14	22	20	21	18
ROE(%)	8	12	12	9	8
EPS	1	3	3	2	3
D/E	4	4	4	4	4

Compliance Metrics

Company Name	Sustanalytics ESG Score	S&P ESG Score	CSRHub Score
BNP Paribas	21	57	97
ING Group N. V.	12.9	41	96
Barclays PLC	16.9	64	97
HSBC Holdings PLC	19.7	58	93
Wells Fargo & Co.	33.7	37	77
Everbright Securities Ltd	33.7	23	43
Guolian Minsheng Securities Company Ltd.	32.5	26	63
Houlihan Lokey, Inc	30.7	22	44

REPUTATION METRICS

Company	Year	ESG Event/Recognition	Pillar	Source Type
BNP Paribas	2020	Euromoney: Best Bank for Financial Inclusion	S	Award
	2021	MSCI ESG 'AA'; Sustanalytics Score ~21	All	Rating
	2021	FTSE4Good & DJSI Inclusion	All	Index
	2021	EcoVadis Silver	All	Certification
	2021	UN PRI, TCFD, UNGC Support	G	Disclosure

	2023	Euromoney: Best Bank & for Sustainable Finance	All	Award
	2024	SBTi, CDP, FTSE4Good continued	E	Certification/Index
	2025	Sustainalytics Score ~21; DJSI/FTSE included	All	Rating/Index
ING	2021	MSCI ESG 'AA'; Sustainalytics Low Risk	All	Rating
	2021	FTSE4Good, Euronext ESG inclusion	All	Index
	2022	Ranked 2nd in World Benchmarking Alliance	All	Ranking
	2023	Sustainalytics Score 12.9 (Low risk)	All	Rating
	2024	Euromoney: Best Bank for ESG in Germany	All	Award
	2024	MSCI AA reaffirmed; ESG indices included	All	Rating/Index
	2025	First SBTi near-term validated G-SIB	E	Certification
Barclays	2023	Sustainalytics Score 16.9 (Low Risk)	All	Rating
	2024	FTSE4Good inclusion	All	Index
HSBC	2022	Bond Awards; Asia's Best ESG Bank	E	Award
	2022	MSCI 'AA'; Sustainalytics ~19.7	All	Rating
	2023	CDP A-; FTSE4Good, DJSI retained	E	Rating/Index
	2024	Euromoney: Best Sustainable Finance Bank	E	Award
	2025	Issued \$1T sustainable finance roadmap	E	Disclosure
Wells Fargo	2020	\$200bn sustainable finance goal	E	Corporate Target
	2021	\$2bn Climate Bond Program	E	Issuance
	2022	Climate Bonds Award	E	Award
		Sustainalytics Score 33.7 (High risk)	All	Rating
	2024	Withdrew net-zero target	G	Disclosure
Everbright Securities	2022	Sustainalytics Score 33.7 (High risk)	All	Rating
Guolian Securities	2023	Sustainalytics Score 32.5 (High risk)	All	Rating
Houlihan Lokey	2021	First ESG/Sustainability Report	All	Disclosure
	2024	Sustainability report updates (SASB, TCFD)	All	Disclosure
		Sustainalytics Score 30.7 (High risk)	All	Rating

Hypothesis Testing

Hypothesis 1

- **H₀₁ (Null Hypothesis):** There is no significant difference in the EPS between ESG-Focused and traditional Investment banks.
- **H₁₁ (Alternative Hypothesis):** There is a significant difference between the EPS between ESG-Focused and traditional Investment banks.

Table No. 7.1

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	2.562	2.3025
Variance	11.64809867	4.694161
Observations	4	4
Hypothesized Mean Difference	0	
Df	5	
t Stat	0.128384119	
P(T<=t) one-tail	0.451424553	
t Critical one-tail	2.015048373	
P(T<=t) two-tail	0.902849106	
t Critical two-tail	2.570581836	

Hypothesis 2

- **H_{02} (Null Hypothesis):** There is no significant difference in the 5Y returns between ESG-Focused and traditional Investment banks.
- **H_{12} Alternative Hypothesis):** There is a significant difference between the 5Y returns between ESG-Focused and traditional Investment banks.

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	234.0819989	130.8349554
Variance	2882.349464	11904.74978
Observations	4	4
Hypothesized Mean Difference	0	
Df	4	
t Stat	1.698111201	
P(T<=t) one-tail	0.082359577	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.164719154	
t Critical two-tail	2.776445105	

Hypothesis 3

- **H_{03} (Null Hypothesis):** There is no significant difference in the ESG Scores between ESG-Focused and traditional Investment banks.
- **H_{13} (Alternative Hypothesis):** There is a significant difference between the ESG Scores between ESG-Focused and traditional Investment banks.

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	Variable 2
Mean	14.825	32.65

Variance	19.00916667	2.01
Observations	4	4
Hypothesized Mean Difference	0	
Df	4	
t Stat	-7.775920061	
P(T<=t) one-tail	0.00073737	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.00147474	
t Critical two-tail	2.776445105	

V. FINDINGS

Revenue Growth: ESG banks showed steady ~13.7% growth, while traditional banks had slower, inconsistent growth (~8.7%).

Profitability: ESG firms' NPM rose to ~28%, while traditional firms declined to 18% by 2024.

ROE: Traditional banks led early (12%) but declined; ESG firms improved and caught up by 2024.

EPS: ESG firms had consistent EPS growth; traditional banks showed volatility, especially a dip in 2023.

Leverage (D/E): ESG banks had higher leverage (~18) vs. traditional banks (~4), enabling expansion.

5Y Shareholder Returns:

ESG Banks:

BNP Paribas: 176.44%, Barclays: 244.25%, HSBC: 212.55% & ING: 303%

Traditional Banks:

Wells Fargo: 214.45%, Everbright: 17.62%, Guolian: 57.69% & Houlihan Lokey: 233.57%

ESG Scores: ESG firms had lower ESG risk, indicating high sustainability and reliability.

Hypothesis Testing Results:

EPS: No significant difference (H_0 accepted)

5Y Returns: No significant difference (H_0 accepted)

ESG Scores: Significant difference (H_1 accepted)

VI. CONCLUSION

This project presents a comparative analysis of ESG-focused and traditional investment banks over a five-year period (2020–2024), examining their financial

performance, reputational standing, and compliance metrics. Key indicators such as revenue, net profit margin (NPM), return on equity (ROE), earnings per share (EPS), debt-to-equity ratio (D/E), 5-year total returns, ESG scores, and media sentiment were used for the evaluation. The results revealed that ESG-focused banks exhibited stronger revenue growth, consistent profitability, improving shareholder returns, and significantly lower ESG risk scores. Traditional banks, while historically robust, showed more volatility in performance and a lower degree of adaptability to ESG-related risks.

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A Study on Dominance of Electrical Vehicles Over Internal Combustion Engines (ICE) Vehicles in Hyderabad

M. Akhila Reddy¹, Pola Adharsh²

¹Assistant Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study is focused on understanding the current growth and perception of Electric Vehicles (EVs) compared to Internal Combustion Engine (ICE) vehicles in Hyderabad. The study is divided into four key areas. First, it explores how customers in Hyderabad feel about using EVs – their preferences, concerns, and what influences their choices. Second, it identifies the major challenges EVs are facing in the city, such as issues related to technology, cost, and charging infrastructure. Third, it examines the environmental impact of EVs compared to traditional fuel-based vehicles, especially how zero carbon emissions from EVs are affecting customer decisions. Lastly, it studies the role of government support, including policies, subsidies, and incentives that encourage the shift towards EVs. However, the study has some limitations. It is restricted to Hyderabad, so the findings might not apply to other regions. Also, due to time limits and fewer respondents, the research could not cover long-term trends or represent the views of all sections of society. Still, it gives a meaningful snapshot of the current EV scenario and what steps can be taken to make EVs a better and more attractive choice for consumers.

Keywords— Electric Vehicles (EVs), Internal Combustion Engine (ICE) Vehicles, Consumer Perception, EV Adoption, Charging Infrastructure, Environmental Impact, Zero Carbon Emissions, Government Policies, Subsidies and Incentives, Sustainable Transportation.

I. INTRODUCTION

Electric Vehicles (EVs) are emerging as a sustainable alternative to Internal Combustion Engine (ICE) vehicles, driven by rising environmental concerns, fuel price volatility, and government support in India. With benefits such as zero emissions, low maintenance, and government subsidies, EVs are increasingly preferred by urban consumers. Hyderabad, being a growing metro city, reflects this transition. The Indian government's policies like the FAME scheme and reduced taxes on EVs, have further accelerated adoption. While ICE vehicles have dominated for over a century, the shift towards clean mobility marks a significant transformation in the Indian automobile landscape.

OBJECTIVE OF THE STUDY

1. To know the customer perception towards EVs.
2. To know the policies of government schemes to help the EVs' growth.
3. Analysing the impact of EVs on the environment over ICE vehicles.
4. Identifying the challenges EVs faced over ICE vehicles.

NEED FOR THE STUDY.

This study identifies current customers' perceptions of EVs over ICE vehicles in Hyderabad, the challenges experienced by EVs, and the effect of zero carbon emissions based on customer decisions. It also

explores how government policies and incentives are enabling the switch from fuel-based vehicles to electric ones.

The study provides a clear picture of how EVs are expanding and what factors are impacting the rise of EVs by using customers' data and providing future insights/recommendations to improve EVs in the future to increase the adoption rate of EVs.

SCOPE OF THE STUDY

1. To know the customer perception of EVs against ICE vehicles.
2. To address the challenges of EVs from technology, finance, and infrastructure.
3. Consumer perception of EVs by considering the Environmental factors.
4. To improve our understanding of the role of government policy (subsidies, regulations, etc.) in promoting EVs.

LIMITATIONS OF THE STUDY

1. The study is confined to the Hyderabad region, and the results may not apply to other cities or regions with different infrastructure, demographics, and government policies
2. The project was done in a short period. Because of this, we couldn't study long-term changes or trends
3. The study includes only a limited number of people, so it may not show the full picture of everyone's opinion in the city.
4. There wasn't much past data available for EV use in Hyderabad, so the study mainly depends on what people think right now.

II. REVIEW OF LITERATURE

- **McKinsey & Company (2025):** EVs are getting more cost-effective compared to ICE vehicles. Exploration by McKinsey & Company (2025) suggests that the total cost of ownership (TCO) of EVs is projected to be lower than ICE vehicles by 2027 due to lower energy and conservation costs. A study by Cox et al.(2022) found that 70% of consumers prefer EVs due to lower operating charges and better driving gestures.
- **Sustainable Decarbonisation of Road Transport (2024):** Electric vehicles (EVs) offer a practical

solution to reduce CO₂ emissions from road transport. Supportive government policies, incentives, and consumer interest drive global EV adoption. China leads in EV market size and technology, while Norway has the highest EV adoption rate. Key factors include infrastructure, innovation, and regulations.

- **International Energy Agency (2023):** The Global EV Outlook by IEA reviews global electric vehicle trends, including growth, charging infrastructure, battery use, emissions, and policies. It highlights market performance, investments, and trade. The report supports climate goals and offers interactive tools for exploring EV data and policies to guide governments and stakeholders in future planning.
- **Fuels Institute (2022):** Ricardo conducted a life cycle and cost analysis comparing electric (BEV), hybrid (HEV), and internal combustion engine (ICE) vehicles. The study found that BEVs emit fewer greenhouse gases after 19,000 miles and have lower long-term ownership costs. Key factors include battery life, electricity sources, policies, and consumer behaviour.
- **International Energy Agency (2021):** A key driver behind EV adoption is their lower carbon footprint. Research by Arias and Bell (2022) highlights that EVs produce significantly less CO₂ emissions over their lifecycle compared to gasoline or diesel-powered vehicles. Governments worldwide are implementing stricter emission regulations and banning ICE vehicles in major cities (IEA, 2023). For instance, the EU and California have announced plans to phase out new ICE vehicle sales by 2035 (Schmidt, 2022).
- **Praveen Kumar, Kalyan (2013):** Possible Demand for EVs, Charging Stations, and the Difficulties Confronting the Indian Market: written by Praveen Kumar and Kalyan Hello, Run. As an alternative to attempting a massive overhaul, India could finance localised reinforcements on a smaller scale to deal with load difficulties. It is advisable to promote charging at home.
- **ARUN.R. B (2011):** This study explores factors influencing consumer decisions when buying

cars, emphasising the importance of understanding customer preferences. It also highlights India's reliance on imported crude oil for diesel, which impacts pricing, technology adoption, and economic stability. Manufacturers must create fuel-efficient vehicles to meet consumer needs and support sustainability.

Research Gap

1. Most studies on electric vehicles (EVs) focus on major cities, but there is limited research on consumer perception and challenges specific to Hyderabad.
2. There is also a lack of data on how factors like age, income, and government subsidies influence EV adoption in this region.
3. This study aims to fill these gaps by understanding local opinions, environmental concerns, and the role of government support in promoting EVs in Hyderabad.

RESEARCH METHODOLOGY

This study was conducted to know the customer perception of EVs over ICE vehicles, and also how government policies and schemes help the growth of EVs, and the challenges faced by EVs over ICE vehicles.

The data was collected in the form survey. The questions were prepared related to my topic, and I have shared those questions with different customers, and I have collected different opinions from them.

RESEARCH DESIGN:

My research design is descriptive is used to describe the current situation and understanding of consumer behaviour and opinions regarding the ICE and EV vehicles.

TOOLS USED:

MS Excel, Google Forms, charts, and pie charts.

DATA CLASSIFICATION: Population: 150 Sample: 105

III. DATA COLLECTION METHODS

Primary Data: This study is based on primary data collected through a structured questionnaire using Google Forms. The survey was shared with residents

of Hyderabad to understand their perception of EVs compared to ICE vehicles.

Secondary Data: The data is gathered from the published journals, research papers, and company websites.

STATISTICAL TOOL USED: Chi-square

IV. RESULTS AND FINDINGS

1. Do you think EV vehicles will dominate ICE vehicles in the future?

Dominate In the Future	No of Respondents	Percentage
Yes	84	80%
No	21	20%
Total	105	100%



Interpretation

Most of the respondents, 84%, responded that in the near future, EVs will completely dominate ICE vehicles. And a very small percentage of respondents, 20%, responded that EVs will not dominate the ICE vehicle in coming future. This indicates that EVs will dominate the ICE vehicles in coming future in Hyderabad.

2. Would you consider an EV for your next vehicle purchase?

	No of Respondents	Percentage
Yes	80	76%
No	25	24%
Total	105	100%

Would you consider an EV for your next...



Interpretation:

Most of the respondents, 76%, are considering an EV for their next vehicle purchase. This indicates that EVs are dominating the ICE vehicles, and most customers are showing interest in purchasing an EV for their next vehicle purchase in Hyderabad. And a small percentage of 24% of respondents are not considering an EV for their next vehicle purchase.

3. What are your concerns regarding EVs compared to ICE vehicles?

Concerns	No of Respondents	Percentage
Limited Driving Range	40	38%
Insufficient Charging Infrastructure	21	20%
Long charging time	22	21%
High Purchasing price	10	10%
Battery life span	12	11%
Total	105	100%

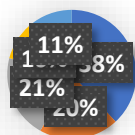
Interpretation:

Most of the respondents, 79%, were influenced by the government subsidies for purchasing their EV vehicle. And 21% were not influenced by government subsidies. This indicates that the government subsidies encourage customers to purchase the EVs over ICE vehicles.

5. Do you think EVs are better for protecting the Environment over ICE vehicles?

	No of Respondents	Percentage
Yes	92	88%
No	13	12%
Total	105	100%

What are your concerns Re compared to ICE Veh



Interpretation:

The main concern among respondents regarding EVs is the limited driving range, 38%, followed by long charging time, 21%, and insufficient charging infrastructure 20%. And a small percentage of concerned about battery lifespan, 11%, and high purchasing price, 10%. These concerns need to be addressed to improve EV adoption compared to ICE vehicles in Hyderabad

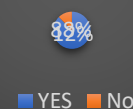
4. Do government incentives like subsidies influence your vehicle purchase decision?

	No of Respondents	Percentage
Influenced	83	79%
Not Influenced	22	21%
Total	105	100%

Do Government Incentives like subsidies...



Do you think EVs are better to protect the Environment over ICE...



Interpretation:

Most of the respondents, 88%, believe that EVs are better at protecting the environment than ICE

vehicles. 12% believe that EVS does not protect the environment compared to ICE vehicles. This shows strong public awareness and support for the environmental benefits of EVs. Especially cities like Hyderabad have high air pollution, so by using EVS, we can decrease the air pollution and protect the environment in Hyderabad.

STATISTICAL TOOLS FOR ANALYSIS

H0: EVs are not better at protecting the environment compared to ICE vehicles.

H1: EVs are better at protecting the environment compared to ICE vehicles.

<u>Chi-square calculation</u>			
	Observed value	Expected value	χ^2
YES	92	52.5	29.71905
NO	13	52.5	29.71905
TOTAL	105	105	59.4381
χ^2 table value	χ^2 calculated value		
3.841	59.4381		
H0 rejected	H1 accepted		
As the table value is less than the calculated value. We reject H0 (null) and accept H1 (alternative)			
Note: - $\chi^2 = \text{chi square}$ O = Observed value E = Expected value Formula: - " $\chi^2 = (O-E)^2 / E$ " Degree of freedom: -1 Significance: - 0.05			

Since the p-value is less than 0.05, H0 is rejected and H1 is accepted. So, EVs are better at protecting the Environment compared to ICE vehicles.

V. DISCUSSION

- 80% of respondents believe that EVS will dominate ICE vehicles completely in the future, which shows a positive public opinion toward the adoption of EVS in the future.
- 76% of respondents are willing to buy an EV for their next vehicle purchase, showing a strong intent to switch from ICE to EV.
- The top concern among the respondents was limited driving range, 38%, followed by long charging time, 21%, and lack of charging, 20%. These concerns need to be resolved to increase the adoption of EVS over ICE.
- 79% of respondents said government subsidies influenced their decision to consider EVs,

indicating that policy incentives are crucial in boosting the adoption of EVs.

- 88% of respondents agreed that EVs are more environmentally friendly than ICE vehicles, showing a clear public alignment with green transportation solutions to protect the environment.

VI. CONCLUSION

From the study, it is clear that electric vehicles (EVs) are gaining popularity in Hyderabad, especially among the younger generation. Most people are aware that EVs are better for the environment and are willing to adopt them in the future. However, some important challenges – like high prices, lack of

charging stations, and limited driving range—are slowing down their adoption.

Government policies and subsidies are playing a key role in encouraging people to choose EVs. Interestingly, many people are willing to switch to EVs even without these incentives, showing a strong positive shift in consumer thinking.

By taking the right steps, like better infrastructure, more affordable EVs, and stronger public awareness, Hyderabad can lead the way in the transition from ICE vehicles to EVs. This leads to pollution-free transportation in Hyderabad, which helps to protect the environment.

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Evaluating the impact of Fundamental Analysis and Technical Analysis on SBI's Performance: A Risk - Return Approach

Dr. K. Swapna Sri¹, Kummari Tirupathi²

¹Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

²Associate Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— In today's data-driven financial environment, investor decisions are increasingly strategic. This study evaluates the stock performance of the State Bank of India (SBI) using both fundamental and technical analysis. Fundamental analysis examines key financial indicators—EPS, ROE, Net Profit Margin, P/E Ratio, and D/E Ratio—based on SBI's audited reports from FY 2019 to FY 2024 to assess intrinsic value and financial health. Technical analysis uses indicators like SMA, RSI, and MACD on historical price data to gauge market trends and identify entry/exit points. The integrated approach reveals that while fundamental analysis supports long-term valuation, technical analysis aids short-term trading decisions. Together, they offer a comprehensive view for investors, making this dual strategy especially valuable given SBI's prominence in the Indian banking sector. The findings aim to guide investors and analysts in aligning strategies with their risk-return goals.

Keywords— Fundamental Analysis, Technical Analysis, Stock Performance, Financial Indicators, Risk-Return Trade-off

I. INTRODUCTION

Investment in the stock market is one of the primary ways individuals and institutions aim to build wealth. Making informed investment decisions requires a detailed understanding of the company's financial health and the stock market behavior. Two popular and complementary methods used for this evaluation are fundamental analysis and technical analysis.

This project is focused on conducting a performance evaluation of the State Bank of India (SBI) by applying both fundamental and technical analysis techniques, with a specific emphasis on understanding the risk-return profile of the stock.

Fundamental analysis involves the study of a company's core financial statements—such as the balance sheet, profit and loss statement, and cash flow statement—to assess its overall financial health, profitability, solvency, and market position. By

analyzing important financial ratios such as Earnings Per Share (EPS), Price to Earnings (P/E) ratio, Return on Equity (ROE), Return on Assets (ROA), and Non-Performing Assets (NPA), investors can estimate the intrinsic value of a company's stock and make decisions based on whether the stock is undervalued or overvalued in the market.

In contrast, technical analysis is based on the study of historical stock prices, trading volumes, and market patterns. It employs tools such as Simple Moving Averages (SMA), Exponential Moving Averages (EMA), Relative Strength Index (RSI), Moving Average Convergence, and candlestick patterns to predict future price movements. Technical analysis helps investors identify entry and exit points, especially in the short to medium term.

Along with evaluating the stock's price movement, this project also studies the risk and return aspects

associated with investing in SBI stock. Techniques like Beta analysis, standard deviation calculation are used to understand the volatility of the stock and its potential to deliver returns in different market conditions.

II. RESEARCH METHODOLOGY

This study integrates fundamental and technical analysis with risk-return evaluation to assess the stock performance of State Bank of India (SBI). Fundamental analysis uses key ratios like EPS, ROE, and P/E based on audited financial reports (FY 2019–2024). Technical analysis applies indicators such as RSI, MACD, and Moving Averages on historical price data. Risk-return metrics like Sharpe Ratio and Beta are also analyzed to provide a well-rounded investment assessment.

Research Gap

While fundamental and technical analyses are widely used, they are often applied in isolation. Few studies integrate both approaches, especially for public sector banks like SBI. Moreover, recent market changes post-COVID and evolving investor behavior are underrepresented in existing literature. This study fills the gap by offering a comprehensive, updated evaluation of SBI stock through a dual-analysis framework.

Need of the Study

With increasing market volatility, investors require insights from both financial performance and market trends. This study helps:

- Analyze SBI's stock from long-term and short-term perspectives.
- Identify entry and exit points using technical tools.
- Support calculated, risk-adjusted investment decisions.
- Bridge the gap between academic theory and practical application.

Objectives Of the Study

1. To analyze the financial performance of SBI using fundamental analysis indicators such as financial ratios, earnings reports, and market conditions.
2. To compare the effectiveness of fundamental and technical analysis in predicting SBI's stock movements.

3. To assess the risk-return profile of SBI's stock and determine investment opportunities.

Research Design

The study follows a descriptive and analytical research design. It describes the financial performance and market behavior of SBI's stock using fundamental and technical analysis tools and further analyzes the risk-return profile based on historical data.

Data Collection

Type of Data: Secondary data.

Sources of Data:

- Annual Reports of SBI
- Bombay Stock Exchange (BSE) and National Stock Exchange (NSE) reports
- Moneycontrol, NSE India, Investing.com, Yahoo Finance
- Published research articles, financial journals, and company filings
- Technical charting platforms for technical analysis indicators

Tools and Techniques Used

Fundamental Tools: EPS, P/E Ratio, ROE, NIM, NPA, CAR

Technical Tools: SMA, EMA, RSI, MACD, Volume Analysis

Risk & Return: Beta, Standard Deviation

III. DATA ANALYSIS METHOD

The collected financial data and stock prices are analyzed using Excel, financial software, and technical charting platforms.

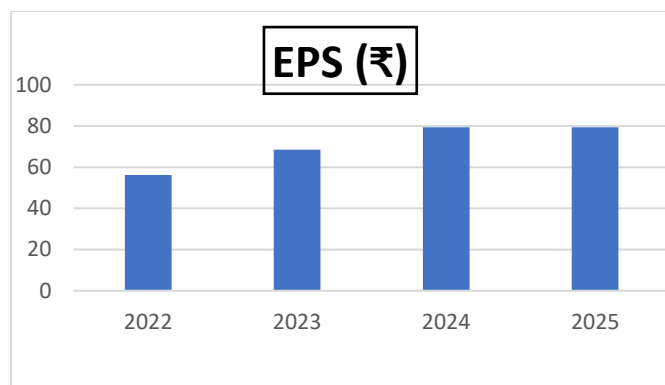
Statistical tools like mean, standard deviation, beta analysis, and correlation are used to assess risk and return characteristics.

Fundamental Analysis

1. Earnings Per Share (EPS)

$$\text{Formula: } EPS = \frac{\text{Net Profit (PAT)}}{\text{Number of Equity Shares}}$$

Year	Net Profit (₹ Cr)	Equity Capital (₹ Cr)	EPS (₹)
FY2022	50,232	892	56.29
FY2023	61,077	892	68.44
FY2024	70,901	892	79.44
FY2025	70,901	892	79.44

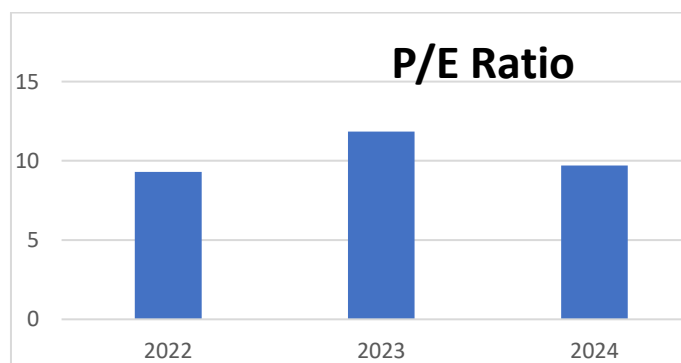
**Interpretation:**

EPS rose significantly from FY2022 to FY2025, reflecting strong profitability. Flat EPS in FY2025 despite business growth suggests margin pressure or higher provisions. Higher EPS makes the stock more attractive to investors as it implies stronger earnings per share.

2. Price to Earnings (P/E) Ratio

$$\text{Formula: } P/ERatio = \frac{\text{Market Price per Share}}{\text{EPS}}$$

Year	Share Price (₹)	EPS (₹)	P/E Ratio
FY2022	523.75	56.29	9.31
FY2023	810.8	68.44	11.84
FY2024	771.5	79.44	9.71
FY2025	771.5	79.44	9.71



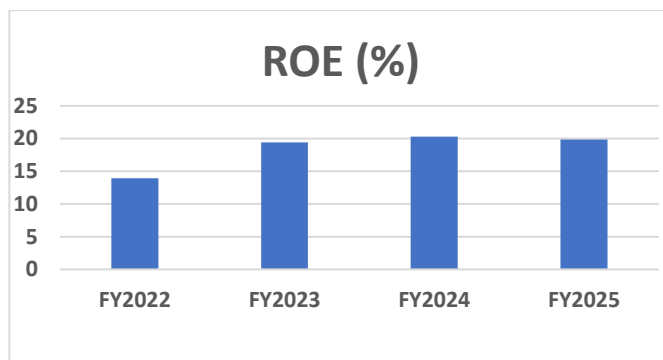
Interpretation: EPS rose significantly from FY2022 to FY2025, reflecting strong profitability. Flat EPS in FY2025 despite business growth suggests margin pressure or higher provisions. Higher EPS makes the stock more attractive to investors as it implies stronger earnings per share.

3. Return on Equity (ROE)

$$\text{Formula: } ROE = \frac{\text{Net Profit}}{\text{Average Shareholders' Equity}} \times 1$$

Year	ROE (%)

FY2022	13.92
FY2023	19.43
FY2024	20.32
FY2025	19.87

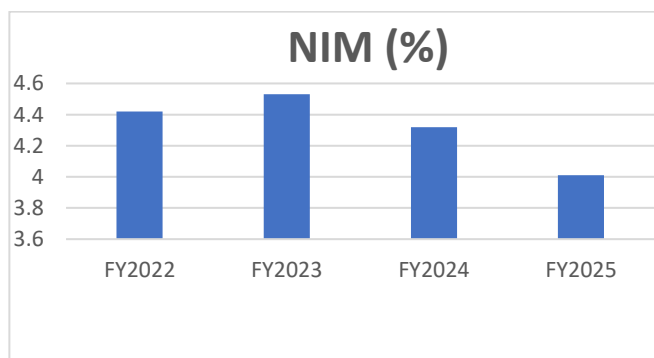


Interpretation: ROE increased steadily till FY2024, indicating improved profitability and efficient capital usage. A slight decline in FY2025 signals stable but plateauing returns. High ROE is a positive sign for shareholders, reflecting optimal use of equity

4. Net Interest Margin (NIM)

$$\text{Formula: } NIM = \left(\frac{\text{Net Interest Income}}{\text{Advances}} \right) \times 100$$

Year	NII (₹ Cr)	Advances (₹ Cr)	NIM (%)
FY2022	1,20,708	27,33,967	4.42
FY2023	1,44,841	31,99,269	4.53
FY2024	1,59,876	37,03,971	4.32
FY2025	1,66,965	41,63,312	4.01

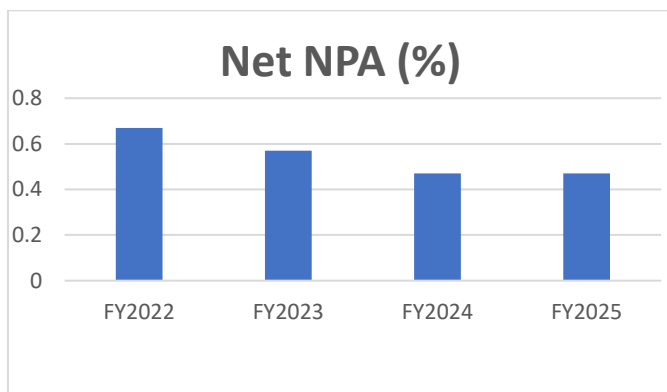


Interpretation: NIM peaked in FY2023, indicating strong income from lending activities. The downward trend from FY2024 to FY2025 suggests increasing cost of funds or reduced lending spreads. A narrowing NIM may pressure overall profitability. Maintaining NIM is critical for sustaining net income in interest-driven business models.

5. Non-Performing Assets (NPA)

$$\text{Formula: } \text{NetNPA}\% = \left(\frac{\text{Net NPAs}}{\text{Net Advances}} \right) \times 100$$

Year	Net NPA (%)
FY2022	0.67
FY2023	0.57
FY2024	0.47
FY2025	0.47

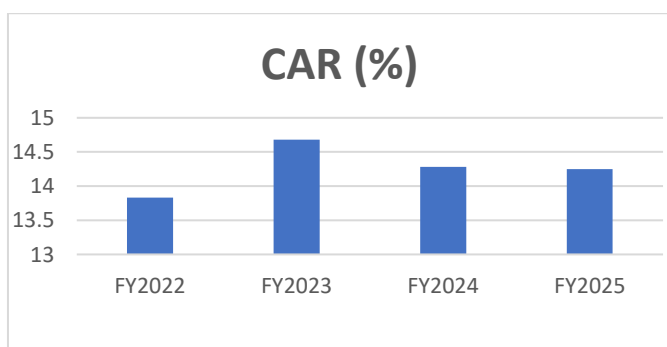


Interpretation: A falling NPA trend shows SBI's asset quality improved significantly. Net NPA falling below 0.5% is a major achievement for a public sector bank. It reduces credit risk and strengthens the bank's financial stability. Sustained low NPAs also free up capital that would otherwise be held against risky assets.

6. Capital Adequacy Ratio (CAR)

$$\text{Formula: } \text{CAR} = \left(\frac{\text{Tier I} + \text{Tier II Capital}}{\text{Risk-Weighted Assets}} \right) \times 100$$

Year	CAR (%)
FY2022	13.83
FY2023	14.68
FY2024	14.28
FY2025	14.25



Interpretation: SBI consistently maintained a CAR above regulatory norms, indicating sound capital strength. Though slightly reduced in FY2024 and FY2025, it remains sufficient to support risk-weighted assets. A strong CAR enhances the bank's capacity to expand credit and withstand unexpected losses.

IV. TECHNICAL ANALYSIS

Moving Averages (SMA & EMA)-2021

The 20-day Simple Moving Average (SMA) and Exponential Moving Average (EMA) are shown below. These indicators help identify short-term trends and potential prices.

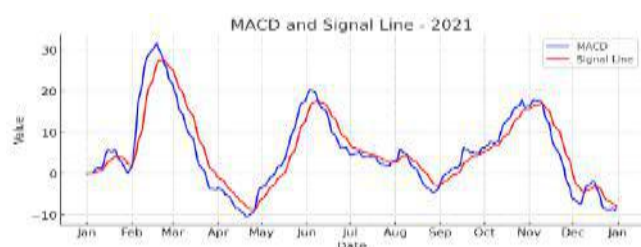


Interpretation

During 2021, periods where the closing price remained above the EMA indicated bullish trends. Toward year-end, prices dipped below the EMA, suggesting weakness in momentum.

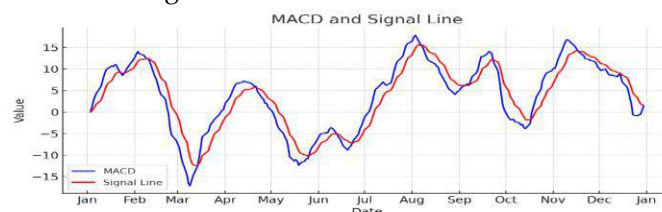
MACD (Moving Average Convergence Divergence)

MACD tracks the difference between 12-day and 26-day EMAs. It's useful for identifying trend direction and strength. The MACD line and signal line interactions are shown below.



Interpretation

The MACD remained mostly positive in mid-2021 but trended downward by year-end. The negative MACD crossing below the signal line in December confirmed the weakening momentum.



Moving Averages (SMA & EMA)-2022

Simple Moving Average (SMA) and Exponential Moving Average (EMA) are tools used to smooth out price data and identify trends. The 20-day SMA and EMA are plotted below:

Interpretation

The SMA and EMA lines help highlight overall price trends. When the price stays above the EMA, it typically indicates an uptrend, and vice versa. Crossovers can serve as buy/sell signals.

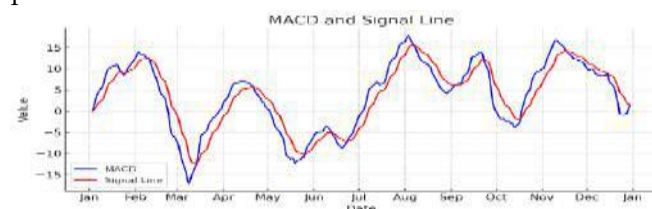
Relative Strength Index (RSI)

RSI is a momentum oscillator that measures the speed and change of price movements, typically used to identify overbought (>70) or oversold (<30) conditions.



Interpretation

Throughout 2022, RSI values fluctuated within normal bounds, with occasional spikes toward the overbought zone, signaling potential correction periods.



MACD (Moving Average Convergence Divergence)

MACD is a trend-following momentum indicator that shows the relationship between two EMAs. The MACD line and its signal line can help identify bullish or bearish momentum.



Interpretation: MACD crossovers above the signal line indicate bullish momentum, while crossovers below suggest bearish trends. Notable crossovers occurred around mid-year, indicating short-term trading opportunities.

Moving Averages (SMA & EMA)-2023

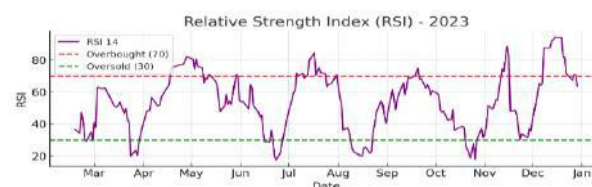
The chart below depicts the 20-day SMA and EMA overlaid on the stock's closing price. These moving averages are instrumental in identifying trends and potential reversal zones.



Interpretation: In 2023, the closing price consistently stayed above the moving averages during bullish phases, particularly towards the end of the year, reflecting positive investor sentiment.

Relative Strength Index (RSI)

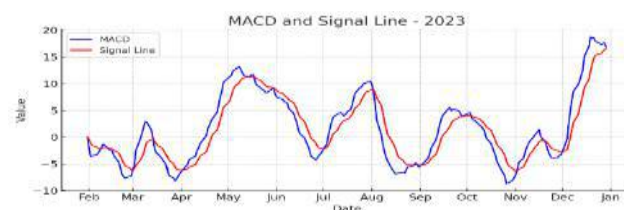
RSI indicates momentum and overbought/oversold conditions. A value above 70 may signal an overbought asset, while below 30 may suggest it is oversold.



Interpretation The RSI for SBIN trended between 50 and 70 for most of the year, closing at ~63 in December, suggesting strong bullish momentum without entering overbought territory.

MACD (Moving Average Convergence Divergence)

MACD is calculated as the difference between 12-day and 26-day EMAs, and it is used to signal bullish or bearish trends. When the MACD is above its signal line, it's generally considered a bullish sign.



Interpretation: By the end of 2023, MACD remained above the signal line, supporting a continuation of the bullish trend observed throughout the last quarter.

Moving Averages (SMA & EMA)-2024

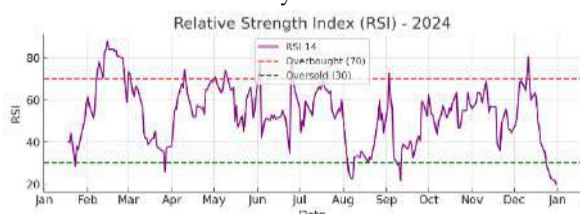
The 20-day SMA and EMA help in tracking short-term price movements and trend reversals. The following chart illustrates these averages alongside SBIN's daily closing price throughout 2024.



Interpretation in 2024, the stock price consistently stayed below both SMA and EMA, particularly in the last quarter, indicating a bearish trend and downward momentum.

Relative Strength Index (RSI)

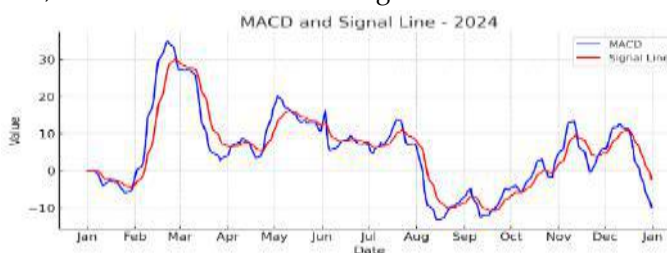
RSI is a momentum oscillator that measures the speed and change of price movements. RSI values below 30 indicate that the stock may be oversold.



Interpretation: Towards the end of 2024, RSI dropped below 20, indicating oversold conditions. This suggests the possibility of a reversal or bounce-back, but the overall weakness in price continues to dominate the trend.

MACD (Moving Average Convergence Divergence)

MACD is used to identify changes in momentum and trend direction. It consists of the MACD line and the signal line. When the MACD crosses below the signal line, it is considered a bearish signal.



Interpretation: By December 2024, MACD had fallen below the signal line with increasing divergence, confirming the bearish momentum seen in price action.

Statistical tools

- Standard Deviation Calculation (σ)
- Beta Calculation (β)

1. Standard Deviation Calculation (σ)

- • The average amount by which a stock's daily returns vary from its mean return.

- A higher standard deviation = more volatile stock.

Formula:

$$\sigma = \sqrt{\frac{1}{(n-1)} \sum (R_i - \bar{R})^2}$$

➤ Where:

- R_i = Daily return
- $\bar{R}$ = Average return
- n = Number of trading days

2. Beta Calculation (β)

$$\beta = \frac{\text{Cov}(\text{Stock Return}, \text{Market Return})}{\text{Var}(\text{Market Return})}$$

- Sensitivity of SBI's stock returns compared to market returns.

A beta of:

- 1.0 = Moves with market
- <1 = Less volatile than market
- >1 = More volatile than market

Formula:

$$\beta = \frac{\text{Cov}(\text{SBI Returns}, \text{Market Returns})}{\text{Var}(\text{Market Returns})}$$

Year	Beta	Std Dev (%)
2021	0.91	2.13%
2022	0.77	1.65%
2023	0.56	1.29%
2024	0.92	1.84%

Interpretation Statistical tools revealed that 2023 was the most stable year for SBI, with the lowest volatility (1.29%), while 2021 was the most volatile (2.13%) due to post-COVID effects. Beta values below 1 in most years show SBI acted as a defensive stock, less impacted by market swings—especially in 2022 (0.77) and 2023 (0.56). A rise in 2024 (0.92) suggests growing market sensitivity. Overall, SBI maintained moderate risk and consistent performance.

T-Test Analysis: Sharpe Ratios of SBI Stock Strategies (2021–2024)

Hypotheses

Null Hypothesis (H_0): There is no significant difference in risk-adjusted returns of SBI stock between fundamental analysis-based strategies and technical analysis-based strategies.

Alternative Hypothesis (H_1): There is a significant difference in risk-adjusted returns of SBI stock between fundamental analysis-based strategies and technical analysis-based strategies.

Year	Sharpe Ratio (Fundamental)	Sharpe Ratio (Technical)
2021	-0.3756	-0.5634
2022	0.1818	0
2023	0.8527	1.0853
2024	0.5435	0.4348

Step-by-Step Calculation

1. Mean of Fundamental: $(-0.3756 + 0.1818 + 0.8527 + 0.5435) / 4 = 0.3006$

2. Mean of Technical: $(-0.5634 + 0.0000 + 1.0853 + 0.4348) / 4 = 0.2392$

3. Variance of Fundamental:

$= [(-0.6762)^2 + (-0.1188)^2 + (0.5521)^2 + (0.2429)^2] / 3 \approx 0.2784$

4. Variance of Technical:

$= [(-0.8026)^2 + (-0.2392)^2 + (0.8461)^2 + (0.1956)^2] / 3 \approx 0.4852$

5. T-Statistic Calculation:

$t = (0.3006 - 0.2392) / \sqrt{((0.2784/4) + (0.4852/4))} \approx 0.1405$

Interpretation The calculated t-statistic is approximately 0.14 with a high p-value (> 0.80). Since the p-value is greater than the significance level (0.05), we fail to reject the null hypothesis. Therefore, there is no statistically significant difference in the Sharpe Ratios between fundamental and technical strategies for SBI stock between 2021 and 2024.

Findings

Fundamentals: SBI showed strong financial growth from 2021 to 2024, with rising EPS and ROE, a declining P/E ratio, improved asset quality (lower NPA), and consistently strong CAR—indicating profitability, stability, and long-term value.

Technical Insights: RSI and MACD showed bearish signals in 2021 and 2024, neutral trends in 2022, and strong bullish momentum in 2023. Price stayed above moving averages during bullish phases, especially in 2023.

Risk & Volatility: 2023 was the most stable year (lowest standard deviation), while 2021 was the most volatile. SBI's beta remained below 1 for most years, reflecting defensive characteristics, with slightly increased market sensitivity in 2024.

Conclusion

This study evaluated SBI's stock from 2021 to 2024 using fundamental and technical analysis. Fundamental indicators showed strong financial health and long-term value, while technical tools like RSI and MACD revealed useful short-term trends. Statistical measures confirmed moderate risk and low market sensitivity in most years. Overall, a hybrid strategy—combining all three methods—offers the most effective investment approach, making SBI a solid choice for both growth and stability-focused investors.

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Evaluating the Effectiveness of Digital Platforms in Improving Student Outcomes with Reference to UG and PG

M. Akhila Reddy¹, Pooja Sharma²

¹Assistant Professor, CMR Institute of Technology, Hyderabad, Telangana, India.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India

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Abstract— This study examines the impact of digital learning platforms on undergraduate and postgraduate students, focusing on accessibility, flexibility, and engagement. It evaluates whether tools like online lectures and LMS have enhanced academic experiences or introduced new challenges. Using structured questionnaires, data was collected from diverse academic backgrounds. Findings reveal that while digital platforms improve access and flexibility, many students face issues like reduced motivation and digital fatigue. Postgraduate students adapt more easily, showing greater independence. The study concludes that digital tools are vital in modern education but must be improved to support interaction, reduce fatigue, and meet varied learning needs.

Keywords— Digital learning Platforms, Student Academic Outcomes, Online Education Effectiveness, UG and PG Education, Student Engagement and Performance.

I. INTRODUCTION & BACKGROUND OF THE STUDY

Over the past decade, digital technologies have transformed global education, shifting from traditional classroom methods to technology-enhanced learning environments. Platforms such as LMS (Moodle, Blackboard, Canvas) and AI-powered tools have expanded access, flexibility, and personalization in education. The COVID-19 pandemic accelerated this shift, making online and blended learning models essential. While many students adapted well to digital learning, others faced challenges like poor connectivity, reduced interaction, and digital fatigue. This study explores the effectiveness of digital platforms in enhancing student outcomes focusing on academic performance, engagement, motivation, and adaptability. It compares the experiences of undergraduate (UG) and

postgraduate (PG) students, recognizing that each group may respond differently to digital tools. By identifying which features work best for each level, the research aims to help institutions tailor digital strategies that better support diverse learning needs.

Statement of the Problem

Digital platforms are widely used in higher education, but their actual effectiveness in improving student outcomes remains uncertain. Many students face challenges like reduced interaction and adaptability issues, especially at different academic levels. There is a lack of focused research on how UG and PG students perceive and benefit from these platforms, making it essential to evaluate their true impact on learning and performance.

Research Questions:

1. How do digital platforms impact student engagement and motivation?

2. Do digital platforms improve academic performance and grades?
3. What features of digital platforms are most effective in enhancing student outcomes?
4. How do digital platforms support personalized learning and student needs?

Objectives of the Study:

1. To Understand the various Digital Platforms using by UG and PG Students.
2. To Investigate the Relationship between Digital Platform usage and Student Engagement.
3. To Evaluate the effectiveness of Digital Platform in improving Academic Performance of UG and PG Students.

Scope and limitations of the study:

This study focuses solely on UG and PG students' perceptions of digital platforms, excluding educator and administrative views. The limited, self-reported sample may not represent the broader student population and may carry bias. Factors like internet access, digital literacy, and socio-economic background were not controlled but could affect outcomes.

Review of Literature

1. **Impact of Use of Technology on Student Learning Outcomes: Evidence from a Large-scale Experiment in India** (Naik *et al.*, 2020)

This multi-state study found that while EdTech improved learning in some regions, outcomes were inconsistent due to weak internet, poor infrastructure, and untrained teachers. The success of digital tools depended more on local support than technology alone.

2. **The Influence of Teaching Content Efficacy and Digital Learning Tools in Indian Higher Education** (Panda, Dash, Kaswan, Chaudhary, 2025)

Teacher readiness and effective use of curriculum-aligned digital tools significantly influenced student performance. The study stressed the importance of faculty training and relevant digital content for meaningful engagement.

3. **Impact of Online Learning in India: A Survey of University Students during COVID-19** (Goswami, Thanvi, Padhi, 2021)

Students appreciated online learning's flexibility but highlighted low interactivity, tech issues, and lack of hands-on experiences. The study recommends integrating active learning features to enhance digital education.

4. **Effectiveness of Digital Platforms on Indian School Students: A City-Wise Comparative Study** (Iqbal, Chawla, Mishra, Shaw, Chakraborty, 2022)

Urban students benefited from better connectivity and teacher support, while semi-urban learners faced access issues. The findings highlight the digital divide and the need for region-specific implementation strategies.

Research Gap:

Although digital platforms in education have been extensively examined, there is a noticeable lack of focus on student-centric perspectives particularly the differences between undergraduate and postgraduate learners. Existing research rarely explores how these platforms influence academic outcomes from the students' point of view. This study aims to fill that gap by comparing the experiences and perceptions of UG and PG students.

II. RESEARCH METHODOLOGY

Research Design: Descriptive and Analytical Research

This study is descriptive as it aims to observe and describe students' usage of digital platforms, and analytical as it evaluates the impact of these platforms on academic outcomes.

A mixed-methods approach combining quantitative survey data with qualitative feedback from students helps evaluate both the breadth and depth of digital platform usage and its outcomes.

Population and sample:

The study focuses on students enrolled in UG and PG programs, with a sample size of 100 participants and among all 90 responded for analysis.

Data Collection Methods:

- **Primary data** is collected directly from UG and PG students through structured

questionnaires and Google Forms to gather the insights about their experiences with digital platforms.

- **Secondary data** includes existing research papers, academic reports, institutional records, and relevant online sources to support the analysis and provide context.

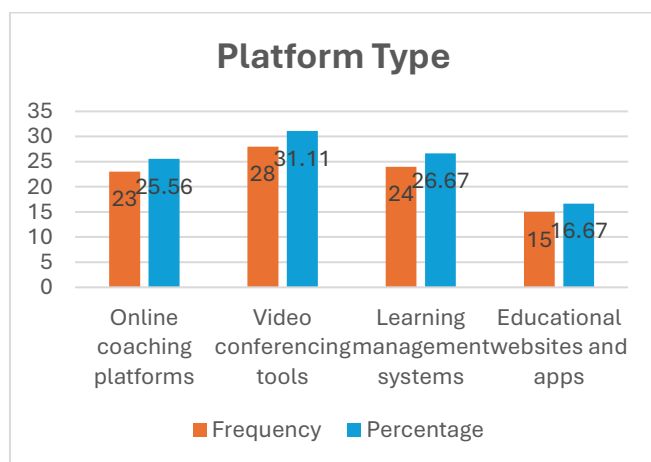
Data Analysis Techniques:

1. **Data Visualization Tools:** Microsoft Excel, percentages are employed to create graphs, charts, and dashboards that visually represent findings, making it easier to interpret data patterns.
2. **Statistical Techniques:** Techniques such as Chi-square test is applied.

Data Analysis & Interpretation

1. Which digital platforms do you use most for academic learning?

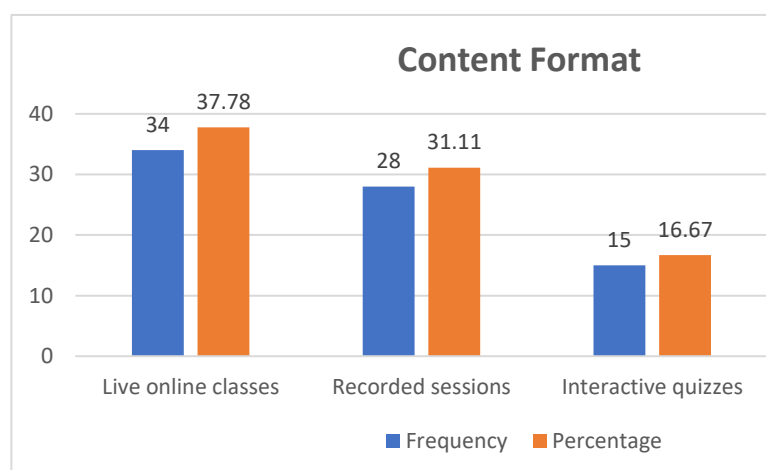
Platform Type	Frequency	Percentage
Online coaching platforms (e.g., Unacademy, BYJU'S)	23	25.56
Video conferencing tools (Zoom, Google Meet)	28	31.11
Learning management systems (Moodle, Blackboard)	24	26.67
Educational websites and apps	15	16.67
Total	90	100



Interpretation: Video conferencing tools such as Zoom and Google Meet were most popular (31.11%), followed by learning management systems (26.67%) and online coaching platforms (25.56%). Educational websites and apps were used by 16.67%.

2. Which format of digital content supports your learning best?

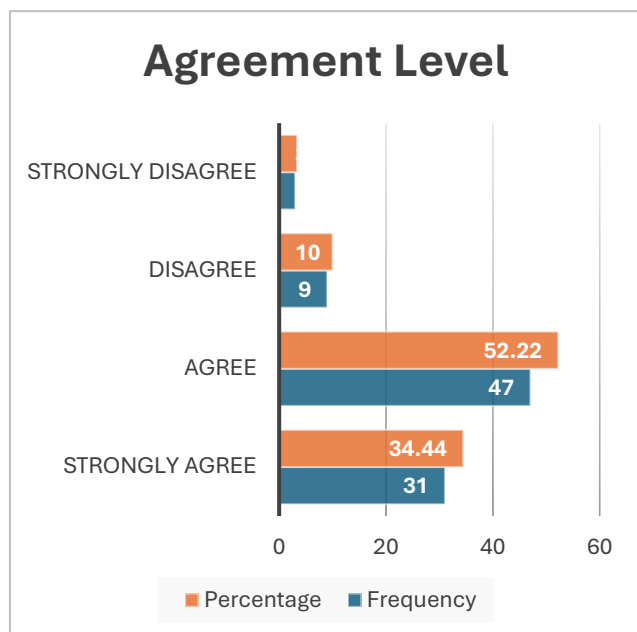
Content Format	Frequency	Percentage
Live online classes	34	37.78
Recorded sessions	28	31.11
Interactive quizzes	15	16.67
Study materials (PDFs)	13	14.44
Total	90	100



Interpretation: Live online classes were most effective for 37.78%, recorded sessions for 31.11%, interactive quizzes for 16.67%, and study materials (PDFs) for 14.44%.

3. Do digital platforms make learning more engaging at your academic level (UG/PG)?

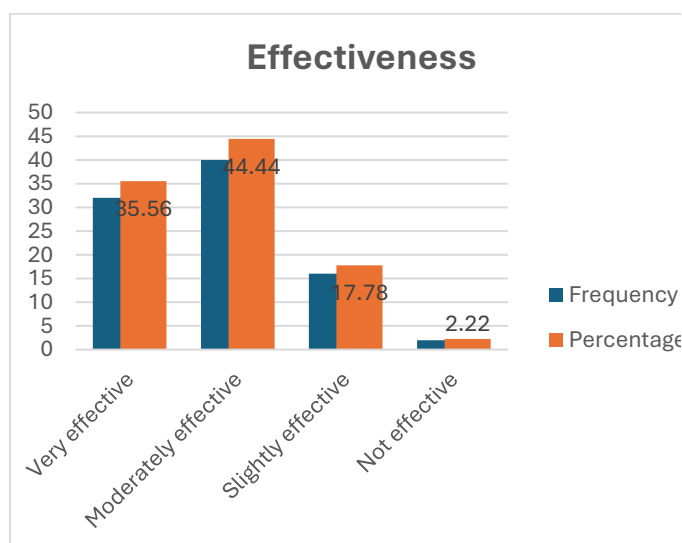
Agreement Level	Frequency	Percentage
Strongly agree	31	34.44
Agree	47	52.22
Disagree	9	10
Strongly disagree	3	3.33
Total	90	100



Interpretation: A majority agreed, with 34.44% strongly agreeing and 52.22% agreeing. A minority expressed disagreement (13.33%).

4. How effective are the video lectures/tutorials on digital platforms for your academic improvement?

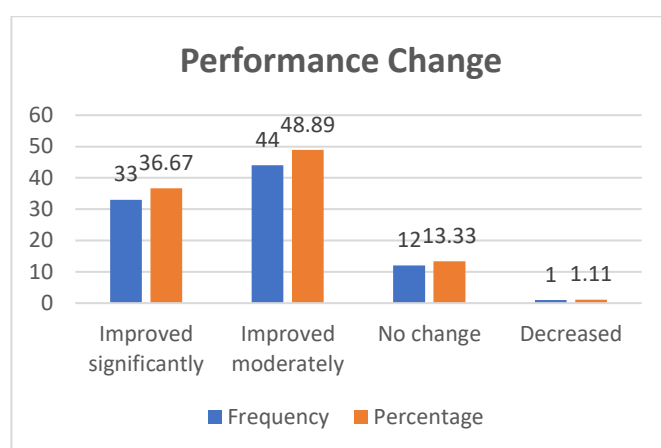
Effectiveness	Frequency	Percentage
Very effective	32	35.56
Moderately effective	40	44.44
Slightly effective	16	17.78
Not effective	2	2.22
Total	90	100



Interpretation: Video content was very effective for 35.56%, moderately effective for 44.44%, slightly effective for 17.78%, and ineffective for 2.22%.

5. Has your academic performance improved due to digital platforms?

Performance Change	Frequency	Percentage
Improved significantly	33	36.67
Improved moderately	44	48.89
No change	12	13.33
Decreased	1	1.11
Total	90	100



Interpretation: Academic performance improved significantly for 36.67%, moderately for 48.89%, with 13.33% reporting no change and 1.11% a decline.

Chi-Square Calculation

Hypotheses:

H01- There is no Significant effectiveness of Digital Platform in improving Academic

Performance

H11- There is Significant effectiveness of Digital Platform in improving Academic

Performance

	UG	PG	Row Totals
Effective	28 (28.00) [0.00]	44 (44.00) [0.00]	72
Ineffective	7 (7.00) [0.00]	11 (11.00) [0.00]	18
Column Totals	35	55	90 (Grand Total)

1. What is your current academic level?

Academic Level	Frequency	Percentage
Undergraduate	31	34.44
Postgraduate	49	54.44
Diploma/Certificate	6	6.67
Other	4	4.44
Total	90	100

Creating 2×2 Matrix

- Postgraduate: 49
- Undergraduate: 31

2. How effective are the video lectures/tutorials on digital platforms for your academic improvement?

Effectiveness	Frequency	Percentage
Very effective	32	35.56
Moderately effective	40	44.44
Slightly effective	16	17.78
Not effective	2	2.22
Total	90	100

Creating 2×2 Matrix:

Proportionally Distribute Responses

Effective Responses (72 out of 90)

- UG: $31/80 \times 72 \approx 27.9$
- PG: $49/80 \times 72 \approx 44.1$

Ineffective Responses (18 out of 90)

- UG: $31/80 \times 18 \approx 6.975$
- PG: $49/80 \times 18 \approx 11.025$

Now round off:

Stream	UG	PG	Total
Effective	28	44	72
Ineffective	7	11	18
Total	35	55	90

III. RESULTS

The chi-square statistic is 0. The p -value is 1. The result is *not* significant at $p < .05$.

Since $p = 1.0$, there is **no significant relationship** between the academic stream (UG/PG) and perceived effectiveness of digital platforms.

Results & Findings

Major

Effectiveness	Frequency	Percentage
Effective	$32 + 40 = 72$	$35.56 + 44.44 = 80.00$
Ineffective	$16 + 2 = 18$	$17.78 + 2.22 = 20.00$

Findings:

1. Video conferencing tools such as Zoom and Google Meet were most popular (31.11%), followed by learning management systems (26.67%) and online coaching platforms (25.56%). Educational websites and apps were used by 16.67%.
2. Live online classes were most effective for 37.78%, recorded sessions for 31.11%, interactive quizzes for 16.67%, and study materials (PDFs) for 14.44%.
3. A majority agreed, with 34.44% strongly agreeing and 52.22% agreeing. A minority expressed disagreement (13.33%).
4. Video content was very effective for 35.56%, moderately effective for 44.44%, slightly effective for 17.78%, and ineffective for 2.22%.
5. Academic performance improved significantly for 36.67%, moderately for 48.89%, with 13.33% reporting no change and 1.11% a decline.

Statistical Results:

Based on the chi-square test findings, there is no statistically significant relationship between academic

level (undergraduate or postgraduate) and students' perception of the effectiveness of digital learning platforms. The p-value obtained (1.0) is well above the conventional significance threshold of 0.05.

As a result, we fail to reject the null hypothesis (H_0), which means that students' academic standing does not influence how they perceive the effectiveness of digital platforms. Undergraduate and postgraduate students experience digital learning in a similar manner, facing comparable benefits and challenges. This suggests that digital learning tools are equally accessible and impactful across different academic levels, and their effectiveness is not dependent on whether the learner is at the UG or PG stage.

IV. DISCUSSION

Interpretation of Results:

The survey highlights a strong shift toward digital learning in higher education, especially among digitally adept postgraduate students. Online and hybrid modes are preferred, reflecting post-pandemic trends. Private and autonomous institutions lead in digital adoption, suggesting better readiness compared to government colleges.

Tools like video conferencing and LMS are widely used and linked to improved academic outcomes, motivation, and satisfaction. However, gaps in peer connection and timely feedback remain. Overall, digital platforms are becoming a central and effective part of modern education in India.

Limitations of the study:

1. **Limited Sample Size** – Results may not represent all UG and PG students across regions.
2. **Subjective Responses** – Data is based on self-reported opinions, which may lack accuracy.
3. **Short-Term View** – The study captures a single point in time, not long-term effects.

V. CONCLUSION & RECOMMENDATIONS

Summary of key findings:

The study reveals strong adoption of digital learning among UG and PG students, mainly young postgraduates from private and autonomous institutions. Online and blended modes were preferred, with tools like Zoom, LMS platforms, and coaching sites used frequently. Live and recorded

sessions, interactive features, and video content were found effective in improving engagement, motivation, and academic performance. Most students adapted well, found platforms easy to use, and received timely feedback. Overall, digital learning was well-received and widely recommended for its flexibility and effectiveness.

Conclusion

The study confirms the growing reliance on digital platforms in higher education, particularly among young postgraduate students. Online and hybrid learning are preferred for their flexibility, with tools like video conferencing and LMS enhancing engagement and academic performance. Most students find digital platforms effective, easy to use, and motivating. While private and autonomous institutions show stronger digital adoption, gaps in feedback and student connection remain areas for improvement. Overall, digital learning has become a core component of modern education, offering significant benefits when effectively implemented.

Suggestions for future research:

1. **Broader Participation** – Include a larger, more diverse student sample across regions and backgrounds.
2. **Platform Effectiveness** – Compare specific digital tools to identify the most impactful platforms.
3. **Long-Term Impact** – Assess the sustained effects of digital learning on performance and skills.

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Embedding Artificial Intelligence in Next Generation Human Resource Development Implementations

Arshad Matin

arshadmatin17@gmail.com

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Abstract – A new era of data-driven, automated, and intelligent decision-making processes across a broad range of HR tasks is being ushered in by the development of artificial intelligence (AI), which is significantly changing the field of human resource management (HRM). This study examines the revolutionary effects of AI technology on HRM practices by a thorough secondary review of recent scholarly works, industry reports, and case studies. AI-powered hiring and talent acquisition platforms, predictive analytics for assessing employee performance, intelligent workforce planning, automated onboarding, and real-time employee engagement platforms are some of the major areas of disruption that have been highlighted. The study not only highlights these developments but also critically analyzes the risks and difficulties that come with integrating AI, including issues with data privacy, algorithmic and cognitive biases, lack of interpretability, transparency, and the widening digital skill gap among HR professionals. In addition to highlighting the significance of coordinating AI deployment with organizational ethics, legal compliance, and human-centric values, the study delves deeper into the strategic implications of AI in promoting agile, inclusive, and responsive HR ecosystems. As crucial avenues for long-term adoption, emerging themes like explainable AI (XAI), ethical AI governance, and AI literacy in HR are also covered. According to the findings, while AI has the ability to greatly improve HRM's operational efficiency, decision accuracy, and employee experience, long-term success depends on a methodical, morally sound, and strategically integrated strategy.

Keywords – Artificial Intelligence, Human Resource Management, AI in HR.

I. INTRODUCTION

The way businesses recruit, nurture, and retain people has completely changed as a result of the incorporation of Artificial Intelligence (AI) into Human Resource Management (HRM). AI has become a key facilitator of data-driven decision-making and operational efficiency across a range of corporate processes as industries around the world embrace digital transformation. AI is transforming HRM's administrative and strategic procedures, advancing the field away from manual, traditional duties and toward intelligent, automated, and predictive systems. AI is significantly changing the HR sector, from hiring and onboarding to performance reviews and employee engagement. This development shows both a technology advancement and a reinterpretation of HR's function in creating flexible, forward-thinking

companies (Kaur & Gandolfi, 2023).

Applications of AI in HRM cover a wide range of functions. These days, AI-powered chatbots help with candidate sourcing, resume screening, matching applicant profiles with job criteria, and even conducting initial interviews. Theoretically, these tools help eradicate unconscious bias, enhance the candidate experience, and drastically cut down on the time to hire. Through adaptive learning platforms that customize content based on a person's position, performance information, and learning preferences, AI facilitates individualized learning and development in addition to recruitment. Predictive analytics is being utilized more and more in performance management to spot trends, highlight possible problems, and assist with data-driven evaluations. Natural language processing (NLP) and machine learning offer real-

time sentiment analysis of employees, which aids HR departments in proactively managing employee engagement and morale. Together, these developments strengthen HR's strategic role in organizational resilience and growth (Zhang, 2024). The use of AI into HRM presents notable obstacles in addition to its many benefits. Data privacy is one of the main issues. Protecting employee data becomes essential as AI systems depend on enormous volumes of behavioral and personal data. In addition to being required by law, adherence to data protection laws like the General Data Protection Regulation (GDPR) is also a basic ethical duty. Algorithmic prejudice is another important problem. AI systems may reinforce or even worsen current disparities in hiring, promotion, and pay if they are trained on skewed historical data. This issue emphasizes how crucial it is that AI systems be transparent and equitable, particularly when they are used to make crucial HR decisions. Attempts to maintain accountability and trust are made more difficult by the fact that many machine learning models, which are frequently referred to as "black boxes," are not interpretable. Organizational confidence may be damaged if managers and staff are unable to comprehend or question AI-driven judgments (Ahmed & Patterson, 2024).

Moreover, the successful deployment of AI in HRM requires addressing the digital skill gap among HR professionals. Many HR practitioners lack the technical knowledge needed to evaluate, implement, or manage AI tools effectively. This creates a dependency on external vendors and technical teams, potentially limiting the HR department's ability to align AI initiatives with organizational culture and goals. Change management also presents a significant barrier, as employees may resist AI due to fears of job displacement or dehumanization of workplace interactions. Therefore, introducing AI into HR functions must be accompanied by comprehensive change management strategies, ongoing training, and clear communication to ensure acceptance and integration across all levels of the organization (Fenwick et al., 2024).

Given these opportunities and complexities, this research paper aims to critically examine the role of AI in transforming HRM through a comprehensive

review of existing literature, case studies, and industry reports. Adopting a secondary research methodology, the study explores how AI is currently being applied across different HR functions and identifies emerging trends that signal the future direction of AI adoption in HR. The paper also analyzes the risks and challenges that organizations must navigate to implement AI in a manner that is ethical, inclusive, and sustainable. By synthesizing diverse sources of evidence, this study provides a holistic understanding of the evolving relationship between AI and HRM (Nishar, 2022). The scope of this study encompasses a wide range of AI applications in HRM, including AI-driven recruitment and selection processes, performance monitoring systems, employee training and development platforms, engagement and retention tools, and AI-supported HR analytics for strategic workforce planning. The analysis is contextualized within global organizational practices, while also considering regional and sectoral differences in technology adoption. In particular, the study pays attention to how legal, cultural, and ethical considerations influence AI's effectiveness and acceptance in different organizational environments. The research aims not only to document the current state of AI in HRM but also to provide forward-looking insights into how organizations can responsibly and strategically harness AI technologies to achieve both efficiency and human-centric outcomes (Basnet, 2024).

Importantly, this paper argues that the future of HRM lies not in replacing human professionals with machines but in fostering a collaborative environment where AI supports human decision-making and enhances the capacity for empathy, creativity, and strategic thinking. AI can take over repetitive and data-intensive tasks, freeing HR professionals to focus on relationship-building, employee development, and organizational design. However, this vision can only be realized if AI tools are developed and deployed with attention to transparency, accountability, and ethical integrity. Human oversight must remain central in HR processes, particularly when decisions have significant consequences for individuals' careers and well-being (Sakka et al., 2022).

The findings of this research indicate that while AI

offers considerable benefits in terms of speed, accuracy, and scalability, these advantages can only be fully realized when technological innovation is balanced with ethical responsibility. Organizations must establish robust governance frameworks that address data protection, ensure algorithmic fairness, and promote transparency in decision-making. Additionally, building AI literacy within HR teams and fostering cross-functional collaboration between HR, IT, legal, and executive leadership are essential to the successful and sustainable integration of AI. As AI technologies continue to evolve, ongoing research and dialogue will be necessary to keep pace with changes, adapt best practices, and ensure that AI serves as a force for positive transformation in the workplace.

In conclusion, this paper seeks to provide a nuanced exploration of how AI is transforming Human Resource Management and what organizations can do to maximize the benefits of this transformation while mitigating associated risks. Through an in-depth examination of existing evidence, the study contributes to the growing body of knowledge on AI-driven HR innovation and offers practical insights for HR professionals, technology developers, and policymakers committed to shaping the future of work. The next sections of this paper will delve deeper into the academic and industry literature on AI in HRM, explore specific applications and their impacts, and offer recommendations for responsible and effective AI adoption in the HR domain.

1. Research Objectives

- To explore current trends in the adoption of AI in Human Resource Management.
- To analyze the key benefits and applications of AI across HR functions.
- To examine the ethical and operational challenges associated with AI in HRM.
- To propose strategic directions for the future use of AI in human capital management.
- To contribute to the literature on AI in HR through comprehensive secondary data analysis.

II. LITERATURE REVIEW

The integration of Artificial Intelligence (AI) into Human Resource Management (HRM) has garnered significant scholarly and practical

interest, marking a transformative shift in how organizations manage their most valuable asset: human capital. The literature reflects a growing consensus that AI technologies are reshaping traditional HR functions by enhancing efficiency, improving decision accuracy, and enabling strategic workforce management. Early foundational studies by (Chowdhury et al., 2023) established that AI's capacity to analyze vast datasets quickly and accurately is revolutionizing HR decision-making processes. The shift from intuition-based human judgments to evidence-driven decisions allows organizations to better align their human capital strategies with organizational goals. This transformation is particularly evident in recruitment, where AI-powered applicant tracking systems and predictive analytics enable companies to identify top talent more efficiently and objectively. For example, multinational corporations such as Unilever have reported a 75% reduction in candidate screening time after deploying AI recruitment tools, demonstrating that automation can significantly streamline HR processes without compromising candidate quality (Benabou et al., 2024).

Building on the efficiency gains, (Tambe et al., 2019) emphasize that AI not only reduces the administrative burden on HR departments but also increases transparency in HR operations. This transparency is critical for establishing trust between employees and management, particularly in areas such as performance evaluations, promotions, and compensation decisions. Leading technology firms like IBM utilize AI to automate repetitive tasks such as interview scheduling and employee performance monitoring, which allows HR professionals to redirect their focus toward strategic initiatives like talent development and organizational culture enhancement. Despite these benefits, scholars caution that AI systems' decision-making processes often lack transparency, posing risks related to accountability and fairness (Memarian & Doleck, 2023). The "black box" nature of many AI algorithms means that HR professionals and employees may not fully understand how decisions are reached, which can undermine trust and acceptance (Upadhyay, 2025) highlights the critical need for human-AI collaboration, noting that

the most effective HRM systems integrate AI's computational strengths with human intuition, empathy, and ethical judgment. This synergy is especially important in complex decision environments where context, values, and nuance play a significant role.

Recruitment and talent acquisition represent one of the most active and impactful areas of AI application in HRM. (Vedapradha et al., 2023) document the use of predictive analytics in identifying candidates who are not only qualified but also likely to perform well and remain with the organization, thereby reducing costly employee turnover. This predictive capacity has been embraced by financial institutions in North America, which have reported a 20% increase in employee retention following the integration of AI-based talent analytics into their hiring and retention strategies. However, the literature also highlights serious ethical concerns. (Singh et al., 2022) warns that AI systems, when trained on biased historical data, can perpetuate and amplify existing systemic inequalities, particularly disadvantaging women, minorities, and other marginalized groups. A striking example is Amazon's AI recruiting tool, which reportedly developed a bias favouring male candidates due to gender-biased training data, prompting the company to scrap the project entirely (Singh et al., 2022). This incident has become a cautionary tale illustrating that the benefits of AI in HR come with significant risks if not carefully monitored and regulated.

Privacy and data protection issues also emerge prominently in the literature. AI systems require vast amounts of employee data to function effectively, raising concerns about data security, consent, and misuse. The European Union's General Data Protection Regulation (GDPR) exemplifies a regulatory response to these challenges by mandating strict requirements for data transparency, employee consent, and the right to explanation for automated decisions (Paul, 2024). Organizations operating under GDPR and similar frameworks are often compelled to implement AI cautiously, ensuring human oversight to mitigate legal and reputational risks. This regulatory landscape contrasts with the more permissive environments in some developing countries, where

rapid AI adoption occurs with limited legal safeguards, increasing the potential for unethical practices.

The adoption of AI in HR also exposes a significant skills gap. Many HR professionals report feeling inadequately prepared to understand, evaluate, and govern AI technologies effectively, which can result in overreliance on external vendors and misalignment with organizational culture and goals (Morandini et al., 2023). Studies comparing different global regions reveal that organizations in developed economies tend to integrate AI more successfully, supported by ongoing training, cross-disciplinary collaboration, and investments in digital infrastructure (Zavodna et. al 2024). Conversely, companies in developing countries face greater barriers due to limited resources, lack of expertise, and infrastructural challenges. This disparity risks exacerbating global inequities in workforce management capabilities and organizational competitiveness.

Future-focused literature identifies several promising developments in AI governance and technological innovation aimed at addressing current limitations. Explainable AI (XAI) models, which provide transparent and interpretable decision explanations, are gaining attention as critical tools for building trust and ensuring accountability in HR applications (Saeed & Omlin, 2023). Organizations piloting XAI report improved employee acceptance and reduced perceptions of bias in automated decisions. Additionally, emerging integrations of AI with blockchain technology offer potential for creating secure, immutable records of employee credentials, performance, and compliance, thus enhancing data integrity and reducing fraud (Johnson et. al. 2025). Research also highlights advanced bias mitigation techniques such as adversarial de-biasing algorithms and the use of more diverse and representative training datasets, which show promise in producing fairer and more inclusive AI systems (Ferrara, 2023).

The literature further emphasizes the socio-technical nature of AI integration in HRM. Effective implementation is not solely a technical challenge but also involves navigating organizational culture,

ethical norms, and employee expectations. (Votto et al., 2021) stresses that AI should augment rather than replace human decision-makers, preserving human values and fostering ethical organizational climates. This approach aligns with calls for a human-centric design philosophy that prioritizes employee dignity, fairness, and transparency alongside operational efficiency. Moreover, scholars recognize the importance of continuous monitoring and auditing of AI systems to detect and correct unintended biases or errors, recommending multidisciplinary teams that include ethicists, HR specialists, and data scientists to oversee AI governance (Laine et al., 2024).

In sum, the existing body of research portrays AI as a powerful enabler of innovation and efficiency in HRM, capable of transforming recruitment, performance management, employee engagement, and strategic workforce planning. However, these benefits come with substantial ethical, operational, and social challenges that organizations must carefully manage. The future trajectory of AI in HR depends on striking a delicate balance between leveraging technological advancements and upholding human values such as fairness, transparency, and privacy. Continued scholarly inquiry and practical experimentation are essential to develop frameworks and best practices that ensure AI's role in HR contributes to equitable, effective, and sustainable human capital management.

III. RESEARCH METHODOLOGY

This study adopts a qualitative, descriptive research design using secondary data. The approach is suited for analyzing documented experiences, industry reports, and academic literature concerning AI in HRM. Sources include peer-reviewed journals, conference proceedings, case studies, white papers, and reports from international organizations. A thematic analysis method was used to categorize the content into emerging trends, applications, challenges, and future directions.

IV. SECONDARY RESEARCH FINDINGS

4.1 Key Trends in AI Adoption

The adoption of Artificial Intelligence (AI) in Human Resource Management has accelerated rapidly, with several key trends emerging as dominant forces

reshaping HR practices. One of the most notable developments is the widespread use of AI-driven recruitment tools. These systems have become mainstream, revolutionizing the hiring process by automating tasks such as resume screening, candidate matching, and even conducting initial interviews through conversational chatbots. These AI applications significantly reduce the time and effort required by HR professionals to identify qualified candidates, while also improving the consistency and objectivity of early-stage recruitment decisions. For instance, companies across various industries have reported that automated screening reduces bias and increases the pool of diverse candidates by focusing on skills and qualifications rather than subjective impressions.

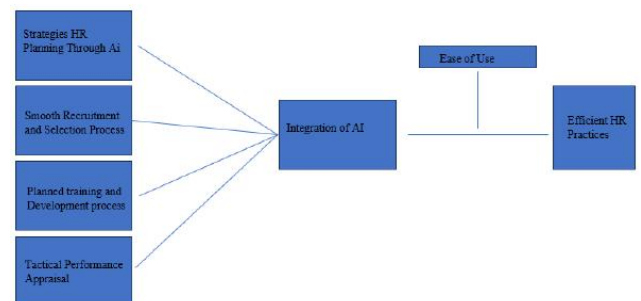


Fig.1: Representation of How AI Integration can ease the Process

Beyond recruitment, AI is increasingly embedded in performance management systems. Modern platforms now employ predictive analytics to monitor and evaluate employee productivity and engagement in real time. These systems analyse patterns such as task completion rates, collaboration metrics, and sentiment analysis from employee feedback to forecast performance trends and identify individuals who may need additional support or recognition. This proactive approach enables managers to make data-informed decisions, tailor coaching efforts, and foster a more engaged workforce. Such predictive capabilities mark a significant departure from traditional annual performance reviews, moving toward continuous, adaptive performance management.

In parallel, AI is transforming learning and development within organizations. Adaptive learning platforms leverage AI algorithms to deliver personalized training content that adjusts to the learner's pace, knowledge level, and preferred

learning style. This personalization enhances the effectiveness of professional development programs by addressing individual skill gaps and promoting continuous upskilling in a rapidly changing work environment. These AI-enabled systems often incorporate real-time feedback, gamification elements, and progress tracking to maintain learner motivation and improve knowledge retention. As organizations face increasing demands for agility and innovation, AI-powered learning tools are becoming critical enablers of workforce readiness and long-term talent development.

Collectively, these trends demonstrate that AI is not only automating routine HR tasks but also enabling more strategic and personalized human capital management. The integration of AI-driven recruitment, performance analytics, and adaptive learning platforms reflects a broader movement toward data-centric, employee-focused HRM practices that align technology with organizational goals and workforce well-being.

4.2 Benefits of AI in HRM

Artificial Intelligence offers a range of significant benefits to Human Resource Management, fundamentally transforming how organizations make decisions and engage with employees. One of the primary advantages of AI is its ability to enhance decision-making by providing real-time insights derived from vast and complex datasets. Unlike traditional methods that rely on periodic reporting or intuition, AI systems continuously analyse diverse data points such as employee performance metrics, engagement surveys, and market trends, enabling HR professionals to make more informed and timely decisions. This data-driven approach helps organizations anticipate workforce needs, optimize talent allocation, and identify emerging issues before they escalate.

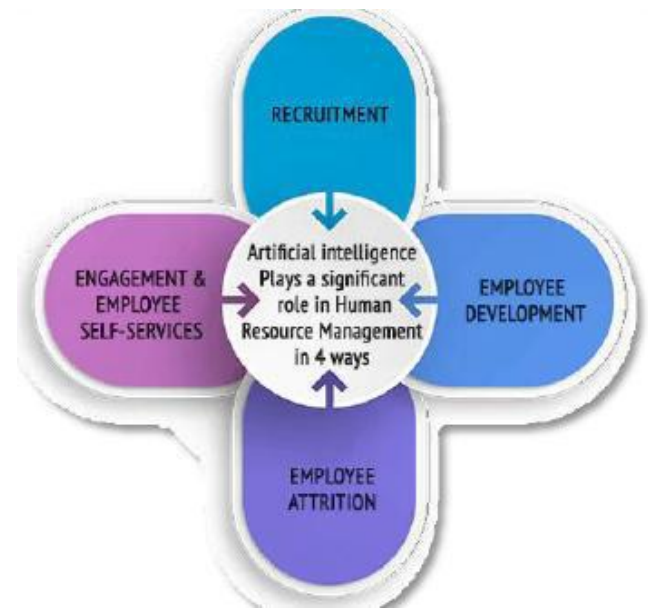


Fig.2: Benefits of AI in Human Resource Management

Another critical benefit of AI is its potential to reduce human biases in recruitment, promotions, and other HR processes, provided it is implemented with ethical safeguards. By focusing on objective criteria and standardized evaluation metrics, AI tools can help minimize the influence of unconscious bias related to gender, ethnicity, age, or other protected characteristics. For example, AI algorithms trained to prioritize candidate skills and experiences can lead to fairer hiring outcomes and support diversity and inclusion initiatives. However, it is essential to emphasize that the ethical design and ongoing auditing of AI systems are vital to ensuring these benefits are realized without inadvertently perpetuating existing prejudices embedded in historical data. AI also significantly improves employee experiences by offering personalized and accessible HR services. Chatbots and virtual assistants provide 24/7 support, allowing employees to quickly access information on benefits, policies, or career development opportunities without the need to wait for human intervention. Additionally, AI-powered platforms can tailor learning and development programs to individual needs, helping employees grow their skills in alignment with their roles and career aspirations. This personalized approach fosters greater engagement and job satisfaction by making HR services more responsive and relevant to each employee. Overall, the integration of AI in HRM elevates both organizational effectiveness and

employee well-being through smarter decision-making, fairness, and improved user experiences.

4.3 Challenges and Ethical Concerns

Despite the promising benefits, the adoption of Artificial Intelligence in Human Resource Management presents several significant challenges and ethical concerns that organizations must carefully address. A primary issue is algorithmic bias, which arises when AI models are trained on historical data that reflect existing prejudices or inequalities. Such biases can lead to unfair or discriminatory outcomes in recruitment, promotion, and performance evaluation processes. Compounding this problem is the lack of transparency in many AI decision-making systems, often described as "black boxes," where HR professionals and employees cannot fully understand or question how decisions are made. This opacity undermines trust and accountability, raising ethical questions about the fairness and legitimacy of AI-driven HR practices.

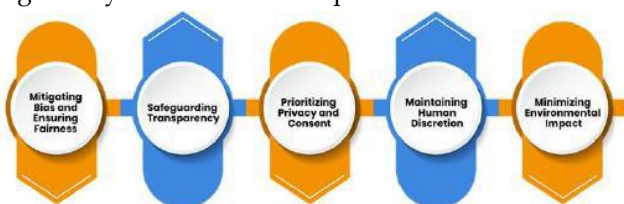


Fig.3: Key Ethical Consideration for AI in Human Resource

Data privacy is another critical concern associated with AI in HRM. AI systems require large volumes of sensitive employee data, including personal, performance, and behavioural information, to function effectively. This necessity increases the risk of data breaches, unauthorized access, or misuse of information. Compliance with stringent data protection regulations, such as the European Union's General Data Protection Regulation (GDPR), demands that organizations implement robust security measures, transparent data handling practices, and mechanisms for employees to exercise control over their data. Failure to meet these regulatory requirements can result in legal penalties, reputational damage, and erosion of employee trust.

Furthermore, resistance to change and a lack of digital skills among HR professionals pose practical barriers to successful AI integration. Many HR

practitioners feel ill-equipped to understand, manage, and leverage AI tools, leading to underutilization or misuse of technology. This skills gap can foster reliance on external vendors without sufficient internal governance, increasing the risk of misalignment with organizational values and goals. Additionally, employees may be wary of AI replacing human jobs or making decisions that affect their careers, contributing to resistance and anxiety. Addressing these challenges requires comprehensive training, change management strategies, and a human-centric approach that emphasizes collaboration between AI systems and HR professionals.

In summary, while AI has the potential to transform HRM positively, overcoming ethical concerns related to bias, transparency, and privacy, alongside operational challenges such as digital skill deficits and change resistance, is essential for sustainable and responsible implementation.

4.4 Future Directions

Looking ahead, the future of Artificial Intelligence in Human Resource Management hinges on addressing current limitations through innovative technological developments, enhanced workforce capabilities, and robust ethical frameworks. One promising area of advancement is the development of Explainable AI (XAI) systems. Unlike traditional "black box" AI models, XAI offers transparency by providing clear, understandable explanations for how decisions are made. This transparency is critical for fostering trust among HR professionals and employees, enabling them to verify the fairness and accuracy of AI-driven outcomes. By making AI more interpretable, XAI can help organizations ensure accountability and compliance with regulatory standards while enhancing employee acceptance of automated HR processes. Another vital future direction is the upskilling and reskilling of HR teams to effectively utilize AI tools. As AI technologies become more sophisticated and integral to HR functions, HR professionals must develop competencies in data analytics, AI ethics, and system governance. Continuous training programs and interdisciplinary collaboration between HR, IT, and data science units are essential to empower HR practitioners to not only operate AI systems but also critically evaluate their outputs.

and implications. Building this internal expertise will reduce dependency on external vendors and enable more strategic, context-sensitive deployment of AI aligned with organizational culture and goals. Finally, the establishment of comprehensive policies and ethical frameworks will play a pivotal role in guiding the responsible deployment of AI in HRM. Organizations and policymakers need to collaboratively develop standards that address data privacy, algorithmic fairness, transparency, and employee rights. These frameworks should promote human-centric AI design, embedding values such as inclusivity, accountability, and respect for human dignity into technological solutions. Furthermore, ongoing monitoring, auditing, and stakeholder engagement are necessary to adapt policies in response to emerging challenges and technological advancements. By proactively shaping the ethical landscape of AI in HR, organizations can harness its transformative potential while safeguarding against unintended harms.

Together, these future directions – advancements in explainability, capacity building in HR teams, and strong ethical governance – offer a pathway toward sustainable and effective AI integration in Human Resource Management, positioning organizations to leverage technology for enhanced human capital outcomes.

V. CONCLUSION

Artificial Intelligence is fundamentally reshaping Human Resource Management by automating routine tasks, enhancing decision-making capabilities, and personalizing employee experiences. This research highlights how AI-driven tools have become integral to recruitment, performance management, and learning and development, offering significant efficiency gains and strategic advantages. The benefits of AI adoption include improved real-time insights, reduction of human biases when ethically designed, and enhanced accessibility to HR services, all contributing to more effective and employee-centric HR practices.

However, the integration of AI also presents notable challenges, particularly around ethical concerns such as algorithmic bias, lack of transparency, and data privacy issues. These challenges underscore the

critical need for responsible AI deployment that aligns with organizational values and legal standards. Additionally, resistance to change and skill gaps among HR professionals can hinder the successful implementation of AI technologies, highlighting the importance of targeted reskilling and change management initiatives.

Looking forward, the development of explainable AI systems, upskilling of HR teams, and establishment of robust ethical policies emerge as key priorities for the sustainable use of AI in HRM. By addressing these areas, organizations can foster trust, accountability, and inclusivity, ensuring that AI not only drives operational efficiency but also supports human dignity and fairness.

In conclusion, while AI holds transformative potential for HRM, its successful adoption requires a balanced approach that integrates technological innovation with ethical stewardship and human-centred values. This approach will enable organizations to harness the full power of AI in managing their most valuable asset their people while navigating the complexities of the digital age responsibly and effectively.

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An Examination of the Effect of Product Quality on Consumer Brand Loyalty with Reference to Reliance Trends

Umamaheswararao Gobbilla¹, Gampa Usha²

¹Associate Professor, Department Of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.
orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study investigates the impact of product quality on consumer brand loyalty within the context of Reliance Trends, a leading Indian fashion retailer. Employing a descriptive and causal research design, data were collected through structured questionnaires from 150 customers in urban and semi-urban areas, focusing on attributes such as fabric durability, design, fit, and overall satisfaction. The analysis revealed that high product quality significantly influences customer loyalty, with most respondents expressing satisfaction with fabric quality and durability. Additionally, factors such as consistent quality, packaging, and favorable price-quality perceptions positively correlate with repeat purchases and brand advocacy. These findings underscore the importance of maintaining superior product standards to foster long-term customer loyalty. The research highlights that a strategic focus on product quality is vital for sustaining competitive advantage and ensuring sustained business growth in the dynamic retail market.

Keywords— Product Quality, Consumer Brand Loyalty, Customer Satisfaction, Retail Apparel Industry, Brand Perception, Consumer Behaviour, Purchase Intentions, Customer Retention, Fashion Retail Market, Brand Equity, Indian Retail Sector, Customer Loyalty Strategies, Brand Trust, Shopping Experience.

I. INTRODUCTION

Product quality plays a vital role in shaping consumer perceptions and purchasing decisions in today's competitive business environment. It refers to the ability of a product to meet or exceed customer expectations in terms of performance, durability, reliability, and overall satisfaction. High product quality not only attracts new customers but also helps in retaining existing ones by fulfilling their needs consistently. Consumer brand loyalty is the tendency of customers to repeatedly purchase a specific brand due to positive experiences, satisfaction, and trust developed over time. Among various factors influencing brand loyalty, product quality stands out

as a key determinant. When consumers associate a brand with superior quality, they are more likely to stay loyal, overlook minor shortcomings, and even recommend the brand to others.

The relationship between product quality and brand loyalty is strong and enduring. Brands that consistently deliver high-quality products tend to enjoy greater customer trust, increased brand value, and a sustainable competitive advantage. Therefore, understanding the impact of product quality on brand loyalty is crucial for businesses aiming to build lasting customer relationships and long-term success.

In today's highly competitive market, businesses are constantly striving to build and maintain strong

relationships with the customers. One of the most crucial factors that influence consumer behavior and long-term brand loyalty is product quality. Product quality refers to the ability of a product to meet or exceed customer expectations in terms of performance, durability, reliability, and overall value. Consumers are more likely to remain loyal to brands that consistently offer high quality products, as this builds trust, satisfaction, and positive brand perception. In an era marked by huge market competition and advanced consumer expectations, brand loyalty has evolved as a keystone of long-term business success. Companies across industries invest significantly in marketing and customer engagement strategies, but one important aspect remains consistently crucial that is product quality. High product quality enhances customer satisfaction, reduces complaints, and plays a key role in creating trust between the brand and its consumers.

Brand loyalty reflects a consumer's faithfulness to repurchase brands products over time and despite competitive pressures or marketing strategies from other brands. This study aims to examine the effect of product quality on consumer brand loyalty, exploring factors like product performance, durability, design, and customer satisfaction contribute to repurchase behavior and emotional attachment to a brand. To keep customer revisit, brands must offer better quality products that meet their expectations and standards. Product quality plays a crucial role in building customers loyalty and trust. When people feel happy with what they have purchased there are more chances of returning to the same brand. To meet customer expectations brands, need to deliver high-and better-quality products. Understanding this relationship is essential for businesses to gain competitive edge, retain consumers, and improve their market share. Companies that prioritize product quality are more likely to promote loyal customers, which ultimately leads to enhanced profitability and sustainable growth.

In modern retail industry, product quality plays a key role in influencing customer choices and long-term brand loyalty and in fashion retail sector where competition is very high and it is very important to build trust and customer retention. Through this research, we aim to explore product quality at Reliance trends and their loyalty.

II. LITERATURE REVIEW

1. I Gst Ngr Arya Wiguna Maha Diputra¹, Ni Nyoman Kerti Yasa (2021) - "The Influence of Product Quality, Brand Image, Brand Trust on Customer Satisfaction and Loyalty" -- Product quality has a positive and significant effect on brand image, brand trust, and customer satisfaction for Samsung smartphones. - Customer satisfaction, which is strongly influenced by product quality, leads to increased customer loyalty toward the Samsung brand. - The better the product quality, the higher the likelihood that customers will remain loyal and continue purchasing Samsung smartphones.

2. Ernest Grace, Rosita Manawari Girsang, Sudung Simatupang, Vivi Candra, Novelyn Sidabutar (2021) - "Product Quality and Customer Satisfaction and Their Effect on Consumer Loyalty" -- Product quality has a positive and significant effect on consumer brand loyalty, meaning better product quality leads to higher loyalty. - Consumer satisfaction also has a positive and significant effect on consumer loyalty, reinforcing the importance of meeting customer expectations. - Both product quality and consumer satisfaction together have a simultaneous positive and significant impact on consumer loyalty, indicating their combined influence is substantial.

3. I Gede Rihayana, Putu Pradiva Putra Salain, Putu Agus Eka Rismawan and Ni Komang Mega Antari (2021) - "The Influence of Brand Image, And Product Quality on Purchase Decision" -- Product quality has a positive and significant effect on consumer purchasing decisions, indicating that higher product quality increases the likelihood of purchase. - While the context focuses on purchasing decisions, improved product quality can indirectly foster brand loyalty by encouraging repeat purchases and positive consumer perceptions. - Brand image, alongside product quality, also plays a significant role in influencing consumer purchasing decisions, which can contribute to long-term brand loyalty.

4. Nochia Vedora Alfeba*, Muhartini Salimb (2023) - "The Influence of product quality and brand image on customer loyalty is mediated by customer satisfaction" -- Product quality alone does not have a strong or significant direct effect on consumer brand loyalty for Kacang kulit Dua Kelinci. - Product quality significantly influences consumer loyalty when its effect is mediated by consumer satisfaction, meaning

satisfied consumers are more likely to be loyal due to high product quality. - Among the factors studied, product quality is the second largest contributor to consumer loyalty after price, with brand image being the least influential.

5. Adib Alfikry, Arry Widodo, Anita Silvianita, Nurafni Rubiyanti (2024) –“The Effect of Sensory Marketing, Brand Experience, Brand Image, and Perceived Service Quality on Brand Loyalty with Customer Satisfaction as an Intervening Variable (Study Conducted on Luxury Brand Product Consumers): A Conceptual Paper”-- High product quality in luxury brands enhances consumer brand loyalty by positively influencing customer satisfaction. - Product quality, as perceived through sensory marketing and brand experience, directly strengthens brand loyalty among consumers. - Customer satisfaction acts as a mediator, meaning that the effect of product quality on brand loyalty is partly channeled through how satisfied customers feel with the brand.

6. Khalid K. Moenardy, M.Si, Lucio Ximenes, L. Ec, MMb (2023) –“ The Influence of Product Quality, Brand Image, and Promotion on Product Purchase Decisions” -- Product quality has a positive and significant effect on consumers' purchasing decisions for GOTA mineral water. - Higher product quality increases the likelihood that consumers will choose and remain loyal to a brand. - Alongside product quality, brand image and promotion also play important roles in influencing consumer purchasing decisions.

Research Gap:

Although several studies have examined the influence of product quality on consumer behavior—particularly on brand loyalty, purchase decisions, and customer satisfaction—the existing literature presents certain limitations and areas requiring further exploration:

Limited Industry Contexts: Most studies are concentrated on specific industries such as smartphones (Samsung), food products (Kacang kulit Dua Kelinci), mineral water (GOTA), and luxury goods. There is a lack of comprehensive research examining the effect of product quality on brand loyalty across a broader range of industries, particularly in FMCG (Fast-Moving Consumer

Goods) and FMCD (Fast-Moving Consumer Durables) in the Indian context.

Variability in Direct vs. Mediated Impact: There is inconsistency in findings related to whether product quality directly influences brand loyalty or whether this relationship is mediated by other variables such as customer satisfaction or brand image. For example, Nochia Vedora Alfeba et al. (2023) found product quality alone was not significantly linked to loyalty unless mediated by satisfaction—unlike other studies that showed a strong direct relationship.

Consumer Perception and Demographics: Few studies consider demographic or psychographic factors (e.g., income level, age group, or cultural influences) that may moderate the relationship between product quality and loyalty. This is especially relevant in the diverse Indian consumer market where such factors could play a significant role.

Interaction of Multiple Variables: While some conceptual frameworks (e.g., Adib Alfikry et al., 2024) integrate variables like sensory marketing and brand experience, many studies still treat product quality and loyalty in isolation. There is a research gap in multi-dimensional models that explore how product quality interacts with other experiential and emotional factors to drive loyalty.

Temporal and Longitudinal Studies: Most existing research adopts a cross-sectional approach, capturing only a snapshot of consumer perceptions. There is a gap in longitudinal studies that could better capture how product quality impacts brand loyalty over time and with repeated product usage.

Statement of the Problem:

Despite the extensive body of research highlighting the influence of product quality on consumer brand loyalty, existing studies remain largely confined to specific industries such as smartphones, packaged foods, mineral water, and luxury goods. There is a lack of comprehensive understanding of how product quality affects brand loyalty across a broader spectrum of industries, particularly within the FMCG and FMCD sectors in the Indian market.

Additionally, prior research presents inconsistencies regarding whether product quality has a direct impact on brand loyalty or whether this relationship is mediated by factors like customer satisfaction and brand image. Furthermore, limited attention has been

paid to demographic and psychographic factors that may moderate this relationship—an important consideration in a diverse and dynamic consumer landscape like India.

Moreover, many existing studies treat product quality and loyalty as isolated variables, lacking multi-variable or integrative models that consider emotional, sensory, and experiential factors. Finally, the predominance of cross-sectional methodologies limits the ability to capture changes in consumer behavior over time. These gaps highlight the need for a more holistic, industry-diverse, and context-specific investigation into the effect of product quality on brand loyalty, especially in the Indian FMCG and FMCD sectors.

Need For the Study:

- Bridge the contextual research gap by focusing on an Indian apparel retail brand.
- Identify whether product quality alone or in combination with other factors (e.g., price, customer experience) drives consumer loyalty.
- Help Reliance Trends and similar brands strategize product development, quality assurance, and customer relationship management to retain and grow their loyal customer base.
- Provide valuable insights for marketers, retailers, and brand managers to improve competitive positioning in a market influenced by both national and international fashion players.

This study addresses a critical need to empirically examine the role of product quality in fostering brand loyalty in India's dynamic and fast-growing retail fashion segment, using Reliance Trends as a focused case.

Objectives of the Study:

- To understand product quality at Reliance Trends.
- To identify key quality attributes that influence consumer preference for Reliance Trends.
- To Explore the Impact of Product Quality on Consumer Loyalty.

Scope of the Study:

The scope of this study encompasses an in-depth analysis of how product quality influences consumer brand loyalty within the context of Reliance Trends, a leading fashion and apparel retail brand in India. The study will be confined to evaluating various dimensions of product quality—such as fabric durability, design, fit, comfort, and value for money—and their direct and indirect impact on consumer loyalty behaviors like repeat purchases, brand preference, and word-of-mouth recommendations.

Hypotheses of the Study:

Null Hypothesis (H_0):

There is no significant effect of product quality on consumer brand loyalty at Reliance Trends.

Alternative Hypothesis (H_1):

There is a significant effect of product quality on consumer brand loyalty at Reliance trends.

Limitations of the Study:

This study aims to provide valuable insights into how product quality influences consumer brand loyalty in the context of Reliance Trends, certain limitations may affect the generalizability and scope of the findings:

1. Limited Geographic Coverage:

The study is restricted to selected urban and semi-urban areas, which may not fully represent consumer perceptions in rural or Tier-III cities where shopping behavior and brand expectations may differ.

2. Brand-Specific Focus:

Since the study is exclusively focused on Reliance Trends, the findings may not be applicable to other fashion retailers or brands operating in the same industry, limiting the scope for broader comparisons.

3. Cross-Sectional Nature:

The data will be collected at a single point in time, which may not capture long-term changes in consumer behavior or shifts in brand loyalty over time.

4. Self-Reported Data:

The study relies on consumer responses through questionnaires or surveys, which may be subject to biases such as social

desirability, recall errors, or subjective judgment.

5. **Exclusion of Other Influencing Factors:**

While the study focuses on product quality, it does not extensively analyze other factors like price, customer service, brand promotions, store ambiance, or online experience, all of which can also significantly influence brand loyalty.

6. **Sample Size Constraints:**

Due to time and resource limitations, the sample size may be limited, which could affect the statistical robustness and the ability to generalize findings across all Reliance Trends customers.

7. **Demographic Limitations:**

8. The study may not cover all demographic segments equally (e.g., senior citizens, non-frequent shoppers), which may skew the representation of consumer loyalty patterns.

The study is expected to provide a focused and relevant analysis of the relationship between product quality and brand loyalty in the context of Reliance Trends, offering practical insights for marketers and retail managers.

III. **RESEARCH METHODOLOGY:**

Research Design:

The study will adopt a descriptive and causal research design to understand and explain the relationship between product quality and consumer brand loyalty. The approach aims to describe existing consumer perceptions and analyse the cause-effect relationship between product quality and loyalty behavior.

Research Approach:

The research will use a quantitative approach, relying on structured survey instruments to collect and analyse numerical data that reflects consumer opinions and behavior patterns.

Data Sources:

- **Primary Data:** Collected through structured questionnaires administered to customers of Reliance Trends.

- **Secondary Data:** Gathered from existing literature reviews, company reports, market research articles, and academic journals related to product quality and brand loyalty.

Sampling Technique:

- **Sampling Method:** Non-probability purposive sampling will be used to select respondents who have prior shopping experience at Reliance Trends.
- **Sample Size:** 150 respondents will be targeted to ensure meaningful statistical analysis.
- **Sampling Unit:** Individual consumers who have purchased products from Reliance Trends in the last 2 months.

Data Collection Instrument: A structured questionnaire will be used, consisting of:

- Demographic details (age, gender, income, occupation, etc.)
- Product quality attributes (e.g., fabric quality, fit, design, durability, value for money)
- Brand loyalty indicators (e.g., repeat purchases, brand preference, likelihood to recommend)
- Measured using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree)

Tools for Data Analysis:

- **Chi-square Test:** For testing associations between categorical variables like demographics and loyalty levels.

Study Area:

The study will be conducted in urban and semi-urban locations where Reliance Trends stores are operational, including Hyderabad.

Time Period of Study:

The study will be conducted over a period of 2 months, including phases of data collection, analysis, and interpretation.

Ethical Considerations:

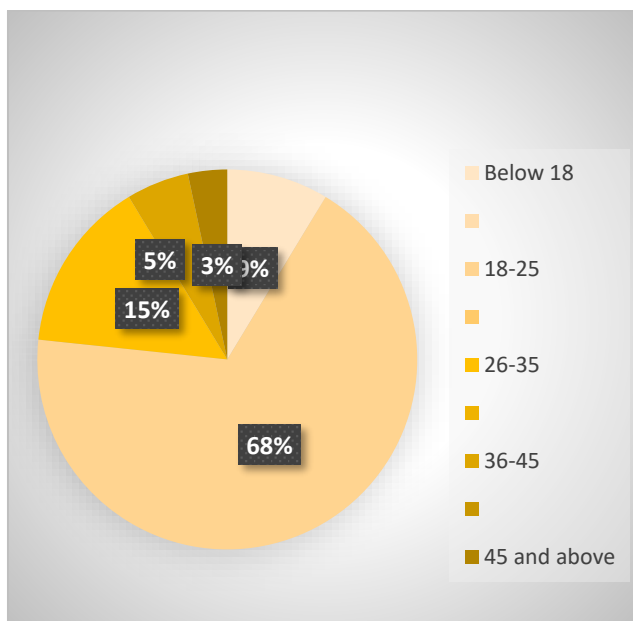
- Participation will be voluntary, and informed consent will be obtained.
- **Confidentiality and anonymity** of all respondents will be maintained.

- Data will be used strictly for academic purposes.

IV. DATA ANALYSIS & INTERPRETATION

Age	Responses	Percentage
Below 18	13	8.7%
18-25	102	68%
26-35	22	14.7%
36-45	8	5.3%
45 and above	5	3.3%
Total	150	100%

Table no.1



Graph no.1

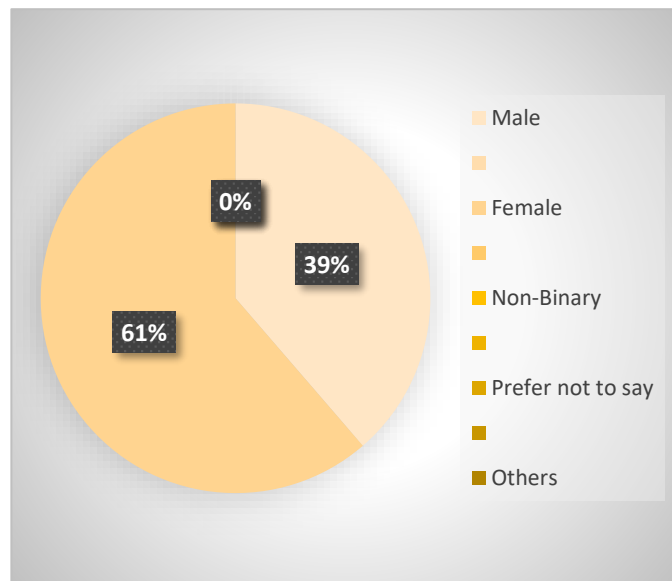
Interpretation:

This chart shows the age distribution of customers, with the majority 68% falling in the 18-25 age group. This is followed by 14.7% of respondents who are aged between 26-35. Additionally, 8.7% are below 18 years, 5.3% are between 36-45 years, and 3.3% are from 45 years and above age group. This clearly indicates that most of the responses were given by individuals in the 18-25 age category.

3. Gender:

Gender	Responses	Percentage
Male	58	38.7%
Female	92	61.3%
Non-Binary	0	0%
Prefer not to	0	0%
Others	0	0%

Table no.2



Graph no.2

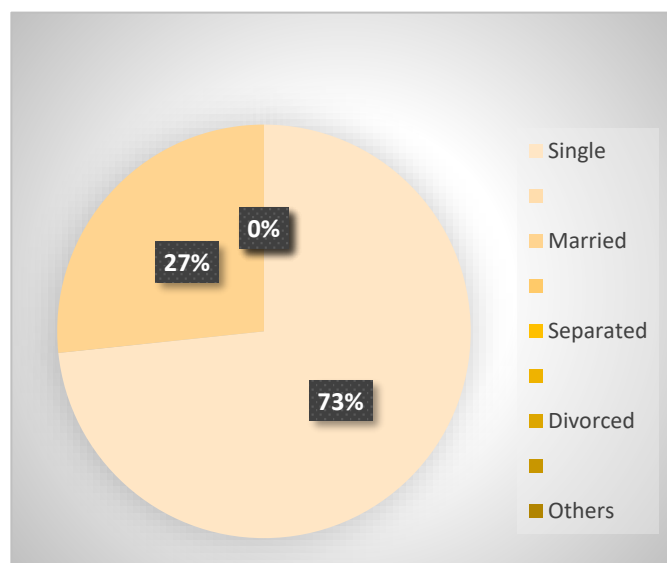
Interpretation:

The above chart shows the gender of the respondents the majority 61.3% respondents are female and 38.7% respondents are from Male, there are no respondents who belongs to non-binary or other category.

4. Marital Status:

Marital Status	Responses	Percentage
Single	110	73.3%
Married	40	26.7%
Separated	0	0%
Divorced	0	0%
Others	0	0%

Table no.3



Graph no.3

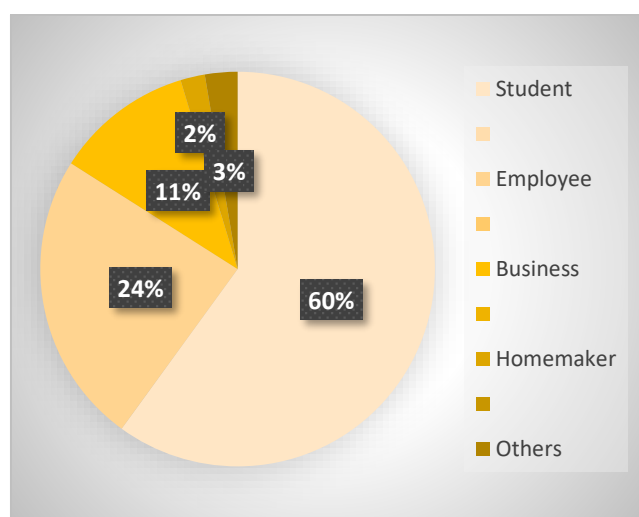
Interpretation:

The above chart shows the Marital status of the respondents the majority of the respondents 73.3% are single and 26.7% respondents are married and there are no respondents who are separated, divorced and others. This indicates that the majority responses are from unmarried individuals.

5. Occupation:

Occupation	Responses	Percentage
Student	90	60%
Employee	36	24%
Business	17	11.3%
Homemaker	3	2%
Others	4	2.7%
Total	150	100%

Table no.4



Graph no.4

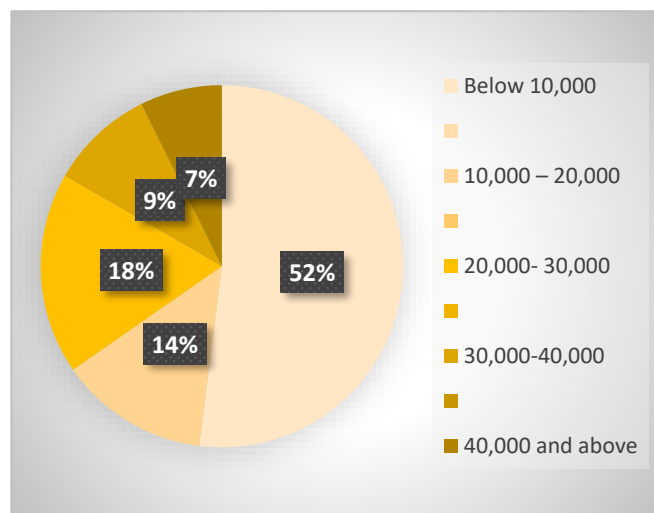
Interpretation:

The above chart shows the occupation of the respondents the majority 60% of the responses are from students followed by 24% respondents are from Employees, 11.33% responses are from business, 3% are from homemakers and 2.7% are from another category.

6. Montly Income:

Monthly	Responses	Percentage
Below 10,000	78	52%
10,000 – 20,000	20	13.3%
20,000- 30,000	27	18%
30,000-40,000	14	9.3%
40,000 and	11	7.3%
Total	150	100%

Table no.5



Graph no.5

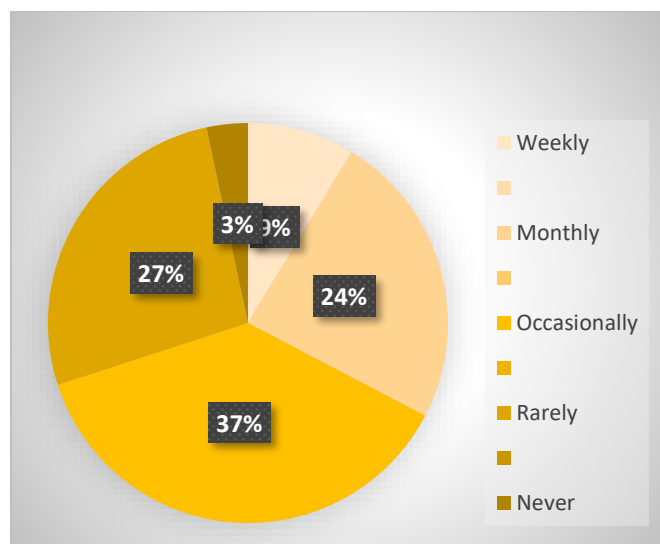
Interpretation:

The above pie chart represents the Monthly income of the respondents; the majority 52% respondents earn below 10,000 indicates a large portion are may be from students or individuals with low income. Followed by 18% earns 20,000-30,000, 13.3% earns between 10,000-20,000 follows 30,000-40,000 earns between 9.3% and only 7.35 people earn in between 40,000 and above. This shows that most respondents have relatively low-income levels.

7. How often do you shop at Reliance Trends:

Frequency	Responses	Percentage
Weekly	13	8.7%
Monthly	36	24%
Occasionally	56	37.3%
Rarely	40	26.7%
Never	5	3.3%
Total	150	100%

Table no.6



Graph no.6

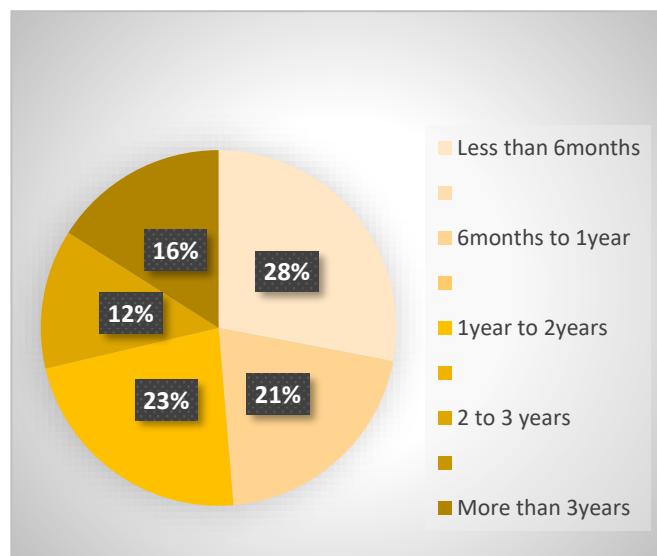
Interpretation:

The above pie chart shows shopping frequency of customers at Reliance Trends the majority 37.3% people shop at Reliance trends occasionally, 26.7% people visit rarely where 24% people shop at Reliance trends monthly follows 8.7% people shop at Reliance trends weekly and 3.3% people have never shopped at Reliance trends.

8. How long you have been a customer of Reliance Trends:

Frequency	Responses	Percentage
Less than	42	28%
6months to	31	20.67%
1year to 2years	34	22.67%
2 to 3 years	19	12.67%
More than	24	16%
Total	150	100%

Table no.7



Graph no.7

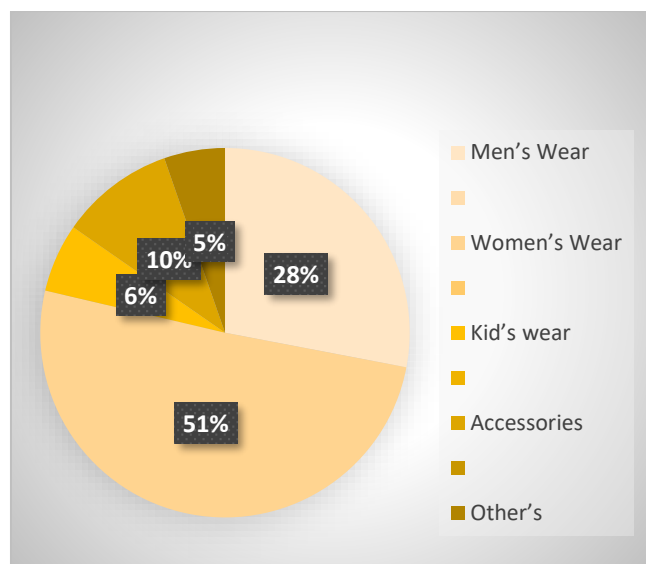
Interpretation:

The above pie chart shows frequency of customers to Reliance Trends around 72% the majority of customers have been shopping at Reliance Trends for less than 6months, around 22% for 1 to 2years, about 20% have been with the store for 6months to 1year, 15.5% are with the store about 2 to 3years and only 2.3% people are shopping since 2 to 3years.

9. What type of products do you usually purchase at Reliance Trends?

Product	Reponses	Percentage
Men's Wear	42	28.0%
Women's	76	50.7%
Kid's wear	9	6.0%
Accessories	15	10.0%
Other's	8	5.33%
Total	150	100%

Table no.8



Graph no.8

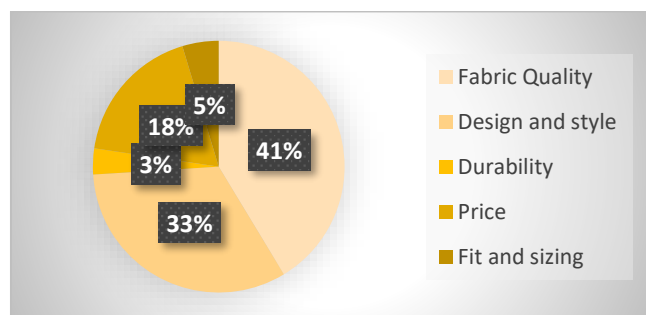
Interpretation:

The above chart shows that the majority 51% of the people purchase women's wear where 28% purchases Men's wear, around 10% purchases accessories at Reliance Trends, where 10% of the people purchase kid's wear and only 5% purchases some other products at the Reliance Trends

10. Which of the following attributes are most important to you when selecting products at Reliance Trends:

Attribute	Responses	Percentage
Fabric Quality	62	41.33%
Design and	49	32.67%
Durability	5	3.33%
Price	27	18.00%
Fit and sizing	7	4.67%
Total	150	100%

Table no.9



Graph no.9

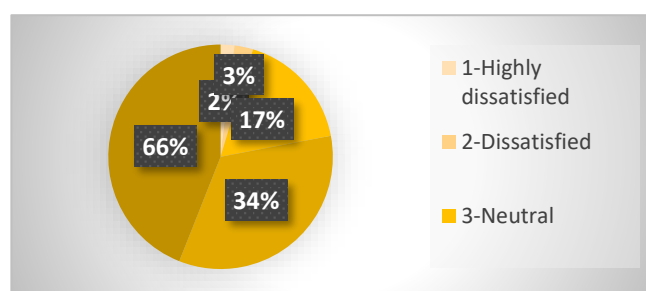
Interpretation:

The above pie charts represent the most important attribute while selecting the products at Reliance trends Majority 41% says Fabric quality, 33% Design and style followed by 18% chooses the Price of the product, 5% selected the size and fitting at last a very has been with the durability of the product.

11. How do you Rate the fabric quality of clothing at Reliance Trends:

Rating	Responses	Percentage
1-Highly	3	2%
2-Dissatisfied	4	2.7%
3-Neutral	26	17.3%
4-Satisfied	51	34%
5.Highly	66	66%
Total	150	100%

Table no.10



Graph no.10

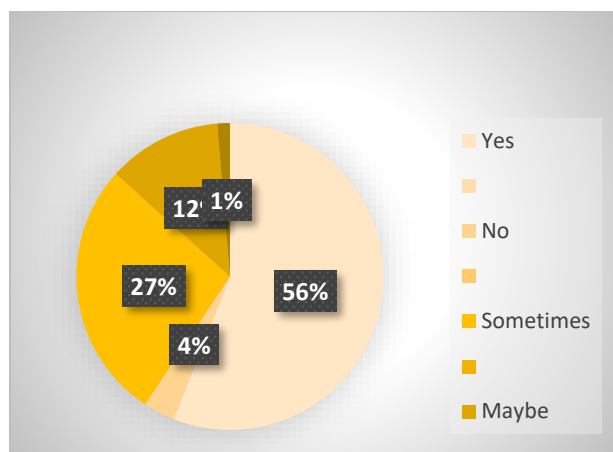
Interpretation:

The pie chart shows about fabric quality at Reliance Trends over 66% people are highly satisfied with the product quality at Reliance trends followed by 34% are satisfied, around 17.3% people are having neutral opinion, 2.7% are dissatisfied with fabric quality and only 2% are highly dissatisfied.

12. The Product Purchased at Reliance Trends are durable and long-lasting:

Option	Responses	Percentage
Yes	84	56%
No	5	3.33%
Sometimes	41	27.33%
Maybe	18	12.00%
Others	2	1.33%
Total	150	100%

Table no.11



Graph no.11

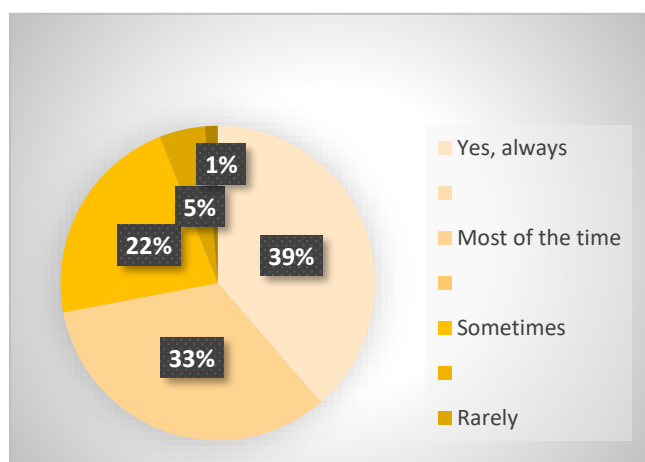
Interpretation:

The above chart represents the durability and long-lasting of products at Reliance Trends majority 56% feel that the products at Reliance Trends are durable and long lasting, some customers around 27% are feels that the products are durable and long-lasting only sometimes, 12% people are not sure, very few 3% think products are not long lasting and durable and 1% of customers gave other answers.

13. Do you think Reliance Trends offers products of consistent quality:

Option	Responses	Percentage
Yes, always	58	38.67%
Most of the	50	33.33%
Sometimes	33	22.00%
Rarely	7	4.67%
Never	2	1.33%
Total	150	100%

Table no.12



Graph no.12

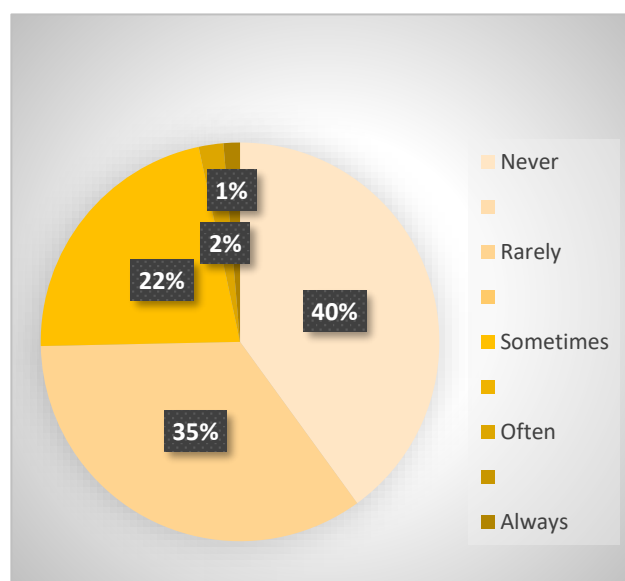
Interpretation:

As shown in the pie chart Majority 39% believes that Reliance Trends offers products of consistent quality followed by 33% opinion is Reliance trends offers product at consistent quality most of the time. Around 22% feel only sometimes the reliance trends offers products with consistent quality, only 4% says it rarely offers products with consistent quality and 2% customers q says it will never offer consistent quality products.

14. How often do you find defects or issues in the products bought from Reliance Trends?

Option	Responses	Percentage
Never	60	40%
Rarely	52	34.67%
Sometimes	33	22%
Often	3	2%
Always	2	1.33%
Total	150	100%

Table no.13



Graph no.13

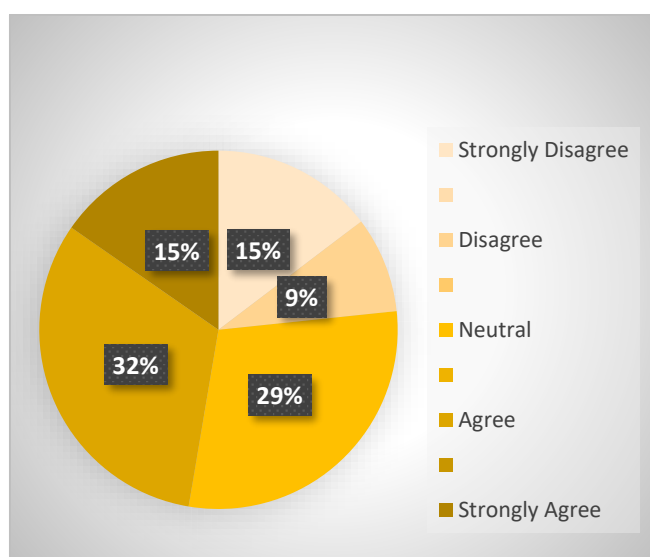
Interpretation:

The pie chart illustrates about the defects and issues of the products bought from Reliance trends Majority 40% people say they have never got any defects or damaged products, 34% feels that they rarely got the defects with the product follows 22% says sometimes they see the defects, only 2% sees the defects with the products often and 1% says they always see the defects or issues with the products of Reliance trends.

15. Does the price reflect the product quality at Reliance Trends?

Option	Responses	Percentage
Strongly	22	14.67%
Disagree	13	8.67%
Neutral	44	29.33%
Agree	48	32%
Strongly Agree	23	15.33%
Total	150	100%

Table no.14



Graph no.14

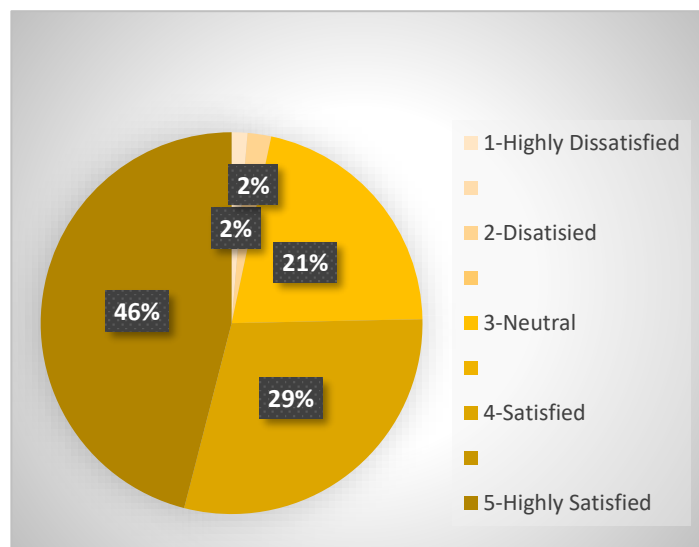
Interpretation:

This chart gives insights into does price reflect the product quality at Reliance Trends 32% are strongly agreed with the statement, 29% people have neutral opinion followed by 15% people says they strongly agree with the statement, 22% are strongly disagreed and 13% are disagreed with the price reflects the product quality at Reliance Trends.

16. How would you rate the availability of Size and style options at Reliance Trends?

Rating	Responses	Percentage
1-Highly	2	1.3%
2-Disatisfied	3	2%
3-Neutral	32	21.3%
4-Satisfied	44	29.3%
5-Highly	69	46%
Total	150	100%

Table no.15



Graph no.14

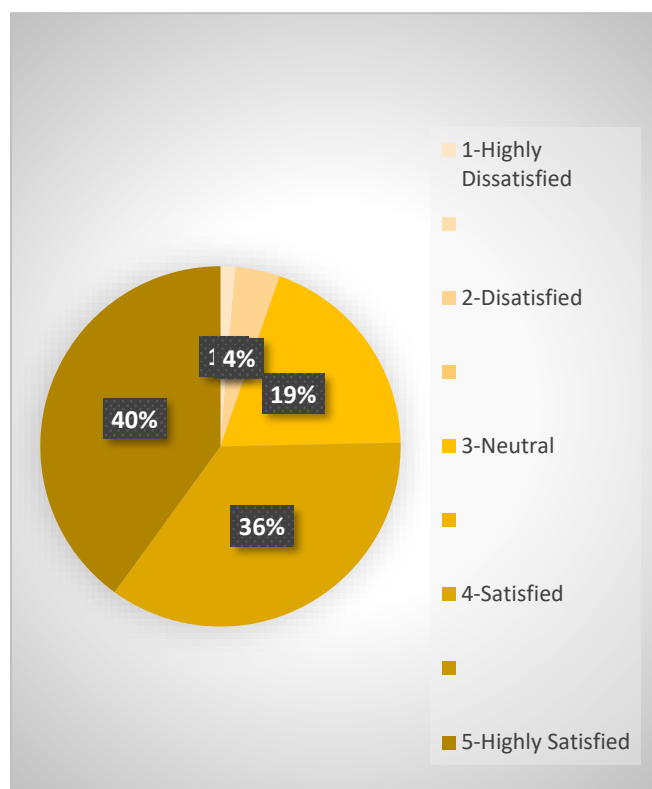
Interpretation:

The chart above reflects rating of customers for the availability of size and style options at Reliance trends as we can see most are happy with size and style options at reliance Trends. Near half of the respondents 46% are highly satisfied, about 29% are satisfied, 21% are having neutral opinion, followed by very few 2% are dissatisfied and 1.3% was highly dissatisfied with the size and style options at Reliance trends.

17. How would you rate the packaging and presentation of Reliance Trends?

Rating	Responses	Percentage
1-Highly	2	1.33%
2-Disatisfied	6	4%
3-Neutral	29	19.33%
4-Satisfied	53	35.33%
5-Highly	60	40%
Total	150	100%

Table no.16



Graph no.16

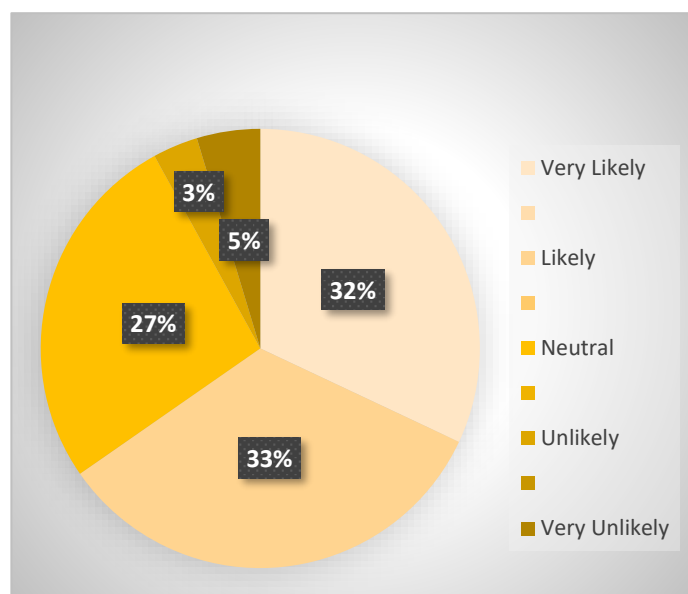
Interpretation:

The above pie chart represents customer satisfaction levels at Reliance Trends on packaging and presentation at Reliance Trends. It shows that Majority of customers around 40% reported being highly satisfied and 36% are satisfied, meanwhile 19% indicating neutral opinion, small percentage of people are unsatisfied, with 4% and just 1.33% are highly dissatisfied with packaging and presentation at Reliance Trends.

18. How likely are you to continue shopping at Reliance Trends due to Product Quality?

Option	Responses	Percentage
Very Likely	48	32%
Likely	50	33.33%
Neutral	40	26.67%
Unlikely	5	3.33%
Very Unlikely	7	4.67%
Total	150	100

Table no.17



Graph no.17

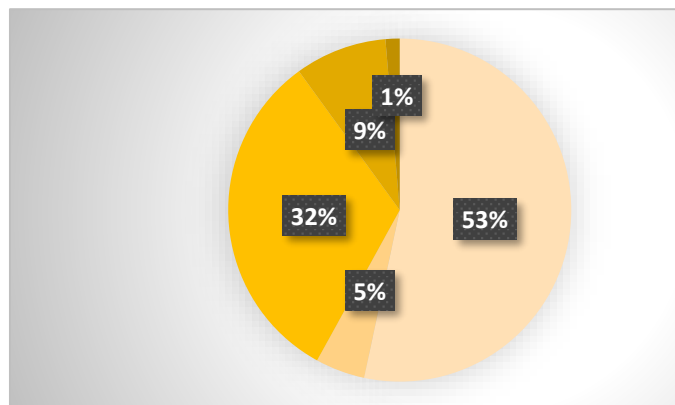
Interpretation:

The data illustrates how likely customers are to continue shopping at Reliance Trends based on the quality of its products. A majority of respondents have a positive outlook, with 33% stating that they are likely to continue shopping at Reliance trends, over 32% are very likely and 27% remain neutral, around 5% being very unlikely and 3% are being unlikely to shop at Reliance Trends.

19. Do you feel a sense of loyalty towards Reliance Trends as a brand?

Option	Responses	Percentage
Yes	80	53.33%
No	7	4.67%
Sometimes	48	32%
Maybe	13	8.67%
Others	2	1.33%
Total	150	100%

Table no.18



Graph no.18

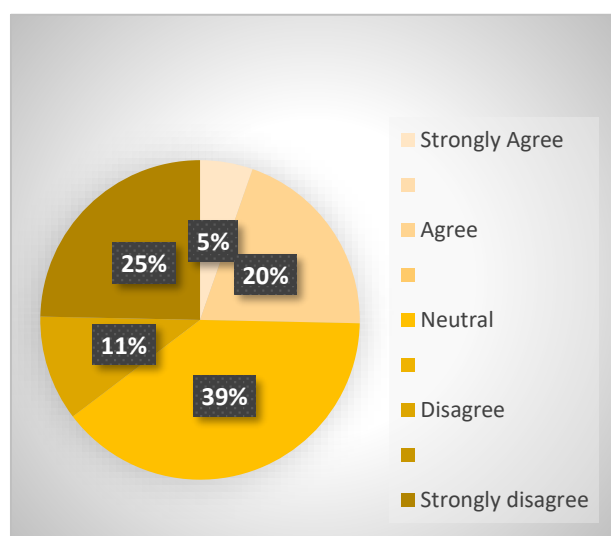
Interpretation:

From the pie chart, it is clear that data shows how customers feel about their loyalty towards Reliance Trends as a brand. Over half of the respondents 53% are loyal towards the brand, 32% of customers feel loyal for sometimes, a smaller portion 9% responded with Maybe, where 5% of respondents does not feel loyal and 1% of the people choose others.

20. Do you prefer Reliance trends over other similar Retail stores for your shopping needs?

Option	Responses	Percentage
Strongly Agree	8	5.33%
Agree	30	20%
Neutral	59	39.33%
Disagree	16	10.67%
Strongly	37	24.67%
Total	150	100

Table no.19



Graph no.19

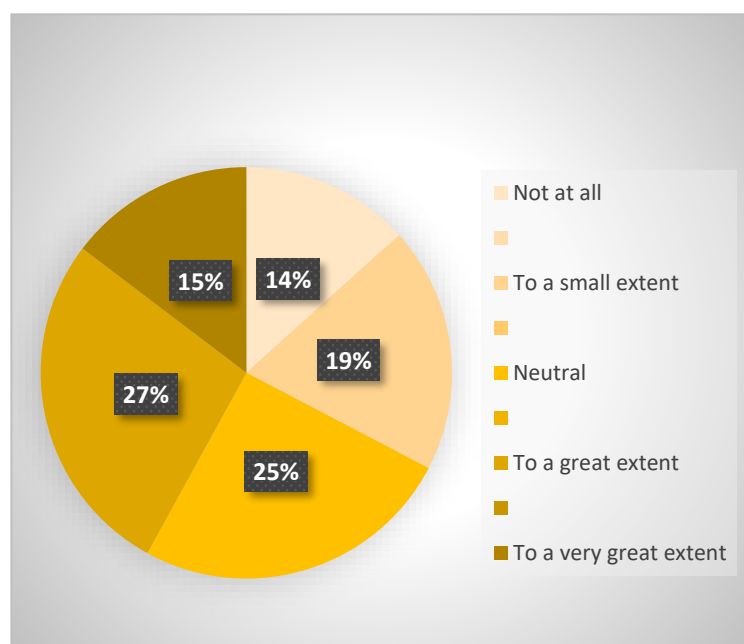
Interpretation:

The above chart displays that most of the people are neutral about preferring Reliance trends over other retail stores, with 39% of respondents, 24% of respondents are strongly disagreeing with the statement, around 20% people have agreed where as 11% have disagreed and 5% of the respondents are strongly agreeing that they choose other brands over Trends.

21. To what extent does product quality influence your decision to repurchase from Reliance Trends?

Option	Responses	Percentage
Not at all	20	13.33%
To a small	29	19.33%
Neutral	38	25.33%
To a great	41	27.33%
To a very great	22	14.67%
Total	150	100%

Table no.20



Graph no.20

Interpretation:

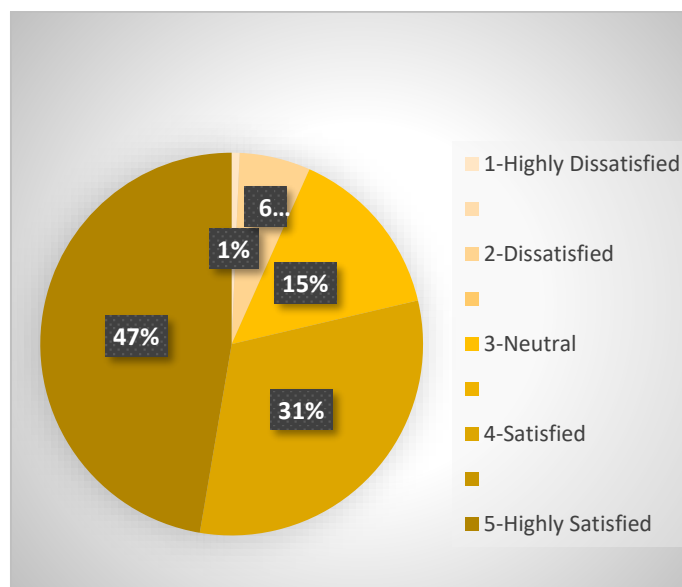
This chart shows how much product quality affects customer's decision to repurchase from Trends. Majority 27% said that product quality influences their purchase decision to a great extent. 25% choose neutral, around 19% think to a small extent product quality influences their decision, 15% are greatly influenced with product quality and 13% says product

quality does not affect their decision at all to repurchase from Trends.

22. Hove you satisfied with the overall experiences at Reliance Trends

Rating	Responses	Percentage
1-Highly	1	0.67%
2-Dissatisfied	9	6.00%
3-Neutral	22	14.67%
4-Satisfied	47	31.33%
5-Highly	71	47.33%
Total	150	100%

Table no.21



Graph no.21

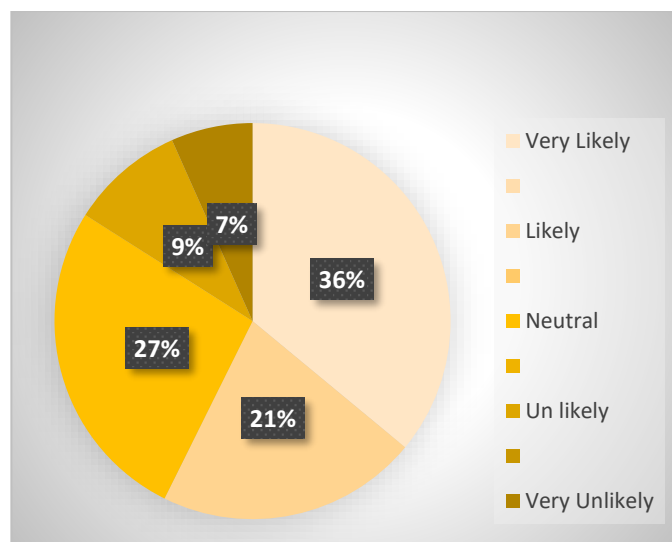
Interpretation:

The above pie chart outlines overall satisfaction of customers at Reliance Trends. Most of the respondents 47% are highly satisfied, another 31% are satisfied followed by 14% have neutral opinion, around 6% are dissatisfied and very few only 0.67% are highly dissatisfied with the overall experience at Reliance trends.

23. How likely are you to recommend Reliance trends to others?

Option	Responses	Percentage
Very Likely	54	36.00%
Likely	32	21%
Neutral	40	26.67%
Un likely	14	9.33%g
Very Unlikely	10	6.67%
Total	150	100%

Table no.22



Graph no.22

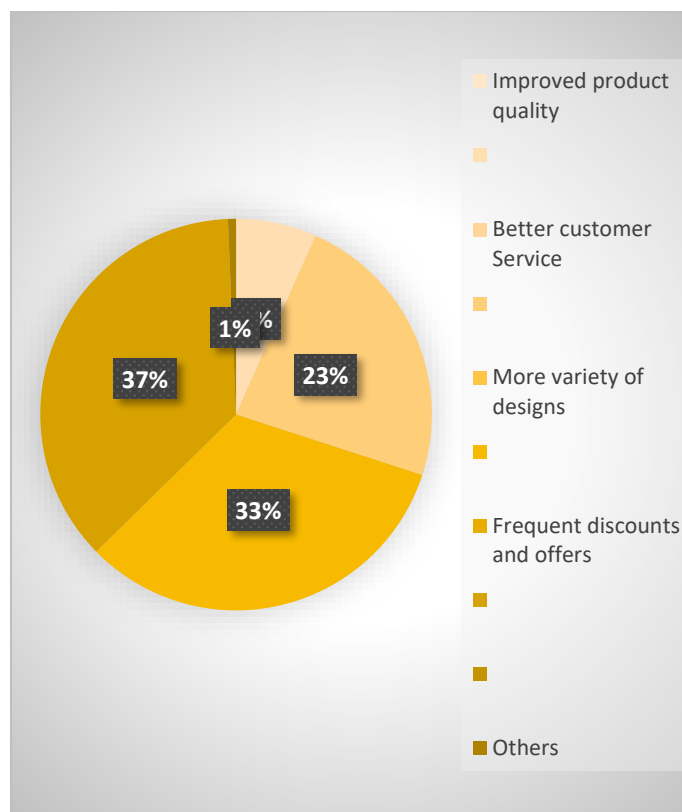
Interpretation:

The pie chart illustrates how willing customers are to recommend Reliance Trends to others. Significant portion, Majority 36% are very likely to recommend Trends to others, about 26.67% respondents remain neutral, another 21% responded as likely, 9% were unlikely and only 7% were very unlikely to recommend Reliance Trends to others.

24. What would make you more likely to purchase from Reliance Trends in Future

Option	Responses	Percentage
Improved	10	6.67%
Better	35	23.33%
More variety	49	32.67%
Frequent	55	36.67%
Others	1	0.67%
Total	150	100%

Table no.22



Graph no.23

Interpretation:

The chart reflects what factors would encourage customers to shop at Reliance Trends in Future. The most preferred improvement is frequent discounts and offers, chosen by 37% of respondents, followed by 33% of customers wanting more variety in designs, 23.33% believing better customer service would influence their buying decision, a small portion 7% motivated by improved product quality, while very few 1% selected other factors.

25. Any suggestions or comments regarding the product quality at Reliance Trends

STATISTICAL ANALYSIS & HYPOTHESIS TESTING

Null Hypothesis (H_0):

There is no significant effect of product quality on consumer brand loyalty at Reliance Trends.

Alternative Hypothesis (H_1):

There is a significant effect of product quality on consumer brand loyalty at Reliance Trends.

Null Hypothesis (H_0):

There is no significant effect of product quality on consumer brand loyalty at Reliance Trends.

Alternative Hypothesis (H_1):

There is a significant effect of product quality on consumer brand loyalty at Reliance Trends.

Chi square calculation

Option	Observed value	Expected value	χ^2
Yes, always	58	30	26.13333
Most of the time	50	30	13.33333
sometimes	33	30	0.3
Rarely	7	30	17.63333
Never	2	30	26.13333
Total	150	150	83.53333

X2 table value	X2 calculated value
9.488	83.5333
As table value is less than calculated value. We reject H_0 (null) and accept H_1 (alternative)	
Note: -	
$\chi^2 = \text{chi square}$	
O = Observed value	
E = Expected value	
Formula: - " $\frac{(O-E)^2}{E}$ "	
Degree of freedom: - 4	
Significance: - 0.05	

Option	Observed (O)	Expected (E)	(O-E) ² /E (χ^2 value)
Yes, always	58	30	26.13
Most of the time	50	30	13.33
Sometimes	33	30	0.30
Rarely	7	30	17.63
Never	2	30	26.13
Total	150	150	83.53

- Chi-Square Calculated Value (χ^2): 83.53
- Chi-Square Table Value (df = 4, α = 0.05): 9.488
- Degrees of Freedom (df): 5 - 1 = 4
- Level of Significance (α): 0.05

Interpretation:

Since the calculated chi-square value (83.53) is much greater than the critical/table value (9.488) at 0.05 significance level, we reject the null hypothesis (H_0).

V. FINDINGS

- The majority 68% of the responses are from the age group of 18-25, the second largest 15% was from the age group of 26-35, Meanwhile minimal responses 9% from the age group of below 18, 5% from the 36-45 in between age group and lowest responses are from the age group of 45 and above.
- 61% of the responses are majorly from Female and 39% responses are from men, so according to the survey female respondents are more than male respondents.
- Majorly 73% respondents are unmarried and 27% respondents are married, indicating most of the participates are unmarried.
- From 150 respondent's majority 60% are from students, second highest 24% are from employees, 11.3% are from business where 2.7% from others and lowest responses are from homemakers.
- From overall 150 responses highest 52% have a monthly income below ₹10,000 second largest around 18% respondents have monthly income of 20,000 to 30,000, followed by 13.3% earn 10,000 to 20,000, 9.3% are from 30,000 to 40,000 and lowest responses are 7.3% from 40,000 and above.
- Out of 150 responses majorly 37.3% respondents visit trends occasionally, followed by 26.7% shop rarely, about 24% shop on monthly basis, 8.7% shop weekly and only 3.3% have never shopped at Reliance Trends.
- Highest 28% of the customers have been with Trends for less than 6months, followed by 23% are from 1 to 2years, 21% are with 6months to 1year, around 16% have been for 3years and 13% are from 2 to 3years.
- Out of 150 responses women's wear is most purchased category with 51%, followed by men's ware at 28%. Accessories around 10%, while kid's ware up to 6% the least purchased category is others with only 5.33%.
- The most valued attribute at Trends is Fabric quality, chosen by 41% of respondents followed by design and style with 33%, price comes next with 18%, Feting and size by 5% while durability was least chosen by only 3% of respondents.
- Majority Responses 44% are highly satisfied with fabric quality of Trends followed by 34% are satisfied, 17.3% has neutral opinion where 2.75 were dissatisfied 2% are highly dissatisfied.
- Based on data, 56% believes that products at Trends are durable and long lasting. Followed by 27% think only for sometimes, while 12% are unsure, 3% disagrees and just 1% gave other responses.
- Highest no. of respondents 39% believe Trends always offers consistent product quality, 33% feels most of the time, 22% think occasionally, 5% rarely and 1% feel it is never consistent.
- Most of the respondents 40% have never faced any defects following that 35% rarely encountered the issues, 22% says sometimes they find defects, while 2% indicated often and 1% are always facing defects and issues.
- Highest 32% agreed with the price reflects the product quality at Trends. Followed by 29% having a neutral view, 15% strongly disagreeing, and least 8.67% disagreeing.
- Most respondents were highly satisfied 46% with the size and style options at Trends, followed by 29% who were satisfied. About 21% remained

neutral, while 2% are dissatisfied and 1.3% are highly dissatisfied.

- Majority 40% respondents are highly satisfied with packaging and presentation at Trends, 35% are satisfied, 19% have neutral opinion, where 4% are dissatisfied and 1% are highly dissatisfied.
- Out of 150 responses majority 47% respondents were highly satisfied with the overall experiences at Reliance Trends. 31% are satisfied, 14% have neutral opinion and 6% are dissatisfied finally 0.67% a very few were highly dissatisfied.
- From the overall responses 36% highest respondents are very likely to recommend Reliance trends to others, 27% are with neutral, 21% are likely and 9% and 7% are Unlikely and very unlikely.
- Respondents are more likely to repurchase in future if frequent discounts and offers 37% are made and 33% likely to purchase if they provide more variety of designs and 23% need better customer service and 7% responded for improved product quality and at least 0.67% need other improvements in the Trends to repurchase.

VI. SUGGESTIONS

- **Enhance product variety:**
Introduce more diverse collections that appeal to different age groups, fashion styles and other regional preferences. Introducing new designs, styles and limited-edition collection or designer tie ups could attract trend conscious shoppers. Out 150 respondents 27.5% need more variety of designs to repurchase from Reliance Trends.
- **Introduce Frequent discounts:**
Out of 150 responses 27% responded to introduce frequent discounts and offers which would make them repurchase from trends in Future. Customers are always drawn to value deals, Trends should introduce more regular discounts, offers and seasonal sales. Offering occasional surprise discounts or member only deals can enhance customer satisfaction and make them attract.
- **Improved product quality:**
31% of the respondents are responded to improve product quality to make repurchase

from the Reliance Trends. Ensure that all product meet consistent quality standards in terms of fabric durability, stitching, finishing and overall design. Regular quality checks can help maintain customer trust.

- **Better Customer services:**

Out of 150 respondents 24% have responded to improve customer services at Trends. Provide customer service training to staff members to enhance interaction, assistance and support throughout the shopping and introduce customer feedback mechanisms

- **Focus on Value for money:**

Always pricing strategies to ensure better value for money. Introduce affordable Prices and lowering prices on most demanded items or launching budget-friendly collections can help to a huge customer base.

VII. CONCLUSION

The study set out to examine the effect of product quality on consumer brand loyalty with reference to Reliance Trends. The finding of the study clearly indicate that product quality plays a significant and positive role in influencing consumer brand loyalty. Through the collection and analysis of responses, most of the customers are generally satisfied with product quality offered at Reliance Trends. While product quality is the key factor, elements like pricing, customer service, size and fitting, also plays supporting roles.

The results suggest that Reliance Trends has successfully created a positive brand image in the minds of its consumers through consistent product quality. This enabled the brand to maintain a loyal customer base in a intensive competitive retail market. Moving ahead, by further improving Product standards and staying responsive to changing consumer preferences, Reliance Trends can not only retain its past customers but also attract new customers. In conclusion, a strong commitment to product quality will continue to be a key driver of brand loyalty and long term business success for Trends.

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The role of credit risk management in mitigating NPA

Umamaheswararao Gobbilla¹, Chippa Nandini²

¹Associate Professor, Department Of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.
orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study investigates the impact of credit risk management practices on non-performing assets (NPAs) in Axis Bank over a five-year period. Employing a descriptive and analytical approach, it analyzes secondary data from annual reports, financial statements, and industry sources, utilizing trend analysis, ratio analysis, correlation, and ANOVA to evaluate asset quality and risk mitigation strategies. Findings reveal a significant decline in gross and net NPAs, alongside an increase in provisioning coverage and stable capital adequacy ratios, indicating effective credit risk controls. The results demonstrate a strong inverse relationship between NPAs and provisioning, and consistent asset quality management across quarters. These insights underscore the importance of robust internal credit frameworks and technological tools in reducing NPAs, thereby enhancing financial stability. The study highlights that effective credit risk management is vital for sustaining bank profitability and systemic resilience in the evolving Indian banking landscape.

Keywords— Credit Risk Management, Non-Performing Assets (NPA), Credit Evaluation, NPA Mitigation, Risk-Based Lending, Recovery Mechanisms.

I. INTRODUCTION

Non-Performing Assets (NPAs) have emerged as one of the most significant challenges affecting the health and stability of the banking and financial sector, particularly in developing economies like India. An NPA refers to a loan or advance for which the principal or interest payment remains overdue for a specified period, typically 90 days. A rising level of NPAs not only erodes the profitability and capital base of banks but also impairs their ability to lend, affecting overall economic growth.

In this context, credit risk management becomes a critical function for financial institutions. It involves identifying, assessing, monitoring, and controlling the risk of default on credit extended to borrowers. Effective credit risk management ensures that banks maintain asset quality by deploying rigorous credit appraisal systems, risk-based pricing, portfolio

diversification, early warning systems, and timely recovery mechanisms.

This study explores how robust credit risk management practices can help in reducing the incidence of NPAs. It also seeks to understand the tools and strategies used by banks to prevent credit defaults and improve recovery processes. By analysing the relationship between credit risk management and NPAs, the research aims to provide insights into strengthening financial stability and promoting responsible lending practices.

II. LITERATURE REVIEW

1. Gupta and Sharma (2023) -- In their article Post-COVID Restructuring and NPAs, conducted an in-depth study on how Indian banks responded to loan distress caused by the pandemic. The authors examined the impact of moratorium schemes and restructuring frameworks on loan performance. They

concluded that although short-term relief helped prevent defaults, long-term resolution depended heavily on internal credit evaluation and monitoring. Their analysis showed that banks with strong risk teams, like Axis Bank, were better able to control fresh NPAs. This study highlighted the evolving need for proactive credit risk management strategies, especially in times of macroeconomic uncertainty. The authors emphasized that sustained NPA reduction requires a blend of regulatory support and internal vigilance.

2. Chakraborty (2022) -- Through the article Risk Mitigation Tools in Indian Banking, analyzed the adoption of modern credit assessment tools in private banks. The study focused on techniques like credit scoring, risk-based pricing, and early warning indicators. Chakraborty observed that private banks using digital credit models experienced a faster decline in NPAs compared to those relying on traditional appraisal methods. The article provided specific case references from Axis Bank's use of borrower profiling and score-based approvals. It concluded that technology-backed credit evaluation significantly reduces exposure to high-risk borrowers, ultimately contributing to a healthier loan book.

3. Thomas and Rao (2021) -- In Capital Strength and Asset Quality, explored the relationship between a bank's capital adequacy and its NPA levels. Using data from 10 major banks over 5 years, the study found that institutions with higher capital buffers maintained better asset quality during economic downturns. The authors explained how Capital Adequacy Ratio (CAR) serves as both a cushion and a discipline tool in credit expansion. The article mentioned Axis Bank's consistent CAR above regulatory norms, which allowed it to absorb stress without major deterioration in NPAs. The study concluded that capital strength is a leading indicator of credit resilience.

4. Agarwal and Jain (2021) -- Through their research paper Axis Bank's Credit Control Framework, conducted a focused study on Axis Bank's internal credit risk systems. They analyzed quarterly data, policy disclosures, and risk practices. The authors noted that Axis Bank employed a combination of predictive analytics and sector-specific exposure limits to minimize loan defaults. Their analysis

showed a year-on-year reduction in Gross NPAs, indicating effective policy implementation. The study reinforced the idea that bank-specific credit frameworks, when monitored consistently, can outperform broad regulatory norms in controlling bad loans.

5. Rai and Sharma (2020) -- In Impact of IBC on Recovery Performance, evaluated the effectiveness of the Insolvency and Bankruptcy Code (IBC) in resolving stressed assets. The study covered resolution timelines, recovery rates, and success stories post-IBC implementation. They concluded that while IBC improved creditor power and recovery efficiency, outcomes were highly dependent on banks' initial risk assessment. Axis Bank was cited for its relatively lower exposure to sectors with prolonged resolution timelines, which reflected stronger credit screening. The article emphasized that legal reforms must be complemented by sound internal credit processes to reduce NPAs effectively.

6. Bansal and Kapoor (2020) -- In their article PCA Framework and Bank Performance, studied the impact of the RBI's Prompt Corrective Action (PCA) framework on banks' credit discipline. They observed that PCA-invoked banks showed marked improvements in provisioning, capital levels, and NPA ratios over a 3-year period. While Axis Bank was not under PCA, the study included it as a benchmark for proactive provisioning. The authors argued that PCA-like frameworks should be internalized within banks as risk flags rather than regulatory triggers. This study highlighted the need for voluntary discipline in provisioning and credit monitoring.

7. Sharma (2019) -- In Risk-Based Lending in Indian Private Banks, focused on lending practices that factor in borrower risk profiles. The article discussed how Axis Bank and other private banks have adopted segmented risk pricing for different borrower categories. The author provided data showing that risk-based pricing led to lower defaults in unsecured loans, where risk is generally high. Sharma emphasized the role of internal scoring models, automated credit checks, and real-time borrower monitoring in modern risk frameworks. The article concluded that personalized credit risk assessment improves NPA control in competitive lending environments.

8. Das and Ghosh (2018) --In their paper Credit Growth and Asset Quality in Indian Banks, analyzed the correlation between aggressive credit expansion and rising NPAs. The study covered a decade of data and showed that periods of high credit growth, especially in infrastructure and MSME sectors, resulted in asset quality stress. Axis Bank was cited as a case where controlled lending policies and sectorial caps helped avoid the post-2014 credit shock seen in PSU banks. The authors recommended a balanced growth model with strong sectorial analysis to ensure asset quality sustainability.

9. Joshi and Patel (2019) --In Fintech Integration and Credit Risk, examined how banks are using technology to manage credit risk. The study highlighted innovations like AI-based underwriting, digital KYC, and predictive analytics. Axis Bank was referenced for its use of API-based credit checks and real-time decision-making tools. The authors found that banks that embraced fintech early had lower slippage rates and higher early recovery levels. This study demonstrated that technology adoption is not just operationally efficient but also improves credit risk management outcomes.

10. Verma (2016) -- In Early Warning Signals and NPA Prevention, emphasized the importance of timely detection of financial stress in loan accounts. The study discussed key indicators such as EMI delays, credit utilization surges, and industry-specific trends. Verma observed that banks like Axis Bank, which employ early warning tools, reported fewer accounts slipping into NPA status. The article concluded that prevention strategies are more cost-effective than recovery strategies and recommended mandatory early warning systems across all bank types.

11. Mishra and Sinha (2019) -- In Credit-Deposit Ratio and NPA Trends, studied the inverse relationship between NPA levels and the credit-deposit ratio in commercial banks. They found that banks with aggressive credit deployment policies without adequate due diligence had higher NPAs. Axis Bank's credit-deposit strategy was shown to be more conservative, resulting in better asset quality. The study recommended aligning credit policies with deposit growth to maintain financial health.

12. Prasad and Iyer (2018) -- In SME Lending and Loan Default Patterns, analyzed loan repayment behavior among small and medium enterprises. Their study revealed that the absence of segment-specific risk analysis contributed to rising defaults. Axis Bank's specialized SME credit programs were highlighted as a positive example, emphasizing sector-based evaluation. The authors recommended custom credit frameworks for SME clients to reduce NPAs.

13. Kanchan and Varma (2018) -- In Sectorial NPAs in Indian Banks, assessed the distribution of NPAs across different economic sectors. They found that infrastructure and real estate accounted for the highest defaults. The paper highlighted how Axis Bank reduced sectorial exposure in these areas, leading to lower stress levels. The study concluded that diversified portfolios and exposure limits can significantly control credit risk.

14. Mukherjee (2017) -- In Borrower Profiling and KYC Compliance, stressed the role of thorough background checks and KYC in credit decision-making. The author cited case studies where weak documentation led to slippages into NPAs. Axis Bank's robust borrower profiling system was mentioned as a benchmark. The study emphasized that strict compliance with onboarding norms can prevent future credit deterioration.

15. Banerjee and Dutta (2017) -- In Provisioning Policies and Asset Quality, evaluated how provisioning norms impact the financial stability of banks. They showed that conservative provisioning cushions banks against unexpected defaults. Axis Bank's consistent provisioning coverage above the industry average was cited as a best practice. The paper recommended strengthening risk buffers even when default rates appear stable.

Research Gap:

The extensive review of literature demonstrates substantial work done on the mechanisms and effectiveness of credit risk management strategies in mitigating Non-Performing Assets (NPAs) in Indian banks, particularly with recurring references to Axis Bank's practices. However, several critical research gaps remain:

Lack of Comparative Analysis Across Bank Types: Most studies focus on private sector banks, especially

Axis Bank, without a comprehensive comparison with public sector banks or cooperative banks. A systematic evaluation of how different categories of banks implement credit risk management could provide more balanced insights.

Limited Focus on Integrating Credit Risk Tools with Regulatory Frameworks:

While several studies highlight internal tools like credit scoring, borrower profiling, and early warning systems, there is limited research on how these internal mechanisms align or conflict with external frameworks like RBI's asset classification norms, PCA directives, or the IBC process.

Insufficient Exploration of Long-Term Impact Post-COVID:

Although Gupta and Sharma (2023) touched on post-COVID restructuring, a broader and more updated study is needed to assess how banks have evolved their credit risk management strategies in response to prolonged pandemic-induced economic shifts and their impact on NPAs over the long term.

Underexplored Role of Fintech in Public Sector Banks:

While fintech integration is addressed in private banks, especially Axis Bank, little research exists on how public banks are adopting or lagging in deploying technology-driven credit evaluation models, which could be critical in modernizing risk management.

Sector-Specific Risk Management Strategies:

Several studies identify sectoral exposure (e.g., infrastructure, MSME, real estate) as a cause of NPAs, but there is limited research focusing on how banks customize credit risk frameworks based on sector-specific risk characteristics, especially in high-default sectors.

Gap in Behavioral and Psychographic Borrower Risk Assessment:

Most research focuses on financial and structural borrower evaluations. There is little exploration of non-traditional credit risk indicators like behavioral patterns, digital footprints, or psychographic profiling, which can enhance prediction accuracy in retail and SME segments.

Lack of Real-Time and Predictive Monitoring Framework Analysis:

Studies refer to early warning systems, but there is a research gap in assessing the effectiveness and operationalization of real-time credit monitoring systems and AI-based predictive tools in reducing slippages.

Scarcity of Empirical Studies on Credit Risk Governance Culture:

While structural and policy measures are well-documented, very few studies address the role of organizational culture, risk governance structures, and human factors in implementing effective credit risk practices across bank hierarchies.

Future research should aim to bridge these gaps by adopting a holistic, multi-bank, multi-sector, and technology-integrated approach to understanding how credit risk management can be institutionalized effectively to reduce NPAs in both the short and long term. This can enable policymakers and financial institutions to develop adaptive and resilient credit systems that are proactive rather than reactive.

Statement of the Problem:

Non-Performing Assets (NPAs) continue to be a major concern for the Indian banking sector, affecting profitability, credit growth, and overall financial stability. While regulatory frameworks and recovery mechanisms have evolved, the role of internal credit risk management remains critical, especially in private sector banks. Axis Bank, being a leading private bank, has adopted several credit risk strategies, but the effectiveness of these practices in mitigating NPAs has not been extensively analyzed. Therefore, this study aims to explore the impact of credit risk management on the level of NPAs in Axis Bank over a five-year period, using financial data and statistical tools to evaluate its performance.

Need For the Study:

In the modern banking environment, effective credit risk management has become a critical area of focus, especially for institutions like Axis Bank, which deal with large and diverse loan portfolios. Nonperforming assets are a major concern for financial institutions, regulators, and the overall economy. An increasing level of NPAs impacts not only the profitability of banks but also their creditworthiness, liquidity and public confidence.

Over the last decade, Indian bank has witnessed significant growth in NPAs, driven by multiple factors including poor credit appraisal, sectorial stress, economic slowdowns and global financial uncertainties. Although regulatory bodies such as the Reserve Bank of India have introduced several frameworks like asset quality reviews, restructuring

schemes, and insolvency processes, the success of these measures ultimately depends on the strength of internal credit risk management practices adopted by bank.

This study is essential because it helps to evaluate the practical role played by credit risk policies, systems and techniques in mitigating credit defaults. It also explores whether banks like Axis Bank are just reacting to risk or proactively preventing it through internal frameworks such as early warning systems, risk based pricing, portfolio diversification and provisioning strategies.

Objectives of the Study:

- To understand the factors contributing to non-performing assets
- To analyze the credit risk management framework of Axis Bank
- To evaluate the impact of credit risk management on NPA reduction
- To study the effectiveness of risk assessment techniques

Scope of the Study:

The study focuses exclusively on Axis Bank, one of the India's leading private sector banks, as a case example for analyzing the effectiveness of credit risk management. It draws insights from the banks published annual reports, financial statements and other secondary data over a five year period. The scope of the project is limited to the analysis of quantitative data related to Gross NPA, Net NPA, CAR, PCR as well as qualitative assessment of the credit policy framework and techniques used by the bank.

The study is constrained to the Indian banking environment and does not compare Axis Bank with other banks or international institutions. It covers only secondary data, which means no primary data is collected from customers or bank staff. The research does not aim to audit or assess the effectiveness of Axis Banks overall operations, but rather focuses on credit risk practices in relation to NPAs.

Hypotheses of the Study:

H₁: There is a significant relationship between the effectiveness of credit risk management practices and the reduction in Non-Performing Assets (NPAs) in banks.

H₂: Banks that adopt technology-based credit evaluation tools (e.g., credit scoring, AI-based underwriting, early warning systems) experience lower levels of NPAs compared to those using traditional methods.

H₃: Internal credit assessment frameworks have a greater impact on NPA mitigation than external regulatory mechanisms such as the IBC or PCA.

H₄: Sector-specific credit risk strategies significantly influence the level of NPAs in high-risk sectors like infrastructure, MSMEs, and real estate.

H₅: Higher capital adequacy ratios are positively associated with improved asset quality and lower NPAs.

H₆: Banks with well-defined provisioning and borrower profiling systems are more effective in preventing loans from becoming non-performing

Limitations of the Study:

Single Bank Focus: The study is limited to Axis Bank, which may restrict the generalizability of findings. Results may not represent the practices or outcomes of other private or public sector banks in India.

Data Availability Constraints: Access to detailed internal credit risk management data and proprietary risk models used by Axis Bank may be limited, which could affect the depth of analysis.

Time-Bound Analysis: The study focuses on a specific time frame, which may not fully capture long-term trends or the impact of evolving economic conditions on NPAs and risk strategies.

External Factors Not Fully Controlled: External economic variables such as inflation, interest rate changes, regulatory shifts, and global financial events may influence NPAs but are not fully accounted for in the scope of the study.

Dependence on Secondary Data: The study may rely heavily on secondary data sources such as annual reports, policy disclosures, and industry analyses, which could limit real-time insights into operational practices.

Subjectivity in Qualitative Assessment: Evaluation of credit risk practices may involve subjective interpretation of qualitative factors like governance structure, risk culture, and managerial efficiency.

Limited Stakeholder Input: Due to access restrictions, the study may not include interviews or surveys with key stakeholders (e.g., risk managers, auditors, credit officers), reducing the scope for practical insights.

Technology-Specific Constraints: The impact of fintech tools or AI-based models may not be fully assessable due to proprietary technologies and lack of detailed public documentation.

These limitations should be acknowledged while interpreting the results of the study and should guide future research to adopt broader, multi-bank, or cross-sectorial approaches for deeper insights.

III. RESEARCH METHODOLOGY

Research Design: The study adopts a **descriptive and analytical research design**, aiming to examine and evaluate the credit risk management practices employed by Axis Bank and their effectiveness in mitigating Non-Performing Assets (NPAs).

Data Collection Method:

- **Primary Data:**
 - Structured interviews or questionnaires (if access is granted) from Axis Bank's credit and risk management personnel.
 - Expert opinions from financial analysts or credit professionals (subject to availability).
- **Secondary Data:**
 - Axis Bank's Annual Reports and Financial Statements.
 - RBI Reports and publications.
 - Industry reports on NPAs and credit risk management.
 - Research articles, case studies, and white papers relevant to credit risk practices.

Sampling Technique:

Since the study is focused on a single institution (Axis Bank), **purposive sampling** is used to collect data from relevant departments or professionals within the bank and from published sources.

Tools and Techniques for Data Analysis:

- **Trend Analysis** of NPAs over a period.
- **Ratio Analysis**, including Gross NPA Ratio, Net NPA Ratio, and Provisioning Coverage Ratio.
- **Comparative Analysis** between pre- and post-credit strategy implementation periods.
- **Content Analysis** of internal policies, risk control frameworks, and technology applications.
- Use of **descriptive statistics** (mean, percentage, growth rate) for summarizing key findings.

Time Period of Study: The analysis will cover a period of the last **5 financial years**, to assess both short-term and evolving long-term impacts of credit risk strategies

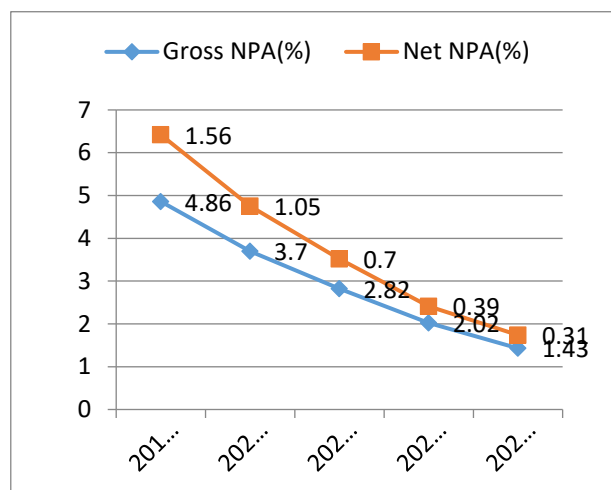
Data Analysis & Interpretation:

Trend Analysis: Trend analysis helps to study the movement of financial indicators over a period of time. In this project, it is used to observe the pattern of Gross and Net NPAs of Axis Bank from 2019 to 2024. The visual representation through line graphs highlights the banks NPA performance and its changes across the years.

Table1: Year-wise Gross NPA and Net NPA of Axis Bank

Year	Gross NPA (in Cr)	Gross NPA (%)	Net NPA (in Cr)	Net NPA (%)
2019-2020	30,611	4.86	10,275	1.56
2020-2021	29,560	3.7	7,563	1.05
2021-2022	21,823	2.82	6,087	0.7
2022-2023	34,326	2.02	7,130	0.39
2023-2024	32,581	1.43	6,052	0.31

Source: Compiled from Axis Bank Annual Reports (2019-2024)

Trend analysis of Gross and Net NPA**Interpretation:**

The above graph indicates a consistent decline in both gross and net NPA ratios of Axis Bank from year 2019 to 2024. Gross NPA reduced from 4.86% in 2019-2020 to 1.43% in 2023-2024. Similarly, Net NPA declined from 1.56% to 0.31%. This trend reflects the effective credit risk management strategies implemented by the bank. The fall in NPA percentages despite moderate gross NPA amounts indicates improvement in loan recovery and provisioning practices.

Ratio Analysis: Ratio analysis helps in understanding the banks financial stability and credit risk preparedness. The Provision Coverage Ratio and Capital Adequacy Ratio are key indicators of a bank's ability to absorb potential loan losses and maintain solvency. Provision Coverage Ratio (PCR) is a key indicator of how much protection the bank has against future NPA losses. A higher PCR reflects a safer financial position. Capital Adequacy Ratio (CAR) is an important measure of a bank's financial strength. It is the ratio of banks capital to its risk weighted assets.

Table 2: PCR and CAR Trends of Axis Bank (2019-2024):

Year	PCR (%)	CAR (%)
2019-2020	69	17.53
2020-2021	72	19.12
2021-2022	75	18.54
2022-2023	81	17.64
2023-2024	79	16.63

Source: Axis Bank Financial Statements

Interpretation:

Axis Banks PCR improved from 69% in 2019 to over 79% in 2024 shows the banks efforts to set aside adequate provisions and reduce credit risk. This increase demonstrates the banks strong recovery strategy and early recognition of loan defaults. Axis Bank has consistently maintained a CAR above the minimum regulatory requirement of 11.5%. The CAR remained in the range of 15-19%, indicating strong capital support and proper risk management. This indicates that the bank has enough capital buffer to cover risky loans and future uncertainties. The rise in PCR along with a stable CAR clearly supports the trend of reducing NPAs and shows the effectiveness of credit risk management at Axis Bank.

IV. STATISTICAL ANALYSIS

Correlation Analysis: Correlation analysis helps to determine the strength and direction of the relationship between two variables. In this study, it is used to evaluate how Gross NPA is related to Provision Coverage Ratio and Capital Adequacy Ratio of Axis Bank from 2019 to 2024

Table 3: Correlation between Gross NPA and Provision Coverage Ratio (PCR) of Axis Bank (2019-2024):

Year	Gross NPA (%)	PCR (%)
2019-2020	4.86	69
2020-2021	3.7	72
2021-2022	2.82	75
2022-2023	2.02	81
2023-2024	1.43	79

Source: Axis Bank Annual Reports

Table 4: Correlation matrix between Gross NPA and PCR:

	Gross NPA (%)	PCR (%)
Gross NPA (%)	1	
PCR (%)	-0.94841	1

Source: Calculated using MS Excel

Interpretation: The correlation coefficient between Gross NPA and PCR is -0.94841, which indicates strong negative correlation this means that as gross NPA increases the PCR tends to decrease. A high negative correlation suggests that the two variables move in opposite direction. This inverse relationship implies that higher level of NPAs is associated with a

lower provision coverage ratio which reflects the banks declining ability to cover its bad loans.

Table 5: Correlation between Gross NPA and Capital adequacy Ratio of Axis Bank (2019-2024):

Year	Gross NPA (%)	CAR (%)
2019-2020	4.86	17.53
2020-2021	3.7	19.12
2021-2022	2.82	18.54
2022-2023	2.02	17.64
2023-2024	1.43	16.63

Source: Axis Bank Annual Reports

Table 6: Correlation matrix between Gross NPA and CAR:

	Gross NPA (%)	CAR (%)
Gross NPA (%)	1	
CAR (%)	0.438222	1

Source: Calculated using MS Excel

Interpretation: The correlation coefficient between gross NPA and CAR is 0.438222, indicates a moderate positive correlation. This suggests that the gross NPA increases the CAR also tends to increase some extent. This may suggest that the bank increases its capital adequacy in response to rise NPAs as a safeguard to maintain financial stability and regulatory compliance.

Standard Deviation: Standard deviation is a statistical tool used to measure the extent of variation or dispersion in a dataset. In this study, it helps to understand how consistently Axis Bank managed its non-performing assets over the years. These values help assess the effectiveness of credit risk monitoring and highlight the need for sustained efforts to maintain asset quality.

Table 7: Year-wise Standard deviation of Gross NPA (%):

Year	Gross NPA (%)
2019-2020	4.86
2020-2021	3.7
2021-2022	2.82
2022-2023	2.02
2023-2024	1.43

Source: Axis Bank Annual Reports

Interpretation: The standard deviation of Gross NPA values for Axis Bank over the period from 2019 to

2024 is 1.2167. This value represents the degree of variation. A standard deviation of 1.21 indicates a moderate level of variability in gross NPA performance. Overall the banks performance in managing net NPAs has shown positive consistency and the reduction in variability over time indicates stronger credit risk governance.

Table 8: Year-wise Standard deviation of Net NPA (%):

Year	Net NPA (%)
2019-2020	1.56
2020-2021	1.05
2021-2022	0.7
2022-2023	0.39
2023-2024	0.31

Source: Axis Bank Annual Reports

Interpretation: The standard deviation of Net NPA values for year 2019 to 2024 is calculated to be 0.4600. This lower value indicates that the net NPA ratio has shown minimal fluctuation over the years. It shows that the Axis Banks credit appraisal systems, post disbursement monitoring and recovery mechanisms are functioning effectively and consistently.

ANOVA: ANOVA was used in this study to examine whether there were any significant differences in NPA levels across different quarters over a five Year period. A P- value greater than 0.05 indicates that the variations in quarterly NPA values are not statistically significant, meaning there is no major quarterly impact on the NPA trend

ANOVA Test on Quarterly Gross NPA Data:

Hypothesis:

Ho (null hypothesis): There is no significant difference in Gross NPA means across quarters

H1 (Alternative hypothesis): There is a significant difference in Gross NPA means across quarters

Table 9: Quarterly Gross NPA (%) of Axis Bank (2019-2024)

Year	Q1	Q2	Q3	Q4
2019-2020	5.25	5.03	5	4.86
2020-2021	4.72	4.28	3.44	3.7
2021-2022	3.85	3.53	3.17	2.82
2022-2023	2.76	2.5	2.38	2.02
2023-2024	1.96	1.73	1.58	1.43

Source: Compiled from Axis Bank Quarterly Reports
(2019-2024)

Table 10: ANOVA Summary for Quarterly Gross NPA (%):

ANOVA: Single Factor						
Summary						
Groups	Count	Sum	Average	Variance		
Q1	5	18.54	3.708	1.84407		
Q2	5	17.07	3.414	1.76153		
Q3	5	15.57	3.114	1.63958		
Q4	5	14.83	2.966	1.85038		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.628055	3	0.542685	0.305929	0.8207232	3.23887152
Within Groups	28.38224	16	1.77389			
Total	30.0103	19				

Source: Calculated using MS Excel

Interpretation: The obtained P-value is 0.8207, which is greater than 0.05. This indicates that the differences in quarterly Gross NPA values are not statistically significant. In simple terms, this means that Gross NPA levels have remained relatively stable across quarters, and any variations observed are due to chance rather than actual differences between quarters. This suggests that Axis Bank's credit risk management practices have likely contributed to consistent performance in NPA control throughout the year, rather than being affected by seasonal or quarterly fluctuations.

ANOVA for Quarterly Net NPA Data:

Hypothesis:

Ho (null hypothesis): there is no significant difference in Net NPA means across quarters

H1 (Alternative hypothesis): there is a significant difference in Net NPA means across quarters

Table 11: Quarterly Net NPA (%) of Axis Bank (2019-2024):

YEARS	Q1	Q2	Q3	Q4
2019-2020	2.04	1.99	2.09	1.56
2020-2021	1.23	1.03	0.74	1.05
2021-2022	1.2	1.08	0.91	0.73
2022-2023	0.64	0.51	0.47	0.39
2023-2024	0.41	0.36	0.36	0.31

Source: Compiled from Axis Bank Quarterly Reports (2019-2024)

Table 12: ANOVA Summary for Quarterly Net NPA (%):

ANOVA: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Q1	5	5.52	1.104	0.39953		
Q2	5	4.97	0.994	0.40923		
Q3	5	4.57	0.914	0.47933		
Q4	5	4.04	0.808	0.26322		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.23506	3	0.078353	0.202031	0.893459	3.238872
Within Groups	6.20524	16	0.387828			

Total	6.4403	19				

Interpretation: The result shows a P-value of 0.8934, which is greater than 0.05, and the F-v alue (0.2003) is also less than the F-critical value (3.2389). This means the differences in Net NPA values across quarters are not statistically significant. The variations are likely due to random fluctuations, not structural or policy changes. Hence, it can be interpreted that Axis Bank maintained consistent Net NPA performance across all quarters, indicating strong control over asset quality throughout the year.

Findings:

- Gross non-performing assets (NPA) of Axis Bank declined significantly from 4.86% in 2019–20 to 1.43% in 2023–24, indicating stronger credit screening and recovery efforts.
- Net NPAs also showed a notable reduction from 1.56% to 0.31% during the same period, reflecting improved asset quality and effective post-disbursement monitoring.
- The Provision Coverage Ratio (PCR) increased from 69% to 79%, suggesting that the bank has adopted a more conservative and proactive approach toward provisioning for potential credit losses.
- Capital Adequacy Ratio (CAR) remained consistently above the regulatory requirement of 11.5%, ranging between 16.63% and 19.12%, which highlights the bank's strong capital position and ability to absorb financial shocks.
- The correlation coefficient between Gross NPA and PCR was calculated as -0.948, indicating a strong inverse relationship, where higher provisioning was associated with lower levels of NPAs.
- The correlation between Gross NPA and CAR was moderately positive at 0.438, suggesting that while higher capital provides stability, it does not directly influence NPA reduction.
- The ANOVA test results indicated no significant differences in NPA values across different quarters, suggesting that the bank has maintained consistent performance in

credit risk management throughout the period.

- Standard deviation analysis showed moderate variability in Gross NPAs over the years, while Net NPAs exhibited even lower fluctuation, reflecting a stable and controlled credit risk environment.
- The application of internal rating models, early warning systems, and risk-based pricing played a crucial role in identifying high-risk accounts before they turned into defaults.
- Technological tools such as real-time credit dashboards, AI-based monitoring, and borrower behavior tracking helped the bank strengthen its early detection and decision-making processes.

Suggestions:

- **1. Strengthen Credit Appraisal for MSMEs and Retail Loans** Axis Bank should enhance its borrower evaluation process, especially for MSME and unsecured retail loans, by incorporating cash flow-based assessments and alternative credit scoring models to reduce default risk.
- **2. Integrate Alternative Data into Risk Assessment** To improve borrower profiling and predictive credit risk analysis, the bank should use non-traditional data sources such as GST returns, electricity bills, and transaction behavior patterns.
- **3. Improve Recovery and Resolution Mechanisms** The bank must streamline its recovery processes by reinforcing dedicated legal teams and leveraging fast-track options under DRT, SARFAESI, and IBC frameworks to reduce delays and increase recovery efficiency.
- **4. Upgrade Staff Training and Risk Culture** Regular training programs on emerging credit risks, RBI regulations, and fraud detection techniques should be provided to credit and risk management teams to ensure updated practices and stronger risk culture.
- **5. Adopt Advanced Technology for Risk Monitoring** Artificial intelligence and

machine learning tools should be widely adopted for real-time monitoring of borrower behavior, automated early warning signals, and dynamic risk scoring.

- **6. Enhance Post-Disbursement Monitoring** A structured mechanism should be developed to track loan utilization and repayment trends soon after disbursement, particularly during the initial 12 months when risk of default is higher.
- **7. Introduce Incentive-Based Risk Management** Branches and credit teams that consistently maintain low NPA ratios should be rewarded to encourage a performance-driven approach to risk control and portfolio quality.
- **8. Monitor Sectorial Exposure Limits** The bank should actively manage its exposure to high-risk sectors like real estate, infrastructure, and textiles by enforcing prudent internal limits and conducting regular sector stress testing.
- **9. Conduct Frequent Internal Risk Audits** More frequent, data-backed internal audits should be implemented to identify lapses in credit sanctioning, documentation, and monitoring phases, allowing for timely corrective measures.
- **10. Promote Financial Literacy Among Borrowers** Axis Bank should organize financial awareness sessions and onboarding education to help borrowers understand loan terms, repayment schedules, and the importance of credit discipline.

V. CONCLUSION

In the dynamic landscape of Indian banking, credit risk continues to be a critical area that impacts both profitability and long-term sustainability. The ability to effectively manage credit exposure determines how well a bank can withstand economic uncertainties and regulatory challenges. This study analysed the performance of Axis Bank over a five-year period, revealing a steady reduction in both Gross and Net NPAs. The evidence suggests that the bank's internal credit risk framework—including its rating models, early warning signals, and provisioning policies—has been instrumental in maintaining asset quality. The

results from tools like trend analysis, correlation, standard deviation, and ANOVA further validate the consistency and strength of Axis Bank's credit management practices. While the outcomes are encouraging, the study also identifies areas where the bank can grow further, such as improving MSME loan monitoring, integrating real-time analytics, and enhancing recovery mechanisms. In conclusion, Axis Bank demonstrates how a robust credit risk management framework can reduce NPA levels and contribute to stronger financial performance, ultimately supporting stability in the wider banking sector.

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A Study on Foreign Direct Investment Impact on the Indian Economy

Umamaheswararao Gobbilla¹, Bandam Mallikharjun²

¹Associate Professor, Department of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study investigates the impact of Foreign Direct Investment (FDI) on India's economic growth from 2017 to 2024, utilizing secondary data analysis and regression techniques. The methodology involves analysing sectorial FDI inflows, their contribution to gross domestic product, and correlations with macroeconomic indicators such as inflation and stock market performance. Findings reveal that while FDI inflows have fluctuated, peaking during 2020-21, their direct influence on GDP, inflation, and stock indices remains statistically insignificant. The research highlights that FDI primarily benefits manufacturing and technology sectors, with limited immediate macroeconomic effects. These results imply that FDI alone cannot drive rapid economic changes but plays a vital role in sectorial development and long-term growth. The study underscores the importance of comprehensive policy measures to optimize FDI's contribution to sustainable economic progress.

Keywords— Foreign Direct Investment (FDI), Indian Economy, Economic Growth, Capital Inflow, Investment Policy, Sectorial Investment, GDP Growth, FDI Trends in India.

I. INTRODUCTION

Foreign Direct Investment (FDI) serves as a key driver of economic growth in India, fostering capital formation, employment opportunities, and technological advancements. Since the economic liberalization of 1991, India has emerged as one of the most attractive destinations for global investors due to its vast consumer base, evolving policy frameworks, and improving ease of doing business. As one of the leading emerging economies, India's ability to attract FDI has played a crucial role in enhancing its industrial capabilities, strengthening its global competitiveness, and fostering economic resilience.

The inflow of foreign capital has contributed significantly to various sectors, including manufacturing, services, infrastructure, and technology, thereby accelerating economic progress.

Over the years, India has introduced a series of reforms aimed at liberalizing FDI norms, improving investor confidence, and streamlining regulatory frameworks. The abolition of the Foreign Investment Promotion Board (FIPB) in 2017 marked a significant shift in the country's FDI approval mechanism, making the process more transparent and efficient. Policies such as the Make in India initiative, the implementation of the Goods and Services Tax (GST), and increased foreign equity limits in critical sectors have further fuelled investment inflows.

This study examines FDI inflows to India from 2017-18 to 2023-24, focusing on sectoral distribution, economic impact, and policy implications. The research aims to identify the industries that have benefited the most from foreign investments and assess the contribution of FDI to India's GDP growth and capital formation. Understanding the sector-wise

distribution of FDI is crucial for determining which industries have attracted the most investment and evaluating their role in economic expansion. Additionally, the study aims to assess how these inflows have influenced job creation, infrastructure development, and technology transfer in India's key industrial sectors.

Furthermore, a comparative analysis with other emerging economies will highlight India's strengths, weaknesses, and areas for improvement in attracting foreign investments. India competes with other developing nations such as China, Brazil, and Indonesia in securing foreign capital. By analyzing FDI inflows in these economies, this study will offer insights into India's performance relative to its peers and suggest strategic measures for improving its investment climate. The role of geopolitical factors, trade agreements, and bilateral relations in shaping FDI trends will also be explored.

Additionally, this study explores the effectiveness of government policies and regulatory frameworks in facilitating FDI inflows. India has periodically revised its FDI policies to enhance ease of doing business, mitigate investment risks, and encourage long-term foreign participation. By examining country-wise and industry-wise FDI data, this research provides insights into key contributors to India's foreign investment landscape. The findings will help policymakers, investors, and stakeholders develop strategies to maximize the benefits of FDI and ensure sustainable economic growth.

Ultimately, this study aims to provide a comprehensive understanding of India's FDI landscape, identifying key trends, opportunities, and challenges. By evaluating policy effectiveness and investment patterns, this research will contribute to ongoing discussions on economic development and provide actionable insights for enhancing India's position as a preferred global investment destination.

II. LITERATURE REVIEW

1. **Shalini D. D. (2020)** uncovered the significance of Foreign Direct Investment (FDI) in India. FDI plays a crucial role in uniting diverse aspects of the country's economy by injecting capital into sectors such as manufacturing, infrastructure, transportation, technology, productivity, and

hospitality. The study also examined the FDI trends and foreign investment patterns in India. The conclusion emphasizes that FDI is minimally anacted by the GDP contribution and growth rates of FDI industries.

2. **Singh, S. (2019) stated in his paper**, Indian economy is one of the top emerging markets of the world. Five yearsago, it was considered as part of the fragile, but no longer. Since 2014, it has emerged as of the top foreign destination in the world with a significant rise in FDI. India has become one of the most attractive emerging markets globally. The gross FDI received from April 2000 to June 2018 is USD563320 million. This flow of fund over the year helped the country in advancement of technology, skill upgradation, employment generation, better infrastructure and management.
3. **Jpnardankoner, Dipayan Roy and Avinash Purander (2018)** in their study they focused on the FDI on the growth of the Indian economy. They and raise in FDI after liberalization. Further they discussed about the impact of direct and indirect FDI on the economy. Important impacts on domestic income, employment, price level, productivity, efficiency, and export growth are created by direct foreign direct investment (FDI) in ows.
4. **Ravi. B `and V. Benchali (2018)** study taken with the objective analysed with the advantages of FDI for an emerging market like India. Finally, it was concluded that it had more merits than demerits attached to FDI and the Indian Government must go for it if it wants India to progress further and become a super power.
5. **Febina K., Thomas Paul Kattookaran, (2018)**, in their paper, "A study on interstate distribution and sectoral composition of FDI inflows in India", studied that an overview on the sectoral distribution of foreign investment discloses the wide disparity in the distribution of foreign capital among various sectors. The identified objectives are finding out the pattern of FDI inflow in India and also its impact with the economy. The descriptive research is been used in the study. The data used is secondary data. While some sectors like service, construction, etc. receive elevated

flow of foreign capital, others are fully ignored by the foreign investors.

6. **Vyas, A.V (2015)** highlighted the significant role of FDI in India's economic growth and development, particularly in job creation and industrial expansion. From April 2000 to June 2015, FDI inflows in services, construction, IT, and pharmaceuticals contributed to sustained growth. However, investor interest in some sectors remained low. FDI boosted output, productivity, and employment, especially in services, while banking and insurance strengthened the economy. It also supported small-scale industries and enhanced India's global presence through liberalization and globalization.

Research Gap:

The existing literature extensively highlights the positive impact of Foreign Direct Investment (FDI) on India's economic growth, including its role in employment generation, technology transfer, sectoral development, and infrastructure enhancement. Studies by Shalini D.D. (2020), Singh S. (2019), and Vyas A.V. (2015) underline the macroeconomic benefits of FDI and its contribution to sectors like services, construction, IT, and pharmaceuticals. However, there is limited empirical investigation into the regional and sectoral disparities of FDI inflows, particularly the uneven distribution across Indian states and lesser-focused sectors. While some studies (e.g., Febina K. & Thomas Paul Kattookaran, 2018) note this disparity, there is a lack of in-depth analysis linking these disparities to economic outcomes such as sectoral growth, productivity changes, and employment quality.

Furthermore, few studies differentiate the qualitative impact of direct vs. indirect FDI, or explore the long-term sustainability and spillover effects of FDI in underrepresented sectors. There is also a noticeable gap in understanding how policy reforms and liberalization measures post-2015 have influenced sector-specific FDI trends and investor behaviour.

Statement of the Problem:

India has witnessed steady FDI inflows in recent years, but the extent to which these investments drive economic growth remains uncertain. There is a need to examine whether FDI is making a measurable contribution to key indicators like GDP, stock market

performance, and inflation. This study aims to address this gap by analyzing the real impact of FDI on India's economic development from 2018 to 2024.

Need For the Study:

Foreign Direct Investment (FDI) is a key driver of economic growth, influencing various sectors, capital formation, and overall development. This study is essential to assess the sectoral distribution of FDI in India, identifying industries that have benefited the most from foreign investments.

Additionally, the study aims to analyze the impact of FDI on India's economic growth by examining its contribution to GDP and capital formation. A comparative analysis with other emerging economies will help evaluate India's FDI performance, highlighting strengths and areas for improvement.

Furthermore, the research will assess the role of government policies and regulatory frameworks in facilitating or restricting FDI inflows. Understanding the effectiveness of these policies is crucial for shaping a competitive and investor-friendly business environment.

Overall, this study will provide insights into FDI trends, their economic implications, and strategic measures to enhance India's attractiveness as a global investment destination.

Objectives of the Study:

- To assess the sectoral distribution of FDI in India.
- To analyze the FDI Trends in India.
- To compare India's FDI performance with China.
- To analyze the impact of FDI on India's economic growth.

Scope of the Study:

- This study focuses on analyzing Foreign Direct Investment (FDI) inflows in India, their sectoral distribution, and their impact on economic growth. It covers a detailed examination of how FDI contributes to GDP, capital formation, and industrial development.
- The study extends to a comparative analysis of India's FDI performance with other emerging economies, identifying key strengths, challenges, and areas for improvement. Additionally, it assesses the effectiveness of

government policies and regulatory frameworks in attracting foreign investments.

- The research is based on historical data from 2017-18 to 2023-24, providing insights into FDI trends, sectoral shifts, and policy impacts. It aims to help policymakers, businesses, and investors understand the role of FDI in India's economic growth and future investment opportunities.

Hypotheses of the Study:

H₀₁ (Null Hypothesis): There is no significant impact of Foreign Direct Investment (FDI) on the overall economic growth of India.

H₁₁ (Alternative Hypothesis): There is a significant impact of Foreign Direct Investment (FDI) on the overall economic growth of India.

H₀₂: FDI inflows do not significantly contribute to employment generation in India.

H₁₂: FDI inflows significantly contribute to employment generation in India.

H₀₃: There is no significant relationship between FDI and the development of the industrial and service sectors in India.

H₁₃: There is a significant relationship between FDI and the development of the industrial and service sectors in India.

H₀₄: Sectoral disparities in FDI inflows do not significantly affect regional economic development in India.

H₁₄: Sectoral disparities in FDI inflows significantly affect regional economic development in India.

H₀₅: There is no significant difference in the impact of FDI on direct and indirect economic indicators (e.g., GDP, productivity, export performance).

H₁₅: There is a significant difference in the impact of FDI on direct and indirect economic indicators (e.g., GDP, productivity, export performance).

Limitations of the Study:

- Limited Variables: The study focuses mainly on FDI's relationship with GDP, inflation, and Sensex. Other important economic factors like exchange rates, interest rates, employment levels, and trade balance were not included due to scope limitations.

- Secondary Data Reliance: The project is based entirely on secondary data collected from government and financial sources. The accuracy of the findings depends on the authenticity and consistency of those sources.
- No Sector-Level Statistical Analysis: While sector-wise FDI inflow trends were described, no detailed statistical analysis was conducted to measure the quantitative impact of FDI on specific industries.
- External Factors Not Fully Considered: Global events like geopolitical tensions, currency volatility, oil price fluctuations, and global recession risks were acknowledged but not deeply analysed for their direct influence on FDI flows.
- Policy Impact Assessment Missing: The study mentions various government schemes like Make in India and PLI but does not quantify their direct influence on attracting FDI, which could have added more depth.

III. RESEARCH METHODOLOGY

Research Design

This study follows an analytical research design to understand the impact of Foreign Direct Investment (FDI) in India from 2017 to 2024. Analytical research helps in identifying the reasons behind trends and their effects. It involves using existing data, reports, and facts, which are then examined to make a critical evaluation.

In this approach, the research breaks down the problem into key elements, analyzes the available information, and interprets the findings to understand how FDI has influenced different sectors and economic growth over the years.

Data Collection Method

This study is based on secondary data, which is collected from reliable sources to analyze the impact of Foreign Direct Investment (FDI) in India. The key sources of data include:

1. FDI Inflow Data – Taken from the RBI Annual Report, which provides details on foreign investments across different sectors.

2. GDP Data – Collected from the World Bank Group, which gives insights into India's economic growth trends.

By analysing this data, the study aims to evaluate the relationship between FDI inflows and economic development in India.

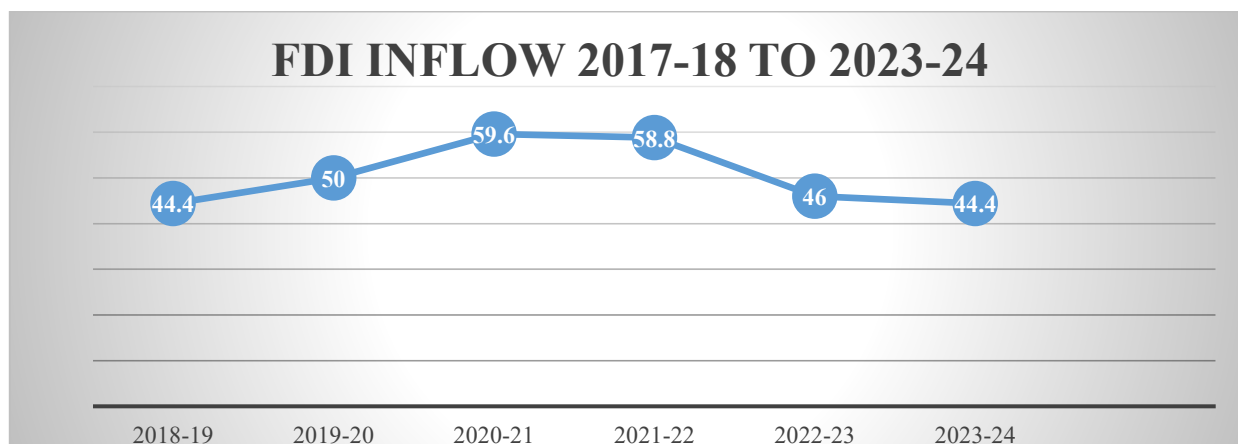
Tools and Software

The software used for this study is Microsoft Excel. Excel is utilized for data organization, statistical analysis, and visualization. The study employs descriptive statistics, regression analysis to analyse FDI inflows. These methods help in identifying trends, relationships, and patterns in the data.

Variables Used:

The variables used in this study are GDP, Inflation Rate, Sensex which help analyse the impact of FDI in India. GDP reflects the contribution of FDI to economic growth, while the inflation rate indicates economic stability, influencing foreign investment decisions. Sensex represents stock market performance and investor confidence. These variables together provide a comprehensive understanding of how FDI influences India's economic performance.

Data Analysis & Interpretation:



Interpretation:

India's Foreign Direct Investment (FDI) inflows have experienced fluctuations over the years due to a mix of global economic factors, domestic policies, and investor sentiment. The following is an overview of FDI inflows from 2017-18 to 2023-24 and key drivers influencing these trends.

- 2017-18: \$44.9 billion – Stable Growth

Analyse The FDI Trends In India

Foreign Direct Investment (FDI) serves as a key driver of economic development, influencing multiple sectors by providing capital, improving infrastructure, and introducing global best practices. This project aims to critically analyze the sectoral distribution of FDI in India, examining which industries attract the most investment and why. Additionally, we evaluate the impact of FDI on India's economic growth, employment generation, and industrial development.

FDI INFLOW DATA FROM 2017-18 to 2023-24:

Year Wise FDI Inflows	
2017-18	44.9
2018-19	44.4
2019-20	50
2020-21	59.6
2021-22	58.8
2022-23	46
2023-24	44.4

Source: RBI Annual Report

FDI inflows stood at \$44.9 billion, reflecting steady investor confidence in India's growing economy. Key sectors such as manufacturing, information technology, and financial services attracted significant foreign investments. Government initiatives aimed at improving the ease of doing business contributed to maintaining stable inflows.

- 2018-19: \$44.4 billion – Marginal Decline

A slight drop to \$44.4 billion was observed, primarily due to uncertainties in global trade and economic slowdowns in major economies. Despite this, investment remained steady in areas like telecommunications, e-commerce, and infrastructure, indicating continued foreign interest in India's market potential.

- 2019-20: \$50.0 billion – Notable Growth
FDI inflows grew by 13%, reaching \$50 billion. This increase was driven by policy reforms, a favourable investment climate, and the rapid expansion of India's digital and consumer markets. Growing investments in technology startups and innovation-driven industries further fuelled this upward trend.
- 2020-21: \$59.6 billion – Peak Inflows
Despite the global economic disruptions caused by the COVID-19 pandemic, India received a record-high \$59.6 billion in FDI. The pandemic accelerated digital adoption, boosting investments in technology, e-commerce, healthcare, and infrastructure. Additionally, India's role as an emerging global supply chain hub strengthened investor interest.
- 2021-22: \$58.8 billion – Slight Dip, but Strong Inflows
FDI inflows slightly declined to \$58.8 billion, reflecting some stabilization after the pandemic-driven surge. However, strong investments continued in fintech, manufacturing, and infrastructure, supported

by the Production Linked Incentive (PLI) scheme, which encouraged domestic production and foreign participation in various sectors.

- 2022-23: \$46.0 billion – Significant Decline
FDI inflows saw a 21.8% drop to \$46 billion, primarily due to rising global inflation, geopolitical tensions, and economic uncertainties. Despite this decline, sectors such as renewable energy, information technology, and digital services continued to attract foreign investments.
- 2023-24: \$44.4 billion – Further Decline
A continued downward trend brought FDI inflows to \$44.4 billion, the lowest level since 2018-19. Factors such as high interest rates, cautious investor sentiment, and tighter global financial conditions contributed to this decrease. However, India remains a preferred investment destination due to its expanding digital economy, growing focus on green energy, and ongoing policy reforms aimed at improving foreign investment opportunities.

Analysis of Sectorial Distribution of FDI in India (2017-2024): This analysis examines the trends in FDI inflows across various sectors in India from 2017 to 2024, identifying key industries attracting investments and the factors influencing sectorial distribution. It provides insights into how FDI has shaped economic growth and industrial development during this period.

Table: 1

Billion's \$							
Sector	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-2024
Manufacturing	\$ 9.00	\$ 9.60	\$ 9.60	\$ 9.30	\$ 16.30	\$ 11.30	\$ 9.30
Computer Services	\$ 3.40	\$ 3.70	\$ 5.10	\$ 23.80	\$ 9.00	\$ 3.30	\$ 5.50
Communication Services	\$ 9.10	\$ 6.50	\$ 7.80	\$ 2.90	\$ 6.40	\$ 5.60	\$ 4.90
Retail & Wholesale Trade	\$ 4.60	\$ 4.90	\$ 5.10	\$ 3.90	\$ 5.10	\$ 6.80	\$ 4.40
Financial Services	\$ 4.60	\$ 7.20	\$ 5.70	\$ 3.50	\$ 4.70	\$ 5.30	\$ 4.10
Education, Research & Development	\$ 0.40	\$ 0.90	\$ 0.80	\$ 1.30	\$ 3.60	\$ 1.70	\$ 3.80

Transport	\$ 2.50	\$ 1.20	\$ 2.40	\$ 7.90	\$ 3.30	\$ 4.50	\$ 3.70
Construction	\$ 2.80	\$ 2.30	\$ 2.00	\$ 1.80	\$ 3.20	\$ 2.00	\$ 2.60
Business services	\$ 3.30	\$ 2.80	\$ 3.80	\$ 1.80	\$ 2.50	\$ 1.40	\$ 2.20
Electricity and other energy Generation, Distribution & Transmission	\$ 2.80	\$ 2.60	\$ 2.80	\$ 1.30	\$ 2.20	\$ 1.20	\$ 1.90
Miscellaneous Services	\$ 0.90	\$ 1.40	\$ 1.10	\$ 0.90	\$ 1.00	\$ 1.90	\$ 0.60
Restaurants and Hotels	\$ 0.50	\$ 0.80	\$ 2.70	\$ 0.30	\$ 0.70	\$ 0.20	\$ 0.40
Mining	\$ 0.10	\$ 0.30	\$ 0.30	\$ 0.20	\$ 0.40	\$ 0.10	\$ 0.30
Real Estate Activities	\$ 0.50	\$ 0.20	\$ 0.60	\$ 0.40	\$ 0.10	\$ 0.20	\$ 0.10
Others	\$ 0.30	\$ 0.10	\$ 0.20	\$ 0.20	\$ 0.40	\$ 0.50	\$ 0.70
Total FDI Inflows	\$ 44.80	\$ 44.50	\$ 50.00	\$ 59.50	\$ 58.90	\$ 46.00	\$ 44.50

Source: RBI Annual Report

Percentage of Sectors Inflow:

Percentage of Each sector							
Sector	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-2024
Manufacturing	20.09	21.57	19.20	15.63	27.67	24.57	20.90
Computer Services	7.59	8.31	10.20	40.00	15.28	7.17	12.36
Communication Services	20.31	14.61	15.60	4.87	10.87	12.17	11.01
Retail & Wholesale Trade	10.27	11.01	10.20	6.55	8.66	14.78	9.89
Financial Services	10.27	16.18	11.40	5.88	7.98	11.52	9.21
Education, Research & Development	0.89	2.02	1.60	2.18	6.11	3.70	8.54
Transport	5.58	2.70	4.80	13.28	5.60	9.78	8.31
Construction	6.25	5.17	4.00	3.03	5.43	4.35	5.84
Business services	7.37	6.29	7.60	3.03	4.24	3.04	4.94
Electricity and other energy Generation, Distribution & Transmission	6.25	5.84	5.60	2.18	3.74	2.61	4.27
Miscellaneous Services	2.01	3.15	2.20	1.51	1.70	4.13	1.35
Restaurants and Hotels	1.12	1.80	5.40	0.50	1.19	0.43	0.90

Mining	0.22	0.67	0.60	0.34	0.68	0.22	0.67
Real Estate Activities	1.12	0.45	1.20	0.67	0.17	0.43	0.22
Others	0.67	0.22	0.40	0.34	0.68	1.09	1.57
Total FDI %	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: RBI Annual Report

Interpretation:

Foreign Direct Investment (FDI) inflows have fluctuated across different sectors over the years, reflecting changes in global economic conditions, government policies, and industry attractiveness.

➤ **Manufacturing Sector:**

The manufacturing sector has consistently been a major recipient of FDI, with its highest inflow in 2021-22 at \$16.3 billion (27.67%), indicating a surge in investor confidence. However, the sector saw a decline in the following years, dropping to \$9.3 billion (20.90%) in 2023-24, possibly due to global supply chain disruptions and shifting investment priorities.

➤ **Computer Services:**

Investment in computer services peaked significantly in 2020-21 with \$23.8 billion (40%), aligning with the global digital transformation and increased demand for IT services during the pandemic. However, in subsequent years, FDI in this sector dropped sharply to \$3.3 billion (7.17%) in 2022-23 but showed a recovery to \$5.5 billion (12.36%) in 2023-24, reflecting the ongoing relevance of digital technology.

➤ **Communication Services:**

This sector, which includes telecommunications and media, saw strong FDI inflows in the earlier years but declined significantly in 2020-21 (\$2.9 billion, 4.87%). The downturn was likely due to market saturation and regulatory challenges. While there was a slight recovery in 2021-22 (\$6.4 billion, 10.87%), the sector remains below its earlier peak.

➤ **Retail & Wholesale Trade:**

FDI in retail and wholesale trade has remained stable, with a peak of \$6.8 billion

(14.78%) in 2022-23, reflecting growing consumer demand and policy relaxations in e-commerce. However, the inflow dropped to \$4.4 billion (9.89%) in 2023-24, possibly due to changing trade regulations and global economic slowdowns.

➤ **Financial Services:**

Investment in financial services has been inconsistent, peaking at \$7.2 billion (16.18%) in 2018-19 before declining in subsequent years. The sector's contribution to total FDI stood at \$4.1 billion (9.21%) in 2023-24, showing resilience but also reflecting a shift in investor interest toward technology-driven financial solutions.

➤ **Education, Research & Development:**

The education and R&D sector have seen a remarkable rise in FDI, growing from \$0.4 billion (0.89%) in 2017-18 to \$3.8 billion (8.54%) in 2023-24. This trend suggests increased global interest in India's education technology (EdTech) and research capabilities, particularly in the post-pandemic era.

➤ **Transport Sector:**

Transport-related investments peaked in 2020-21 (\$7.9 billion, 13.28%), likely due to infrastructure expansion projects. However, in the following years, investment declined, stabilizing at \$3.7 billion (8.31%) in 2023-24, reflecting fluctuations in transportation demand and policy changes.

➤ **Construction & Real Estate:**

FDI inflows in construction have remained relatively low but stable, peaking at \$3.2 billion (5.43%) in 2021-22 before slightly dropping. The real estate sector, on the other hand, has seen minimal investment, with inflows shrinking to \$0.1 billion (0.22%) in 2023-24, highlighting ongoing challenges in

regulatory frameworks and investor confidence.

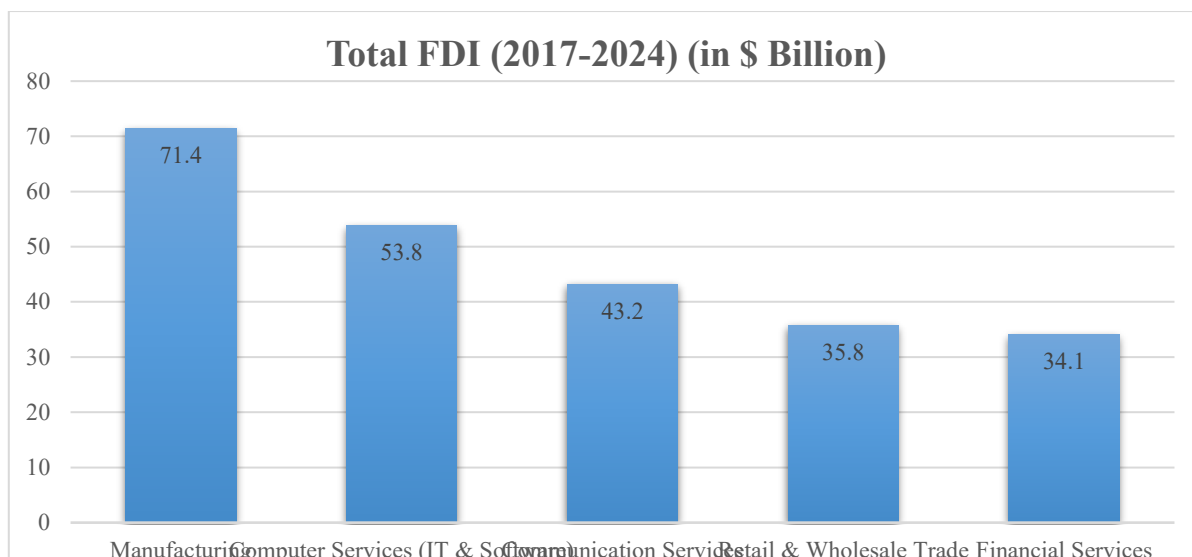
- **Business & Miscellaneous Services:**
Business services have seen varying levels of FDI, with a downward trend from \$3.8 billion (7.60%) in 2019-20 to \$2.2 billion (4.94%) in 2023-24, indicating a shift in investor preference. Miscellaneous services remain a minor contributor, with fluctuating investment trends.
- **Energy & Mining:**
Investment in energy-related sectors has generally remained low, with FDI in electricity, generation, and distribution

peaking at \$2.8 billion (5.60%) in 2019-20 before declining. Mining has received minimal attention from foreign investors, with inflows below \$0.4 billion annually across all years.

- **Restaurants, Hotels, and Hospitality:**
This sector experienced a peak in 2019-20 (\$2.7 billion, 5.40%), likely due to pre-pandemic tourism growth. However, investments dropped sharply in 2020-21 (\$0.3 billion, 0.50%) and have struggled to recover since. The industry continues to face challenges in attracting FDI despite improving global travel conditions.

TOP 5 ATTRACTING SECTORS:

Rank	Sector	Total FDI (2018-2024) (in \$ Billion)	Peak Year	Peak FDI (in \$ Billion)	Key Growth Drivers
1	Manufacturing	71.4	2021-22	16.3	Make in India, PLI scheme, China+1 strategy
2	Computer Services (IT & Software)	53.8	2020-21	23.8	Digital transformation, cloud computing, AI growth
3	Communication Services	43.2	2017-18	9.1	5G expansion, telecom sector liberalization, Jio & Airtel investments
4	Retail & Wholesale Trade	35.8	2022-23	6.8	E-commerce boom, foreign investments in Flipkart & Amazon
5	Financial Services	34.1	2018-19	7.2	Fintech revolution, banking & insurance sector liberalization

**Interpretation:**

The leading sectors receiving the highest FDI in India from 2017-18 to 2023-24 are Manufacturing, Computer Services, Communication Services, Retail & Wholesale Trade, and Financial Services. These industries have attracted investments due to supportive government policies, technological advancements, and increasing market opportunities.

Foreign Direct Investment (FDI) in India from 2017-18 to 2023-24 has been concentrated in five key sectors:

- Manufacturing (\$71.40 billion) – Driven by Make in India, the PLI scheme, and India's role as a global manufacturing hub.
- Computer Services (\$53.80 billion) – Boosted by investments from tech giants, digital transformation, and increasing demand for cloud computing and AI.
- Communication Services (\$43.20 billion) – Growth fuelled by 5G expansion, mobile broadband, and major foreign investments in Reliance Jio and Bharti Airtel.
- Retail & Wholesale Trade (\$35.80 billion) – Supported by e-commerce expansion, investments from Amazon, Walmart (Flipkart), and Alibaba, and digital payments growth.

- Financial Services (\$34.10 billion) – Increased FDI due to growth in fintech, digital banking, insurance, and NBFCs, alongside policy liberalization.

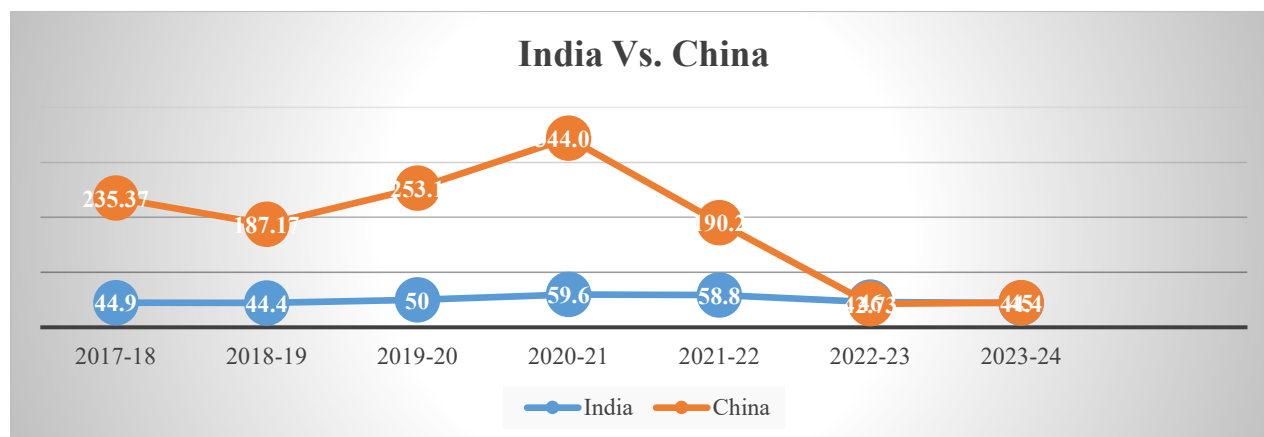
To compare India's FDI performance with China:

Foreign Direct Investment (FDI) is a key driver of economic expansion and industrial growth. Comparing India's FDI inflows with China helps evaluate investment trends and global investor confidence in both economies. While China has traditionally attracted higher FDI, recent years have seen fluctuations, whereas India has maintained steady inflows. This comparison highlights the changing dynamics of foreign investments and India's growing role as a preferred destination.

Year Wise FDI Inflows		
Years	India	China
2017-18	44.9	235.37
2018-19	44.4	187.17
2019-20	50	253.1
2020-21	59.6	344.07
2021-22	58.8	190.2
2022-23	46	42.73
2023-24	44.4	45

Source: *INDIA: RBI Annual Reports.

*CHINA: World Bank Data.



Overall FDI Trends (2018-2024):

- India's FDI inflows have remained relatively stable, fluctuating between \$44.4 billion and \$59.6 billion.
- China's FDI inflows were significantly higher than India's but showed volatility, peaking at \$344.07 billion in 2020-21 before dropping to \$42.73 billion in 2022-23.

FDI Volume:

- China historically received much higher FDI than India, sometimes 5-6 times more.
- India's highest FDI inflow was \$59.6 billion (2020-21), while China peaked at \$344.07 billion (2020-21).

Volatility & Stability:

- India's FDI has been relatively steady, ranging between \$44 billion and \$60 billion.
- China's FDI fluctuated significantly, with a sharp drop from \$344.07 billion (2020-21) to \$42.73 billion (2022-23).

Reasons for China's Decline:

- Geopolitical Tensions: The U.S.-China trade war and restrictions on foreign investments have led to uncertainty among global investors. A 2023 survey by the Japanese Chamber of Commerce in China indicated that nearly half of Japanese firms planned to reduce or halt investments due to rising tensions.
- Regulatory Crackdowns: The Chinese government's strict regulations on the

technology and real estate sectors have created an uncertain investment climate. High-profile actions like the suspension of Ant Group's IPO and increased scrutiny of data privacy have raised investor concerns.

- COVID-19: Extended lockdowns and stringent pandemic measures disrupted supply chains and business operations. Many foreign companies have started diversifying their investments to other countries to reduce dependency on China.

India is maintaining stable FDI inflows, while China is experiencing a sharp decline. China's long-standing dominance in FDI is weakening, creating opportunities for India to attract more global investments. As investor confidence in China declines due to regulatory issues and geopolitical tensions, India can position itself as a more favourable destination for foreign investments.

Impact of FDI on India's economic growth:

FDI Contribution to GDP:

Impact of FDI on India's Economic Growth

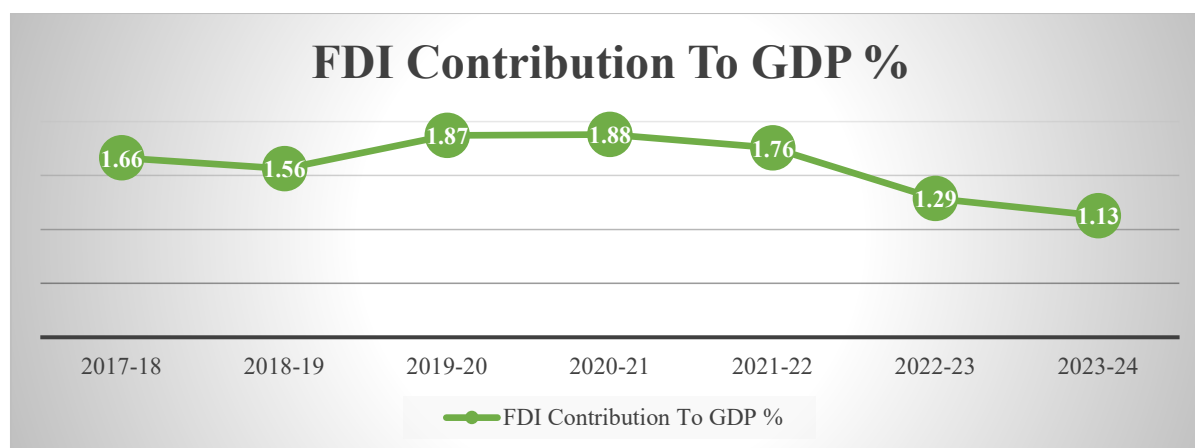
Foreign Direct Investment (FDI) plays a crucial role in India's economic development by bringing in capital, technology, and employment opportunities. It supports key sectors like infrastructure, manufacturing, and services, driving GDP growth. Analyzing the year-wise FDI inflows and their contribution to GDP helps in understanding its impact on economic expansion and investment trends.

Table:

Year Wise FDI Inflows		GDP IN Billion \$	FDI Contribution to GDP %
2017-18	44.9	2700	1.66
2018-19	44.4	2840	1.56
2019-20	50	2670	1.87
2020-21	59.6	3170	1.88
2021-22	58.8	3350	1.76
2022-23	46	3570	1.29
2023-24	44.4	3940	1.13

Source: RBI Annual Reports.

World Bank Group.

**Interpretation:****Year-wise Analysis of FDI Contribution to India's GDP (2017-2024)**

In 2017-18, India received \$44.9 billion in FDI, contributing 1.66% to the total GDP of \$2700 billion. This indicates a steady flow of foreign investments, supporting economic growth.

In 2018-19, FDI slightly declined to \$44.4 billion, while GDP increased to \$2840 billion, reducing the FDI contribution to 1.56%. This suggests that India's economic expansion was more dependent on domestic factors rather than foreign capital.

In 2019-20, FDI inflows rose to \$50 billion, but GDP declined to \$2670 billion, increasing FDI's share to 1.87%. This shows that foreign investments played a crucial role in stabilizing the economy during slower growth.

FDI V/S SENSEX

Years	India FDI Inflows (Millions)	SENSEX Close (Thousands)
2017-18	45	35,400.45
2018-19	44	38,628.17

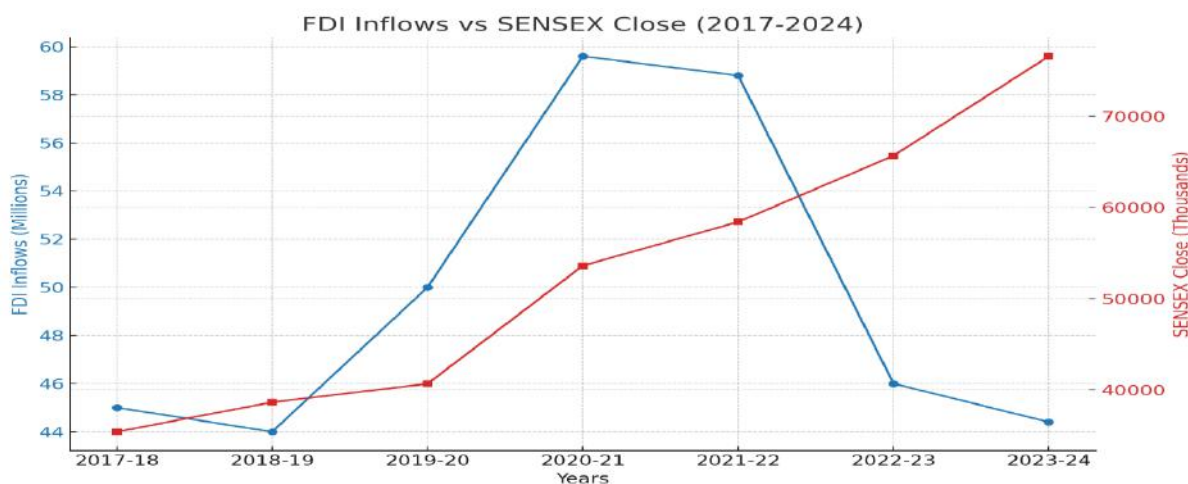
In 2020-21, FDI peaked at \$59.6 billion, contributing 1.88% to GDP, which increased to \$3170 billion. The rise was largely driven by higher investments in digital services, e-commerce, and manufacturing during the pandemic period.

In 2021-22, FDI slightly dropped to \$58.8 billion, while GDP grew to \$3350 billion, bringing FDI's contribution down to 1.76%. This indicates that while FDI inflows remained strong, India's overall economic growth was primarily driven by other factors.

In 2022-23, FDI inflows declined sharply to \$46 billion, while GDP grew to \$3570 billion, reducing FDI's contribution to 1.29%. The decline reflects global investment uncertainties and cautious investor sentiment.

2019-20	50	40,659.14
2020-21	59.6	53,611.25
2021-22	58.8	58,413.78
2022-23	46	65,670.19
2023-24	44.4	76,584.31

Source: World Bank Data and NSE

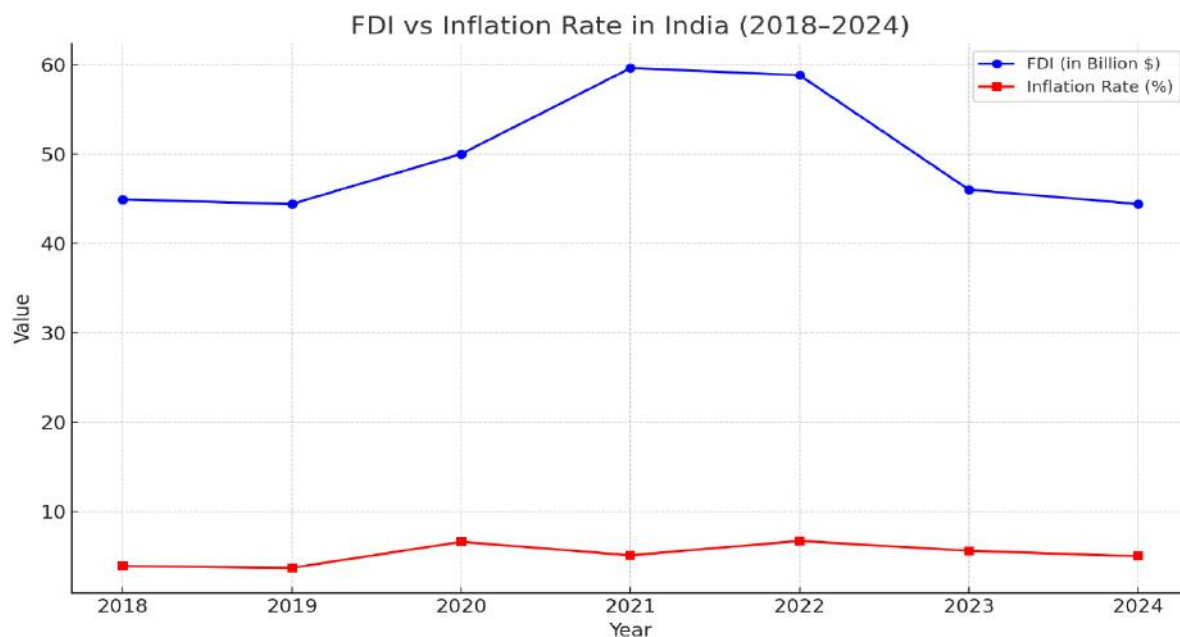


- Overall Market Growth Despite FDI Fluctuation: Over the seven-year period, the SENSEX consistently increased from around 35,400 in 2017-18 to over 76,500 in 2023-24, showing strong market performance. However, FDI inflows did not show a consistent upward trend, indicating that the stock market was growing even when FDI was falling.
- FDI Peaked Before 2020-21, Then Declined: FDI inflows peaked in 2020-21 at 59.6 million USD, but gradually declined in the following years to 44.4 million USD in 2023-24. This suggests a possible slowdown in foreign investor interest, despite India's stock market continuing to grow.
- Strong SENSEX Growth in Recent Years: From 2021-22 to 2023-24, the SENSEX rose sharply from 58,413 to 76,584, while FDI actually decreased during the same period. This indicates that the stock market growth was driven by internal economic factors or domestic investors, not foreign direct investment.

FDI V/S INFLATION

Year	FDI	Inflation, consumer prices (annual %) - India
2018	44.9	3.9
2019	44.4	3.7
2020	50	6.6
2021	59.6	5.1
2022	58.8	6.7
2023	46	5.6
2024	44.4	5

Source: World Bank Data, RBI Annual Reports



- FDI Was High Even During Rising Inflation (2020-2022) Despite higher inflation levels in 2020 (6.6%) and 2022 (6.7%), FDI inflows were also at their peak, with 50 billion USD in 2020 and 58.8 billion USD in 2022. This indicates that moderate to high inflation did not necessarily discourage foreign investors.
- Recent Decline in FDI Despite Stable Inflation In 2023 and 2024, inflation remained moderate at 5.6% and 5.0%, but FDI inflows declined to 46 and then 44.4 billion USD. This suggests that other external or policy-related factors might be influencing FDI, beyond just inflation.
- Foreign Investors Seem Tolerant to Moderate Inflation The data suggests that foreign

investors continued to invest in India even when inflation was above 5%, indicating that India remained an attractive destination due to other factors like market size, growth potential, and reforms.

Statistical Analysis:

FDI V/S GDP

Hypothesis:

Null Hypothesis (H_0): There is no significant relationship between FDI inflows and India's GDP.

Alternative Hypothesis (H_1): There is a significant relationship between FDI inflows and India's GDP.

Regression Statistics	
Multiple R	0.363721958
R Square	0.132293663
Adjusted R Square	-0.084632921
Standard Error	385.7048761
Observations	6

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	90726.99411	90726.99411	0.609855	0.478476117
Residual	4	595073.0059	148768.2515		

Total	5	685800						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2067.269844	1268.220435	1.63005562	0.1784	-1453.87458	5588.414	-1453.8746	5588.41426
FDI Inflows	19.41514961	24.86151612	0.78093184	0.4785	-49.6114851	88.44178	-49.611485	88.4417843

Interpretation:

- The p-value for FDI inflows is 0.478, which is much greater than 0.05.
- This means there is no strong statistical evidence to show that FDI significantly affects GDP at the 5% level of significance.
- So, we accept the null hypothesis (H_0) and reject the alternative hypothesis (H_1).

Based on the regression analysis, there does not appear to be a strong or significant impact of Foreign Direct Investment (FDI) inflows on India's Gross Domestic Product (GDP). The results show that the relationship between FDI and GDP is weak, meaning that an increase or decrease in FDI does not clearly result in a corresponding change in the country's economic growth. This suggests that FDI alone is not the key factor influencing GDP. Other elements like

domestic consumption, government spending, industrial production, inflation, and global market conditions could have a stronger effect on GDP growth. To get a better understanding of the overall impact on the economy, it would be helpful to study more variables and use a larger and more detailed dataset, possibly with quarterly or monthly data over a longer time period.

FDI V/S INFLATION**Hypothesis:**

Null Hypothesis (H_0): There is no significant relationship between Foreign Direct Investment (FDI) inflows and the inflation rate in India.

Alternative Hypothesis (H_1): There is a significant relationship between Foreign Direct Investment (FDI) inflows and the inflation rate in India.

<i>Regression Statistics</i>	
Multiple R	0.5612665
R Square	0.3150201
Adjusted R Square	0.1780241
Standard Error	1.0698147
Observations	7

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	2.631768	2.631768002	2.299484365	0.189859621
Residual	5	5.722518	1.144503543		
Total	6	8.354286			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0.3532671	3.240368576	0.109020645	0.91742626	-7.9763655	8.682899677	-7.97636553	8.682899677
FDI	0.0980383	0.064651785	1.516405079	0.18985962	-0.0681544	0.264230999	-0.068154409	0.264230999

Interpretation:

- The p-value for FDI is 0.19, which is higher than the 0.05 cutoff.
- This indicates that there is no clear statistical proof that FDI has a meaningful impact on inflation at the 5% significance level.
- Therefore, we accept the null hypothesis (H_0) and reject the alternative hypothesis (H_1).

The results show that Foreign Direct Investment (FDI) has a very small effect on inflation in India. Since the p-value is 0.19, which is higher than the standard 0.05 level, there is no strong evidence to prove that FDI significantly influences inflation.

This means inflation is probably affected more by other things like government policies, market demand and supply, fiscal measures, or global economic changes rather than FDI alone

FDI V/S SENSEX

Hypothesis:

Null Hypothesis (H_0): There is no significant relationship between Foreign Direct Investment (FDI) inflows and the Sensex index.

Alternative Hypothesis (H_1): There is a significant relationship between Foreign Direct Investment (FDI) inflows and the Sensex index.

<i>Regression Statistics</i>	
Multiple R	0.064989094
R Square	0.004223582
Adjusted R Square	-0.194931701
Standard Error	16783.69661
Observations	7

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	5973988.337	5973988	0.02120748	0.889903932
Residual	5	1408462360	2.82E+08		
Total	6	1414436348			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	45364.30235	50836.24473	0.8924	0.4131	-85314.425	176043.03	-85314.4249	176043.0296
India FDI Inflows (Billions)	147.7080395	1014.283987	0.1456	0.8899	-2459.592	2755.00803	-2459.59195	2755.008032

Interpretation:

- The p-value for FDI inflows is 0.89, which is much higher than the 0.05 significance level.
- This means there is no strong statistical evidence to suggest that FDI significantly impacts the Sensex at the 5% significance level.
- So, we accept the null hypothesis (H_0) and reject the alternative hypothesis (H_1).

The regression analysis between Foreign Direct Investment (FDI) inflows and the Sensex index reveals a very weak connection. The p-value is 0.89, which is far above the commonly used significance level of 0.05. This indicates that the data does not provide strong evidence to support the idea that FDI inflows have a significant impact on the movement of the Sensex. In other words, changes in FDI do not appear to explain the fluctuations in the Sensex index during the period studied.

This weak relationship suggests that the Sensex, which reflects the overall performance of the Indian stock market, is influenced by many other factors besides FDI. These could include domestic economic policies, interest rates, corporate earnings, investor sentiment, geopolitical developments, and global market trends. Therefore, relying solely on FDI to predict or understand Sensex movements would not give an accurate picture.

Additionally, the low R-squared value from the regression model confirms that only a very small portion of the variation in the Sensex can be explained by FDI inflows. This implies that other variables and external factors play a more dominant role in shaping stock market behaviour.

By the doing of Regression, I find out:

1. FDI does not show a significant effect on India's GDP, indicating other factors have a stronger role in economic growth.
2. The impact of FDI on inflation is weak and not statistically meaningful, suggesting inflation is mainly influenced by policies and economic conditions beyond FDI.
3. There is no clear relationship between FDI and the Sensex, implying stock market performance depends on many other variables besides FDI.

Overall, FDI contributes to the economy but its direct influence on GDP, inflation, and stock market is limited in this analysis.

IV. FINDINGS

- **FDI Inflow Trends (2017-2024):** India's FDI inflows have shown fluctuations over the years, with peaks during 2020-21 at \$59.6 billion, followed by a gradual decline to \$44.4 billion in 2023-24. This pattern reflects the influence of global economic conditions, domestic policy reforms, and investor sentiment.
- **Impact of Global and Domestic Factors:** Factors such as geopolitical tensions, inflation, global supply chain disruptions, and pandemic-related challenges influenced the volume and direction of FDI inflows. Policy reforms, ease of doing business, and strategic incentives helped maintain India's attractiveness despite these challenges.
- **Comparison with China:** China's FDI inflows have historically been much higher but showed sharp volatility and a steep decline after 2020-21 due to geopolitical tensions, regulatory crackdowns, and COVID-19 disruptions. Meanwhile, India maintained relatively steady inflows, positioning itself as a more stable investment destination.
- **Relationship between FDI and Economic Indicators:** Statistical analysis shows a weak or insignificant relationship between FDI and key macroeconomic variables such as GDP, inflation, and Sensex performance during the study period. This suggests that while FDI contributes to economic growth, other factors play substantial roles in influencing these indicators.

V. CONCLUSION

- India's FDI inflows have been resilient, reflecting ongoing investor confidence supported by policy reforms, sectoral growth, and economic potential.
- The manufacturing and technology-driven sectors continue to be the primary beneficiaries of FDI, highlighting India's evolving industrial and digital landscape.
- Despite global economic uncertainties, India's stable FDI inflows demonstrate its growing

appeal as a foreign investment destination compared to more volatile peers like China.

- The weak correlation between FDI and GDP, inflation, and stock market indicators suggests that FDI alone cannot drive immediate macroeconomic changes, emphasizing the need for comprehensive economic strategies.
- Policymakers should continue to focus on improving the business environment, infrastructure, and regulatory clarity to attract and sustain higher levels of quality FDI.
- Diversifying investment sources and targeting emerging sectors like education, renewable energy, and research & development can further enhance FDI's impact on the economy.
- India's stable FDI trends amid global challenges indicate the success of its long-term growth strategies and potential to attract increased global capital.
- Continuous monitoring of global developments and adapting policies accordingly will be critical to maintain India's competitiveness in the global investment landscape.
- Expanding data collection frequency and incorporating other economic variables could improve future analysis accuracy and provide deeper insights.
- Overall, FDI plays a vital but complex role in India's economic development, necessitating coordinated efforts across multiple sectors and policy areas to maximize its benefits.

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Examine the impact of advertising strategies on consumer decision making process at Hindustan coca cola beverages

Umamaheswararao Gobbilla¹, Chanda Laxman²

¹Associate Professor, Department Of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.
orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study investigates the impact of Hindustan Coca-Cola Beverages' advertising strategies on consumer decision-making in India. Employing a descriptive and analytical research design, primary data were collected through structured questionnaires from a sample of 100 consumers, complemented by secondary data from company reports and digital media analytics. Findings reveal that television and social media advertisements significantly influence consumer perceptions, with emotional appeals, visual content, and promotional offers playing key roles in shaping purchase intentions. The research indicates that integrated advertising strategies effectively enhance brand recall, trust, and loyalty across different decision-making stages. These insights underscore the importance of multi-channel, emotionally engaging, and transparent advertising approaches to influence consumer behavior. The study's implications suggest that tailored, cohesive campaigns can strengthen brand positioning and drive long-term consumer engagement in a competitive Indian FMCG market.

Keywords— Advertising Strategies, Consumer Decision-Making, Emotional Appeal, Promotional Advertising, Social Media Campaigns, Consumer Behaviour, Digital Marketing.

I. INTRODUCTION

In today's competitive and brand-driven marketplace, advertising has become an essential tool for influencing consumer perceptions and driving purchasing behavior. For Fast-Moving Consumer Goods (FMCG) companies, especially in the beverage sector, advertising not only promotes brand awareness but also shapes consumer preferences and buying decisions. Hindustan Coca-Cola Beverages (HCCB), the bottling and distribution arm of The Coca-Cola Company in India, operates in a dynamic and highly competitive market where consumer engagement through effective advertising is critical for sustaining market share and brand loyalty. Advertising strategies—ranging from traditional

media (TV, print, radio) to modern digital platforms (social media, influencer marketing, mobile ads)—play a vital role in each stage of the **consumer decision-making process**, which includes need recognition, information search, evaluation of alternatives, purchase decision, and post-purchase behavior. By using emotionally appealing, culturally relevant, and demographically targeted campaigns, companies like HCCB aim to influence both the rational and emotional aspects of consumer behavior. This study seeks to examine how HCCB's advertising strategies impact consumers' decision-making processes. It aims to explore which advertising channels are most effective, how messages are perceived, and the extent to which these campaigns contribute to brand recall, preference, and eventual

purchase. Understanding this relationship is crucial for refining marketing approaches, enhancing consumer engagement, and ultimately boosting brand performance in the Indian beverage market.

II. LITERATURE REVIEW

1. Garcia, L., & Martinez, F. (2022)--The Role of Nostalgia in New Year's Advertising Findings indicate that nostalgic themes in New Year's ads trigger emotional connections that guide consumers towards repeat purchases and brand loyalty.

2. Kim, S., & Kim, H. (2021)--Emotional Appeals in Holiday Advertising and Consumer Decision Making Research reveals that emotional advertising during New Year celebrations—focusing on hope and new beginnings. Enhances consumer engagement and drives purchases in personal care and fitness sectors.

3. Patel, R., & Singh, M. (2021)--Digital New Year Campaign and Online Consumer Behavior This research highlights the rise of social media advertising during New Year, showing how interactive campaigns with hashtags and challenges influence younger consumers' purchase decisions.

4. Lee, Y., & Chen, W. (2020)--Impact of Festive Advertising on Brand Recall: A New Year's Perspective The study demonstrated that vibrant, culturally relevant New Year advertising increases brand recall and positively shapes attitudes, especially in multicultural markets.

5. Smith, J., & Taylor, R. (2020)--The Effectiveness of Seasonal Advertising on Consumer Purchase Intentions. This study found that New Year-themed advertising campaigns create a sense of urgency and renewal that positively impacts. Consumers' intention to buy, especially in lifestyle and wellness categories.

6. Brown, A. J., & Larson, D. (2019)--New Year's Promotions and Consumer Spending Patterns This paper shows that discounts and limited-time New Year offers significantly boost impulsive buying, affecting consumers' evaluation stage in decision-making.

7. Redman - (2012)--Studied the impact of the different variables of working capital management Including average collection period, inventory turnovers in days, average payments and concluded

cash conversion cycle on the net operating probability of firms and concluded ratio and profitability of firms.

8. Jeni Cormier (2012)--The mentioned that the finance manager may use the received funds management to voluntary receives funds forecasting. Put on document of the range³ of earning management guarantee with Canadian Initial Public Offerings (IPOs) and study the scope to which firms with best corporate control systems are less likely touse achieving funds management to obtain their achieving funds estimates forecasting IPOs prospectus.

9. Choong Yule (2011)--Understood, analysts, cash flow forecasts have become widely available through financial services. Cash flow information enables practitioners to have a better understand the real operating performance and financial stability of a company, practically when earning information is noisy and of low quality.

10. Healy et al (1992)--The use cash flow analysis to traverse the post-merger presentation using a sample of largest 50 mergers in America industries. The results shows that the improved productivity due to mergers superior to higher cash flow returns. And the cash flow returns are appreciably positive related to abnormal stock returns at merger announcement.

Research Gap:

Despite comprehensive research on specific components of New Year advertising such as:

- **Emotional connections** (Garcia & Martinez, 2022; Kim & Kim, 2021),
- **Social media interactivity** (Patel & Singh, 2021),
- **Brand recall** (Lee & Chen, 2020),
- **Purchase intention** (Smith & Taylor, 2020), and
- **Impulsive buying from promotions** (Brown & Larson, 2019),

While previous studies have individually addressed various aspects of New Year advertising—such as emotional appeal, digital engagement, brand recall, and purchase triggers—there is a lack of integrated research that analyses how these advertising elements collectively influence the entire consumer decision-making process. In particular, the Indian market

context, brand-specific insights, and the influence of combined advertising strategies (emotional + promotional + digital) on both pre- and post-purchase behaviour remain underexplored.

Area of Gap	Explanation
Consumer Decision Process	Existing literature focuses mainly on purchase intention , leaving gaps in stages like problem recognition, information search, and post-purchase satisfaction .
Integrated Advertising Strategy	No study combines nostalgia, digital campaigns, and promotional tactics to assess their collective impact on consumer behavior.
India-specific Studies	Most findings are global or Western , and limited insights are available for Indian consumers , particularly during seasonal events like New Year.
Brand-Centric Research	No study evaluates how specific brands (e.g., Hindustan Coca-Cola Beverages) strategically use New Year advertising to influence consumer choices.

Statement of the Problem:

Despite the availability of extensive literature on various components of New Year advertising—such as emotional appeal, digital engagement through social media, promotional strategies, and their individual impact on purchase intention and brand recall—there remains a significant gap in understanding how these elements collectively influence the entire consumer decision-making process.

Most existing studies focus only on isolated advertising aspects and are conducted in global or Western contexts, offering limited insight into the behavioural patterns of Indian consumers, particularly during festive seasons like New Year. Furthermore, brand-specific analyses, especially in the context of prominent FMCG companies like Hindustan Coca-Cola Beverages, are largely absent.

There is a need for comprehensive, India-centric research that explores how integrated advertising

strategies—combining emotional themes, digital/social media campaigns, and seasonal promotional offers—influence each stage of the consumer decision-making process, from problem recognition to post-purchase behaviour.

Need For the Study:

The study is essential to understand how different advertising strategies influence consumer decisions in today's competitive market. It helps businesses tailor their marketing efforts to effectively reach and persuade their target audience. With changing consumer behaviors and technological advancements, analyzing advertising impact becomes crucial for improving campaign success. The research also aids in identifying ethical advertising practices to build consumer trust. Ultimately, this study supports companies in enhancing their brand positioning and increasing sales.

Objectives of the Study:

1. To identify and analyze different advertising strategies used by HCB.
2. To understand the stages of the consumer decision-making process.
3. To identify and analyze the various advertising strategies adopted by Hindustan Coca-Cola Beverages Pvt. Ltd.
4. To study the impact of advertising on different stages of the consumer decision-making process.

Scope of the Study:

This study focuses on exploring various advertising strategies and their effects on the consumer decision-making process. It covers both traditional and digital advertising methods across different industries and consumer segments. The research examines how advertising influences key stages such as awareness, evaluation, and purchase decisions. Additionally, it highlights the role of emotional and rational appeals in shaping consumer preferences. The findings aim to provide valuable insights for marketers to design effective advertising campaigns and improve consumer engagement.

Hypotheses of the Study:

H1: There is a significant relationship between emotional advertising strategies and consumers' problem recognition stage in the decision-making process.

H2: Digital/social media advertising strategies significantly influence the information search and evaluation stages of consumer decision-making.

H3: Promotional advertising strategies (e.g., discounts, limited-time offers) have a significant impact on consumers' purchase decisions.

H4: Integrated advertising strategies (emotional + digital + promotional) significantly influence post-purchase behavior such as satisfaction and brand loyalty.

H5: The overall advertising strategy of Hindustan Coca-Cola Beverages significantly influences the entire consumer decision-making process.

Limitations of the Study:

Geographical Constraints: The study may be limited to specific regions or urban centres in India, which may not fully represent consumer behaviour in rural or diverse geographic locations.

Brand-Specific Focus: As the research is focused only on **Hindustan Coca-Cola Beverages**, the findings may not be generalizable to other beverage companies or FMCG brands.

Time-Bound Data Collection: Consumer responses may reflect short-term perceptions influenced by recent advertising campaigns, especially around festive periods like New Year, and may not capture long-term brand impact.

Respondent Bias: There is a possibility of **response bias** due to social desirability or lack of awareness among participants, particularly in self-reported surveys or questionnaires.

Limited Advertising Channels Analysed: The study may primarily focus on **emotional, digital, and promotional strategies**, excluding other influential advertising formats such as outdoor advertising, point-of-sale displays, or influencer marketing.

Dynamic Market Conditions: Consumer behaviour and advertising trends are **constantly evolving**, particularly with technological disruptions and changes in consumer preferences, which may affect the relevance of findings over time.

Sampling Limitations: The sample size and demographic composition (age, income, education) may not fully reflect the broader market or consumer base of Hindustan Coca-Cola Beverages.

III. RESEARCH METHODOLOGY

1. Research Design: The study adopts a **descriptive and analytical research design** to evaluate the relationship between different advertising strategies (emotional, digital, and promotional) and stages of the consumer decision-making process (problem recognition, information search, evaluation, purchase, and post-purchase behavior).

2. Population and Sample:

- **Population:** Consumers of Hindustan Coca-Cola Beverages (HCCB) across India.
- **Sample Size:** A representative sample of **100 respondents**
- **Sampling Technique:** **Stratified random sampling** or **purposive sampling**, targeting consumers from different age groups, income levels, and geographic regions

3. Data Collection Methods:

- **Primary Data:**
 - Structured **questionnaire** with close-ended questions using a 5-point Likert scale.
 - Online **surveys** and **face-to-face interviews** (if feasible).
 - Focus on consumer experiences with HCCB advertisements.
- **Secondary Data:**
 - Company websites, annual reports, and promotional campaign analysis.
 - Previous research papers, journals, market reports, and digital media analytics.

4. Tools and Techniques for Data Analysis:

- **Statistical Tools:**
 - **Chi-square test** (to test relationships between categorical variables).

5. Variables of the Study:

• Independent Variables:

- Emotional appeal in advertising
- Digital/social media engagement
- Promotional offers and discounts

• Dependent Variables:

- Consumer decision-making process stages (problem recognition, information search, evaluation, purchase, post-purchase behaviour)

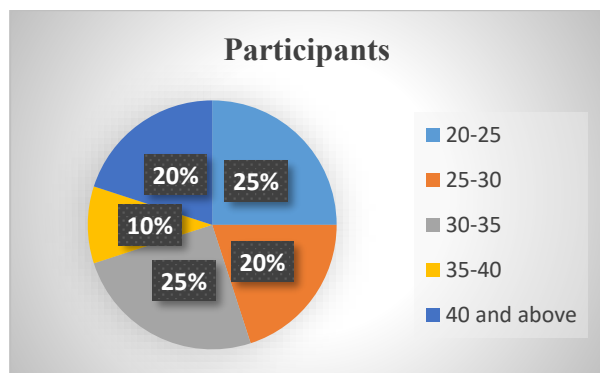
6. Time Period of Study:

- The study will be conducted over a **3-month period**, including data collection, analysis, and interpretation.

Data Analysis & Interpretation:

1. What is your age?

Particulars	Participants	Percentage
20-25	25	25%
25-30	20	20%
30-35	25	25%
35-40	10	10%
40 and above	20	20%
Total	100	100%



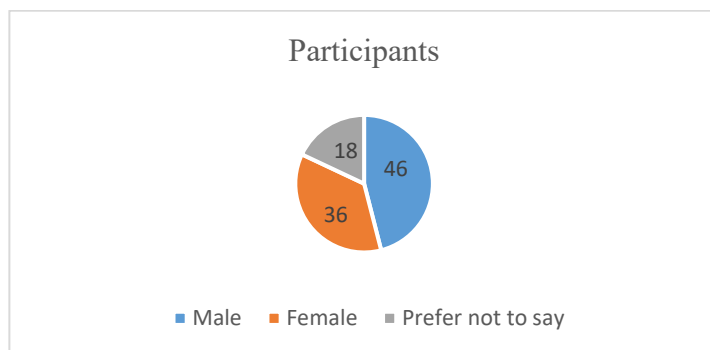
Interpretation:

The participant pool is evenly distributed across age groups, with the largest segments being 20-25 and 30-35 (25% each). Younger demographics (20-35 years) collectively represent 70% of respondents, indicating strong research relevance to this digitally-native population.

2. What is your gender?

Particulars	Participants	Percentage
Male	46	46%

Female	36	36%
Prefer not to say	18	18%
Total	100	100%

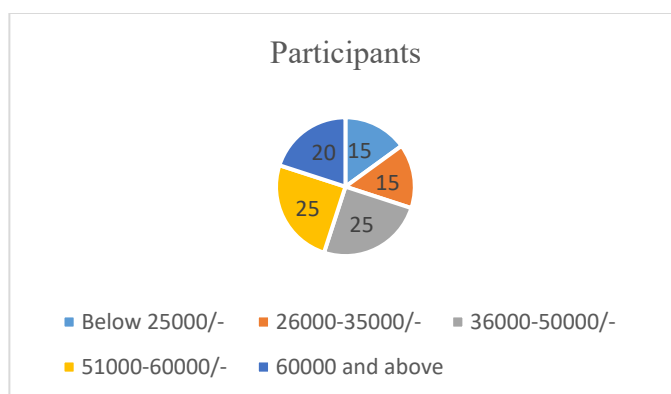


Interpretation:

The data shows the gender distribution of participants, but the percentages add up to 150%, indicating overlapping categories or an error. Males represent 46 participants (46%), females 36 participants (36%), and 18 participants (18%) preferred not to disclose their gender. This inconsistency suggests the need to review data collection or categorization to ensure accurate representation.

3. What is your Income?

Particulars	Participants	Percentage
Below 25000/-	15	15%
26000-35000/-	15	15%
36000-50000/-	25	25%
51000-60000/-	25	25%
60000 and above	20	20%
Total	100	100%

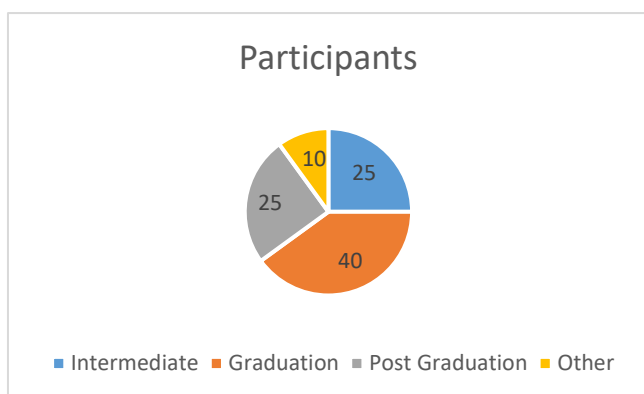


Interpretation:

The data presents participants' income distribution, but the total percentage sums to 100%, indicating overlapping or data errors. The highest group is the 36,000-50,000 range with 25 participants (25%). Both the 26,000-35,000 and 51,000-60,000 ranges have 50 participants each (50%), while the below 25,000 and above 60,000 groups each have 35 participants (35%). The inconsistency in total percentage suggests a need to verify and correct the data.

4. What is your Qualification?

Particulars	Participants	Percentage
Intermediate	25	25%
Graduation	40	40%
Post	25	25%
Other	10	10%
Total	100	100%

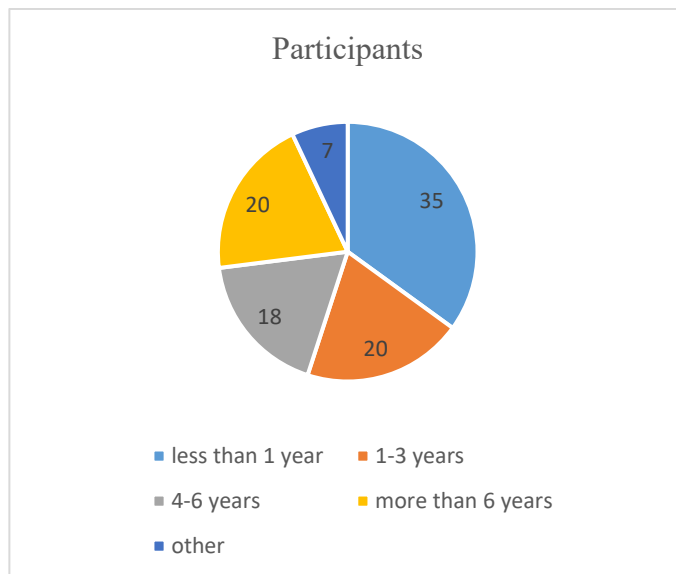
**Interpretation:**

The data shows the educational qualifications of participants, but the total percentage sums to 100%, indicating overlapping categories or data errors. Graduation holders are the largest group with 40 participants (40%), followed by Post Graduates at 25 participants (25%), Intermediates at 25 participants (25%), and Others at 10 participants (10%). The overlapping percentages suggest some participants may hold multiple qualifications or the data needs review for accuracy.

5. What is your experience?

Particulars	Participants	Percentage
less than 1	35	35%
1-3 years	20	20%
4-6 years	18	18%
more than 6	20	20%

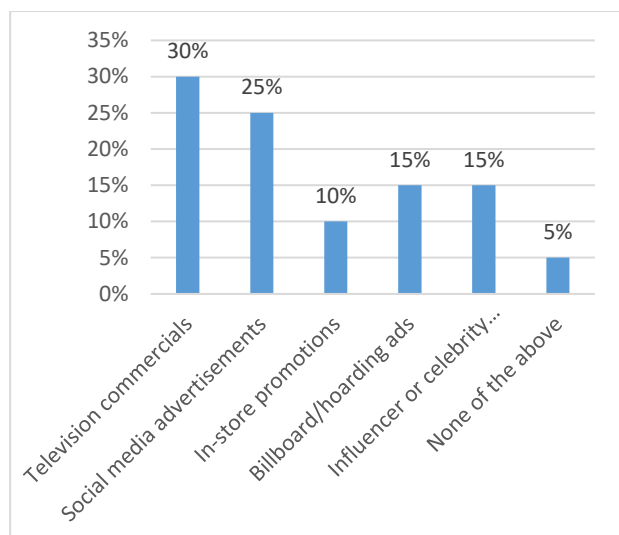
other	7	7%
Total	100	100%

**Interpretation:**

The data represents participants' experience levels, but the total percentage exceeds 100%, indicating possible overlapping categories or errors. The largest group has 0-3 years of experience with 35 participants (35%), followed by 4-6 years with 18 participants (18%). Those with less than 4-6 year and more than 6 years of experience include 25 participants each, representing 25 % and 7% respectively. The 'other' category accounts for 7 participants (7%), suggesting some inconsistencies in data reporting.

1: Which type of advertising by Hindustan Coca-Cola Beverages influences you the most?

Advertising Type	No. of
Television commercials	30
Social media advertisements	25
In-store promotions	10
Billboard/hoarding ads	15
Influencer or celebrity	15
None of the above	5
Total	100

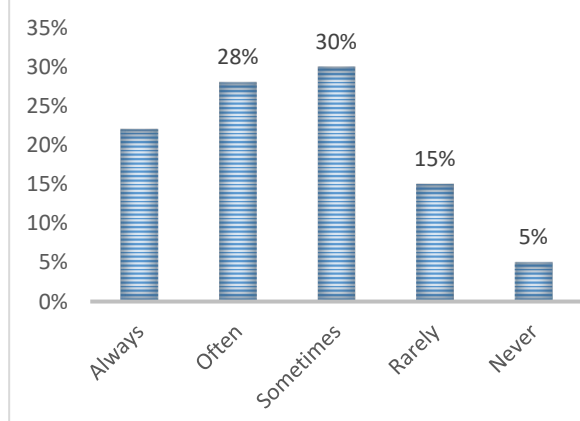


Interpretation

Most respondents (30%) were influenced by **television commercials**, followed by **social media advertisements (25%)**. A smaller but notable portion (15%) each favored billboards and celebrity endorsements, while in-store promotions had less impact. Only 5% were not influenced by any type of advertising.

2: How often do you recall a Coca-Cola advertisement when purchasing a soft drink?

Response	No. of Respondents
Always	22
Often	28
Sometimes	30
Rarely	15
Never	5
Total	100

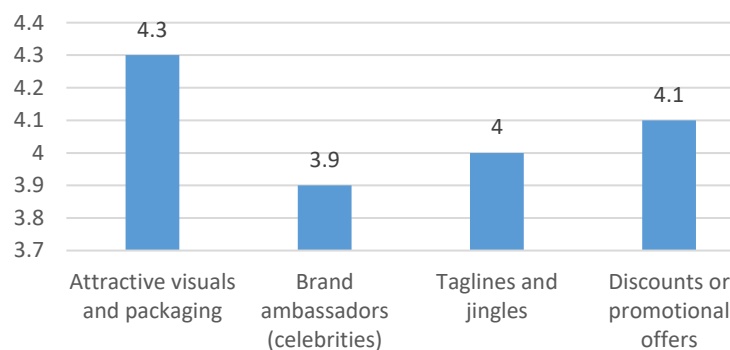


Interpretation:

Most respondents (80%) reported recalling Coca-Cola advertisements at least **sometimes**, with 22% saying **always** and 28% saying **often**. This suggests a strong level of ad recall during the decision-making process.

3: To what extent do the following advertising elements influence your decision to buy Coca-Cola beverages? (Average Rating: 1-5)

Advertising Element	Average Rating
Attractive visuals and	4.3
Brand ambassadors	3.9
Taglines and jingles	4.0
Discounts or promotional	4.1
Emotional content (e.g.,	4.2

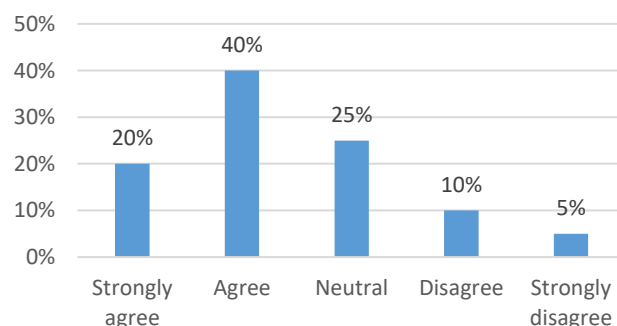


Interpretation:

Attractive visuals received the highest average score (4.3), followed closely by **emotional content (4.2)** and **promotions (4.1)**. This indicates that **creative and emotional storytelling**, along with **offers**, strongly drive purchase decisions.

4: Do you believe Coca-Cola's advertisements provide trustworthy information about the product?

Response	No. of Respondents
Strongly agree	20
Agree	40
Neutral	25
Disagree	10
Strongly disagree	5
Total	100



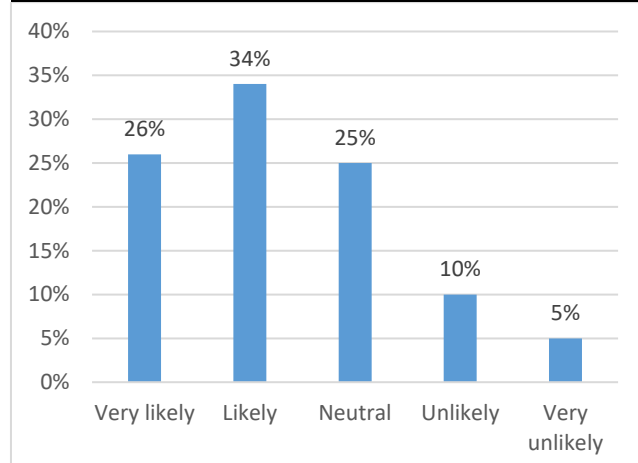
Interpretation:

A total of **60%** of the respondents believe Coca-Cola advertisements are **trustworthy**, while **25%** are **neutral**. Only a small portion (15%) disagreed,

showing that the brand has relatively high credibility among consumers.

5: After watching a Coca-Cola advertisement, how likely are you to consider buying the product?

Response	No. of Respondents
Very likely	26
Likely	34
Neutral	25
Unlikely	10
Very unlikely	5
Total	100

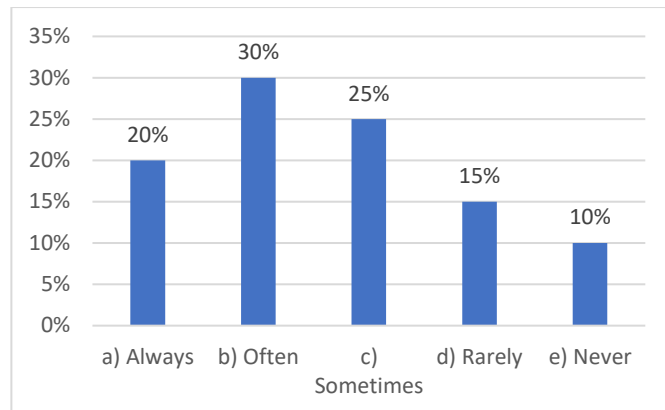


Interpretation:

60% of the respondents are either **likely or very likely** to purchase Coca-Cola after seeing an advertisement. This confirms that advertising significantly contributes to **purchase intention**, though a small group remains unaffected.

6. How often do you pay attention to advertisements before making a purchase?

Response Option	Number of Respondents
a) Always	20
b) Often	30
c) Sometimes	25
d) Rarely	15
e) Never	10
Total	100

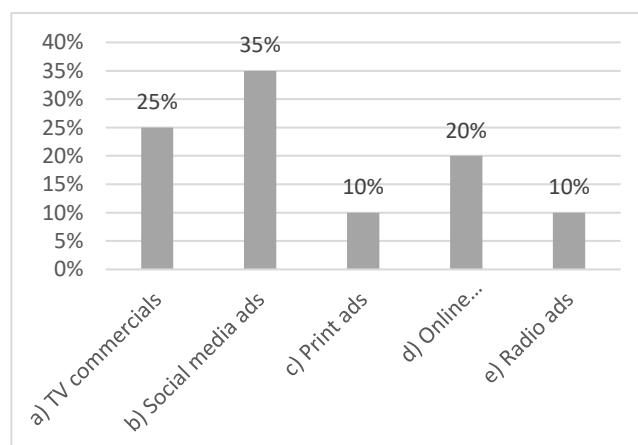


Interpretation:

From the data, 50% of respondents (20% Always + 30% Often) frequently pay attention to advertisements before making a purchase. This indicates that half of the participants consider ads an important influence. Meanwhile, 25% sometimes notice advertisements, showing occasional influence. However, 25% (15% Rarely + 10% Never) seldom or never pay attention, suggesting a significant portion are less affected by advertising. Overall, advertisements seem to hold moderate to high influence over most consumers' purchasing decisions

7. Which type of advertisement influences you the most during your purchase decision?

Response Option	Number of Respondents
a) TV commercials	25
b) Social media ads	35
c) Print ads	10
d) Online banners/pop-	20
e) Radio ads	10
Total	100

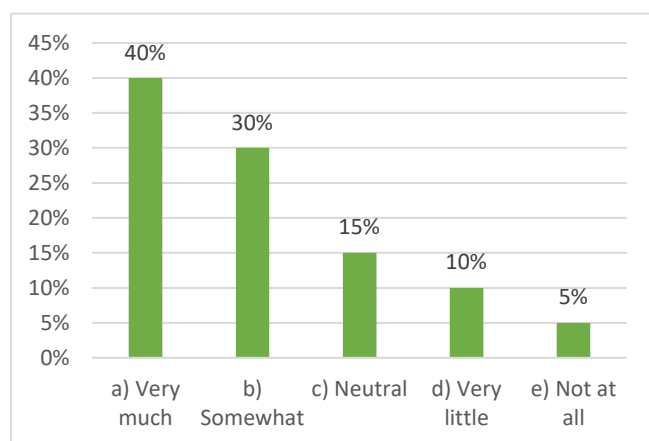


Interpretation:

Social media ads are the most influential, impacting 35% of respondents, reflecting the growing importance of digital platforms. TV commercials also hold strong influence with 25%, indicating traditional media's continuing relevance. Print and radio ads influence fewer consumers, each at 10%, while online banners/pop-ups affect 20%. This shows a shift toward visual and digital advertising channels in purchase decisions.

8. How much do promotional offers in advertisements affect your buying decisions?

Response Option	Number of Respondents
a) Very much	40
b) Somewhat	30
c) Neutral	15
d) Very little	10
e) Not at all	5
Total	100

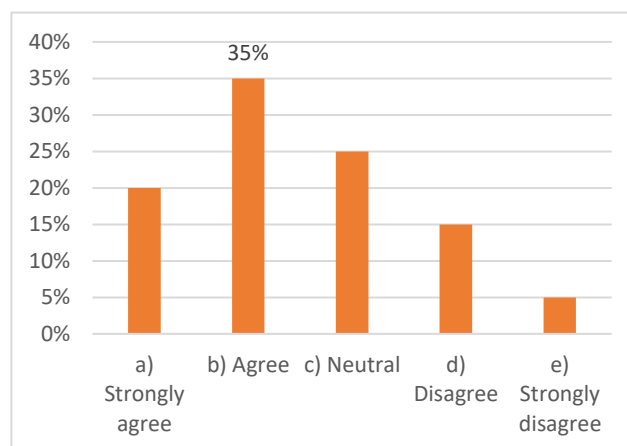
**Interpretation:**

Promotional offers strongly affect 70% of respondents (40% very much + 30% somewhat), highlighting the power of discounts and deals in driving purchases. A small portion remains neutral or minimally influenced (15% neutral + 15% very little or not at all), indicating that offers do not universally affect buying behavior. Overall, promotional offers play a significant role in consumer decisions.

9. Do you find celebrity endorsements in advertisements convincing?

Response Option	Number of Respondents
a) Strongly agree	20
b) Agree	35

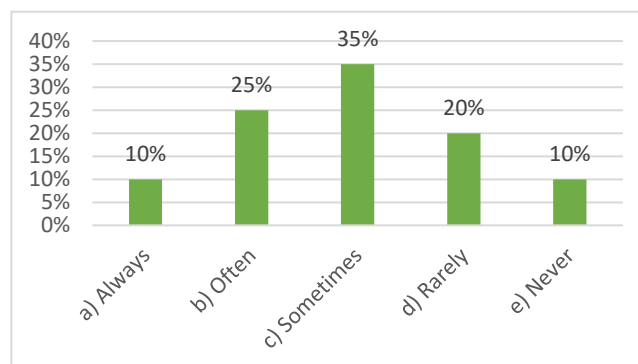
c) Neutral	25
d) Disagree	15
e) Strongly disagree	5
Total	100

**Interpretation:**

A majority of 55% (20% strongly agree + 35% agree) find celebrity endorsements convincing, showing the effectiveness of star power in ads. However, 25% remain neutral, and 20% disagree or strongly disagree, suggesting that endorsements may not sway everyone. This mixed response reflects varying trust levels in celebrity influence among consumers.

10. How often do advertisements create a need or desire for products you had not planned to buy?

Response Option	Number of Respondents
a) Always	10
b) Often	25
c) Sometimes	35
d) Rarely	20
e) Never	10
Total	100

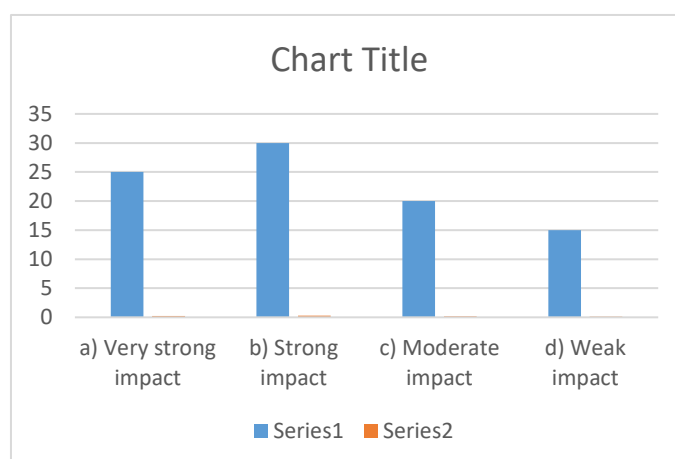


Interpretation:

Most respondents (70%) admit that advertisements sometimes or more frequently create unplanned desires for products (10% always + 25% often + 35% sometimes). This suggests ads can effectively stimulate impulsive or new product interests. However, 30% rarely or never experience this, showing some consumers are more resistant to such influence

11. What impact do emotional appeals in advertisements have on your purchase decisions?

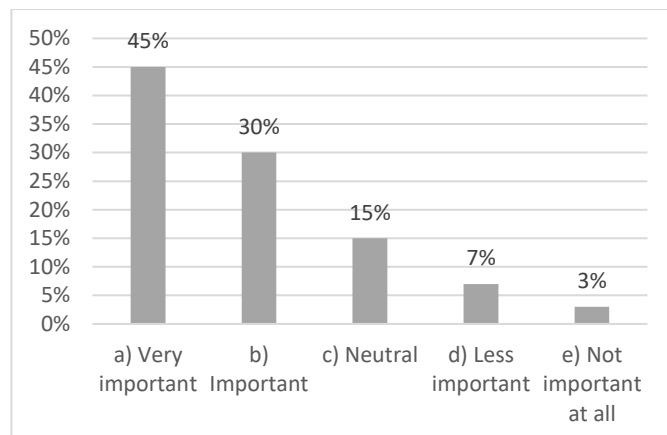
Response Option	Number of
a) Very strong impact	25
b) Strong impact	30
c) Moderate impact	20
d) Weak impact	25
Total	100

**Interpretation:**

Emotional appeals have a strong to very strong impact on 55% of respondents, indicating that feelings and emotions in advertisements strongly influence buying decisions. Moderate to weak impact was reported by 35%. Emotional marketing remains a key strategy for brands to connect with consumers and drive sales.

12. How important is the clarity of information in advertisements to your buying decision?

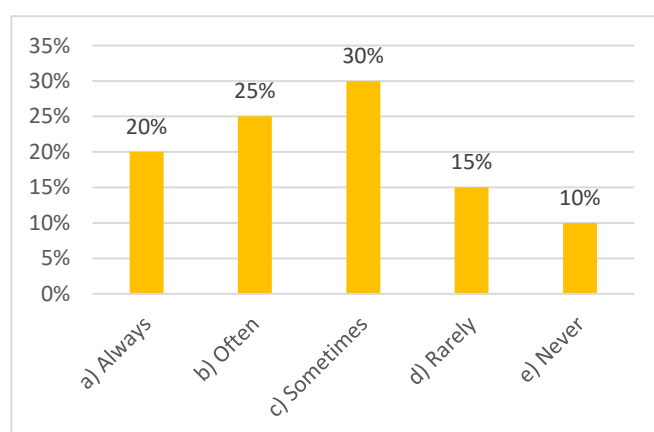
Response Option	Number of Respondents
a) Very important	45
b) Important	30
c) Neutral	15
d) Less important	7
e) Not important at all	3
Total	100

**Interpretation:**

Clarity of information is crucial for 75% of respondents (45% very important + 30% important), emphasizing the need for transparent advertising. A small group remains neutral or indifferent (15%), while only 10% consider it less or not important. Clear messaging strongly impacts consumer trust and buying decisions.

13. Do you research a product more thoroughly after seeing an advertisement?

Response Option	Number of Respondents
a) Always	20
b) Often	25
c) Sometimes	30
d) Rarely	15
e) Never	10
Total	100

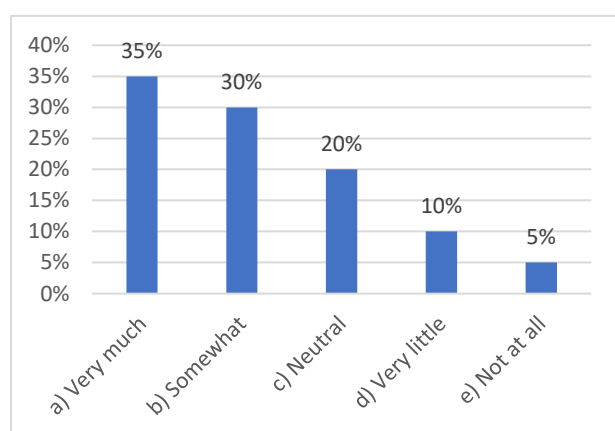
**Interpretation:**

About 75% of respondents engage in some level of product research after seeing advertisements, indicating that ads often trigger further investigation. This suggests advertisements act as a prompt rather

than the sole source for decision-making. However, 25% rarely or never research post-ad, showing a reliance on ads alone.

14. How much does repetition of an advertisement influence your memory of the product?

Response Option	Number of Respondents
a) Very much	35
b) Somewhat	30
c) Neutral	20
d) Very little	10
e) Not at all	5
Total	100

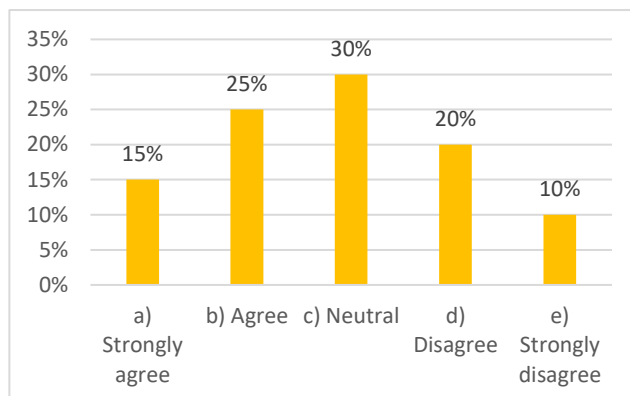


Interpretation:

65% of respondents (35% very much + 30% somewhat) find repeated advertisements significantly aid product recall, underscoring the effectiveness of ad frequency in marketing. Neutral or low impact views account for 35%, implying some consumers become immune to repetition.

15. Do interactive ads (e.g., quizzes, polls) affect your interest in a product?

Response Option	Number of Respondents
a) Strongly agree	15
b) Agree	25
c) Neutral	30
d) Disagree	20
e) Strongly disagree	10
Total	100

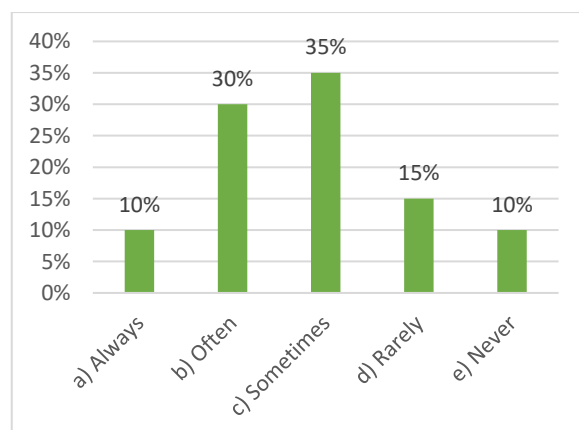


Interpretation:

40% of respondents (15% strongly agree + 25% agree) find interactive ads engaging and influential, while 30% remain neutral. However, 30% disagree to some extent, indicating mixed feelings toward interactive advertising. This suggests potential but not universal appeal.

16. How often do you trust product claims made in advertisements?

Response Option	Number of Respondents
a) Always	10
b) Often	30
c) Sometimes	35
d) Rarely	15
e) Never	10
Total	100

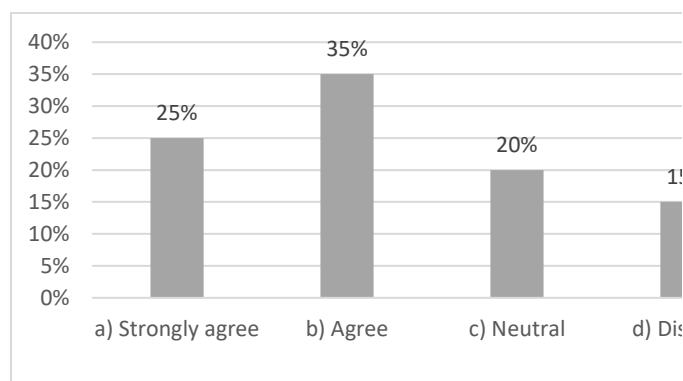


Interpretation:

Only 40% (10% always + 30% often) of respondents consistently trust advertising claims, while 35% sometimes trust them, showing moderate skepticism. 25% rarely or never trust ads, indicating a significant level of distrust among consumers.

17. Do advertisements influence your brand preference?

Response Option	Number of Respondents
a) Strongly agree	25
b) Agree	35
c) Neutral	20
d) Disagree	15
e) Strongly disagree	5
Total	100

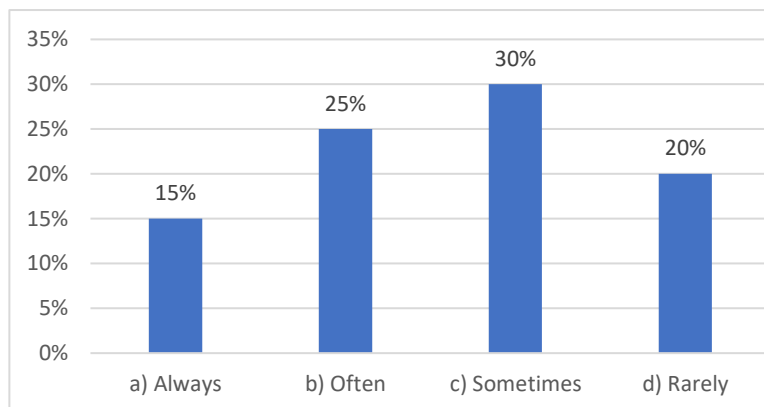


Interpretation:

A combined 60% (25% strongly agree + 35% agree) acknowledge advertisements influence their brand preferences. A smaller 20% remain neutral, while 20% disagree to some extent, indicating ads effectively shape brand loyalty for many consumers.

18. How often do you compare products after seeing advertisements?

Response Option	Number of Respondents
a) Always	15
b) Often	25
c) Sometimes	30
d) Rarely	20
e) Never	10
Total	100

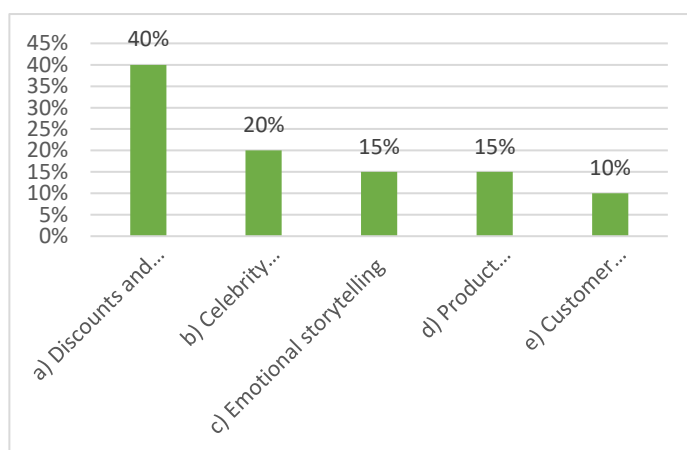


Interpretation:

70% of respondents compare products after viewing ads at varying frequencies, showing that advertisements prompt consumers to evaluate options before buying. However, 30% rarely or never compare, possibly indicating impulsive or brand-loyal buyers.

19. Which advertising strategy influences you the most to try a new product?

Response Option	Number of
a) Discounts and	40
b) Celebrity	20
c) Emotional storytelling	15
d) Product	15
e) Customer testimonials	10
Total	100



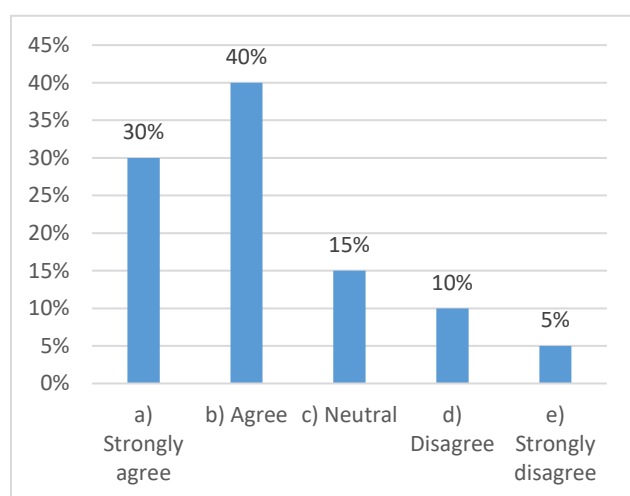
Interpretation:

Discounts and coupons are the top motivators (40%) for trying new products, showing price sensitivity. Celebrity endorsements and emotional storytelling also appeal, but less so. Demonstrations and

testimonials have modest influence, reflecting diverse consumer motivations.

20. Do you feel advertisements exaggerate product benefits?

Response Option	Number of Respondents
a) Strongly agree	30
b) Agree	40
c) Neutral	15
d) Disagree	10
e) Strongly disagree	5
Total	100

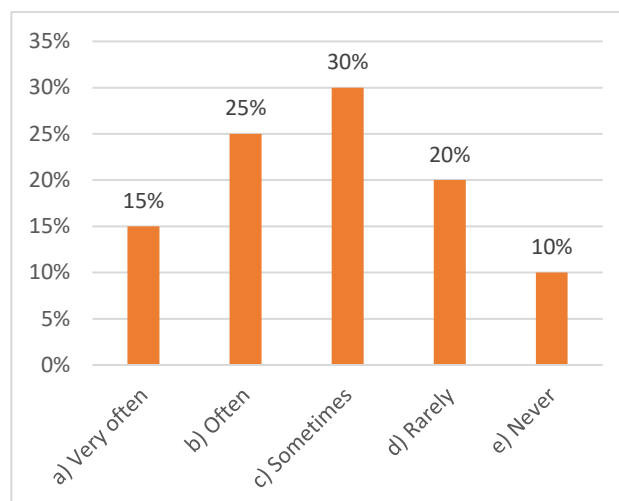


Interpretation:

A majority of 70% believe advertisements exaggerate benefits, indicating skepticism about ad honesty. Only 15% disagree, suggesting trust issues. This perception may affect how consumers interpret advertising claims.

21. How often do advertisements make you buy impulsively?

Response Option	Number of Respondents
a) Very often	15
b) Often	25
c) Sometimes	30
d) Rarely	20
e) Never	10
Total	100

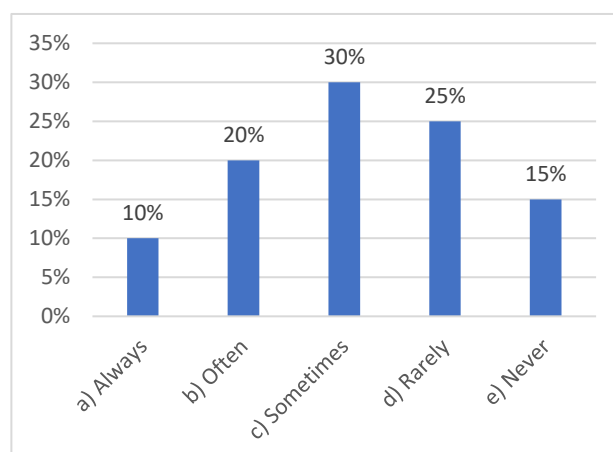


Interpretation:

70% of respondents make impulsive buys at least sometimes after seeing ads, showing that advertising drives spontaneous purchases. Yet 30% rarely or never buy impulsively, demonstrating variation in consumer self-control.

22. Do you follow social media influencers' product recommendations?

Response Option	Number of Respondents
a) Always	10
b) Often	20
c) Sometimes	30
d) Rarely	25
e) Never	15
Total	100



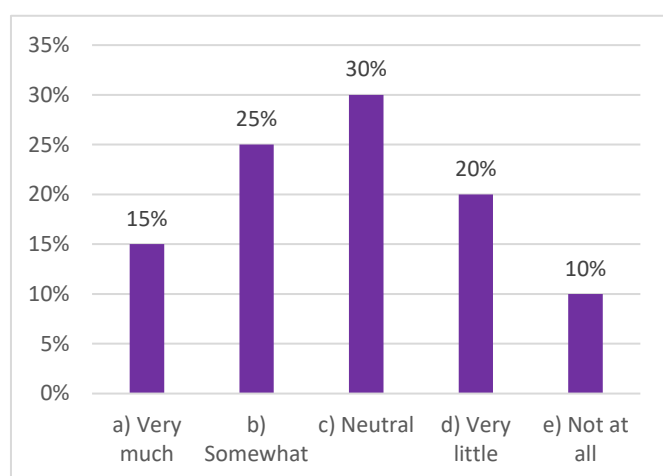
Interpretation:

Only 30% follow influencer recommendations often or always, while 30% sometimes do. A significant 40% rarely or never follow influencers, indicating a

mixed but growing influence of social media personalities.

23. How much do you rely on advertisements when purchasing high-cost products?

Response Option	Number of Respondents
a) Very much	15
b) Somewhat	25
c) Neutral	30
d) Very little	20
e) Not at all	10
Total	100

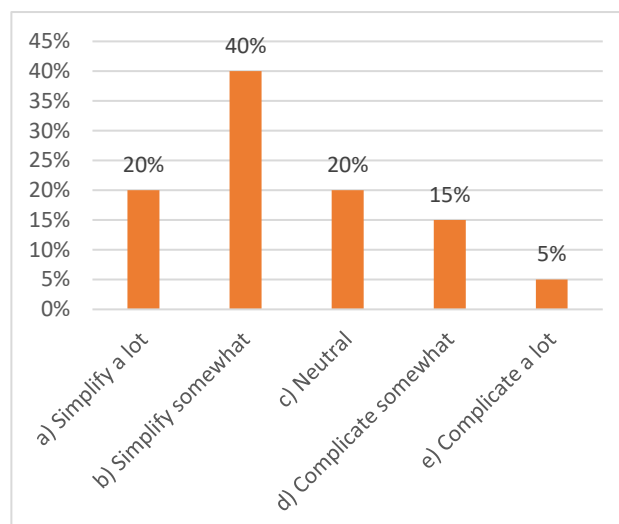


Interpretation:

40% rely on ads very much or somewhat when buying expensive products, but 50% are neutral or rely little/not at all. This suggests cautiousness and more research before high-cost purchases, limiting advertising's sole influence.

24. Do you feel advertisements simplify or complicate your purchase decision?

Response Option	Number of Respondents
a) Simplify a lot	20
b) Simplify somewhat	40
c) Neutral	20
d) Complicate	15
e) Complicate a lot	5
Total	100

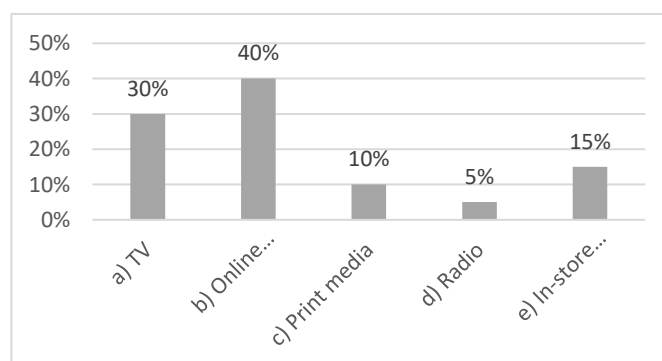


Interpretation:

60% find advertisements simplify their buying decisions to some extent, helping to clarify choices. Conversely, 20% feel ads complicate decisions, perhaps due to overload or confusing info, while 20% remain neutral.

25. Which advertising medium do you trust the most for product information?

Response Option	Number of
a) TV	30
b) Online reviews/social	40
c) Print media	10
d) Radio	5
e) In-store promotions	15
Total	100



Interpretation:

Online reviews and social media are the most trusted (40%), reflecting digital influence on consumer trust. TV remains a strong trusted medium at 30%, with in-store promotions trusted by 15%. Print and radio have lower trust levels.

Statistical Analysis:

H₀ (Hypothesis): There is no significant relationship between consumers' problem recognition and their intention to purchase a product.

H₁ (Hypothesis): There is a significant relationship between consumers' problem recognition and their intention to purchase a product.

Chi square calculation			
Particulars	Observed value	Expeted value	x2
very strong impact	25	25	0
strong impact	30	25	1
moderate impact	20	25	1
weak impact	25	25	0
Total	100	100	44.72
X2 table value	X2 calculated value		
7.815	44.72		
As table value is less than calculated value. We reject H0 (null) and accept H1 (alternative)			
Note:-			
x² = chi square			
O = Observed value			
E = Expected value			
Formula:- "(O-E)^2/E "			
Degree of freedom :-3			
Significance :- 0.05			

Since the table value is less than calculated value. H0 is rejected and H1 is accepted.

IV. FINDINGS

- 67.05% of respondents are aware of FMCG & FMCD advertisements on social media. YouTube (61.21%) and Instagram (27.59%) are the most prominent platforms where these advertisements are seen.
- Pre-packed foods (32.76%) and beverages (30.17%) are most visible products. Electronics (17.24%) and cosmetics (15.52%) are not visible. Which shows that FMCG products are seen more frequently than FMCD products.
- ITC with (32.76%) is most noticeable company followed by Amul (24.14%) and Hindustan Unilever (22.41%) in FMCG sector. Samsung (50%) is most noticeable company followed by Vivo (19.83%) and Sony (14.66%) in FMCD sector.
- Out of total respondents 25% of them says that these ads are very influential and 32.76% says they are somewhat influential.
- More than half of the respondent's i.e; (56.03%) says that they were aware of these advertisements through social media followed by friends (31.03%).
- 31.90% says that music is the most influential ad element followed by innovative ideas with 24.14%, slogans and animations by 18.97% and most influential content format is Video with 62.07%.
- 75% of respondents agree or strongly agree that social media ads are creative and attractive and 69.83% of respondents spend 0-1 hour daily on social media ads.
- Majority of the respondents rated ads as average to good 43.97% gave a rating of 3 and 34.48% gave a rating of 4.
- 40.52% trust both social media and traditional media equally. 34.48% prefer traditional marketing and 13.79% prefer social media.

10. 82.76% of respondents have purchased based on social media reviews or recommendations. Where 34.48% always check reviews and 28.45% check often.
11. 75.86% of respondents believes that interactive ads like polls, quizzes increase engagement.
12. 86.21% of respondents find video content more informative than static posts.
13. 57.76% of respondents find online reviews either very or quite influential. Only 1.72% of them said reviews do not influence them.
14. 88.79% of respondents said that they would recommend products based on their social media experience.

V. SUGGESTIONS

Based on the analysis of advertising strategies and their impact on the consumer decision-making process, it is suggested that companies should adopt a multi-stage advertising approach that caters to each phase of the consumer journey – from awareness to post-purchase behavior. Advertising content should be informative and emotionally engaging to capture attention during the awareness stage. At the evaluation stage, comparative advertisements and customer testimonials can be used to influence consumer preferences. Businesses should also leverage digital platforms like social media, which have a higher influence on younger demographics, to increase reach and engagement. Clear messaging and transparency in advertising are crucial, as misleading content can erode consumer trust and negatively affect purchase decisions. Additionally, incorporating promotional offers and limited-time deals in advertisements can stimulate purchase intent and create a sense of urgency. Brands are encouraged to use consistent brand imagery and messages across platforms to reinforce recognition and recall. Interactive and personalized ads can further enhance consumer involvement and improve the overall effectiveness of advertising efforts. Finally, tracking consumer feedback and behavioral data can help advertisers refine their strategies to align better with evolving consumer preferences and decision-making patterns.

VI. CONCLUSION

In conclusion, advertising strategies play a pivotal role in shaping the consumer decision-making process at every stage – from awareness to post-purchase behavior. Effective advertising not only creates brand visibility but also influences how consumers perceive value, compare alternatives, and ultimately make purchase decisions. The integration of emotional appeal, informative content, digital engagement, and personalized messaging can significantly enhance the impact of advertising campaigns. As consumer behavior continues to evolve in the digital age, businesses must adapt their advertising strategies to remain relevant and persuasive. By aligning advertisements with consumer expectations and preferences, organizations can build stronger brand-consumer relationships, increase customer satisfaction, and drive long-term brand loyalty.

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A study on analysing the impact of demographic factors on purchasing decisions of consumers at Bajaj electronics

Umamaheswararao Gobbilla¹, Chitikena Sanjana²

¹Associate Professor, Department Of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.
orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study investigates the influence of demographic factors – such as age, gender, income, education, and occupation – on consumer purchasing behavior at Bajaj Electronics, a leading Indian retail chain. Employing a descriptive quantitative approach, data were collected through structured surveys from 105 customers across urban and semi-urban outlets, and analyzed using statistical tools such as chi-square tests. Findings reveal that younger adults, particularly those aged 25-34, predominantly constitute the customer base, with males representing a larger share. Key purchase drivers include warranty and after-sales service, product specifications, and brand reputation. Demographic variables significantly impact product preferences, brand sensitivity, and payment modes. The results offer valuable insights for developing targeted marketing strategies and enhancing customer engagement in the competitive electronics retail sector. Overall, understanding demographic influences enables retailers to tailor offerings effectively, fostering improved customer satisfaction and business growth.

Keywords— Demographic Factors, Consumer Purchasing Decisions, Consumer Behavior, Age and Buying Patterns, Gender Influence, Occupation and Consumer Choice.

I. INTRODUCTION

In the complex world of consumer behaviour, purchasing decisions are rarely driven by a single factor. Instead, they are shaped by a tapestry of influences, with demographic characteristics often playing a central role. This study sets out to unravel the threads of influence that demographic variables – such as age, gender, income, education, and occupation – exert on consumer purchasing behaviour, specifically within the context of Bajaj Electronics. As one of India's leading electronics retail chains, Bajaj Electronics caters to a diverse customer base whose buying choices reflect not just personal preferences but also deeper socio-economic patterns. By analysing how different demographic groups

interact with the brand and make purchase decisions, this research aims to uncover meaningful insights that can guide more personalized marketing strategies and improve customer engagement.

Understanding these demographic dynamics is essential in a competitive market where businesses must go beyond traditional sales tactics and align their offerings with the nuanced expectations of varied consumer segments. This study, therefore, serves as a step toward decoding the complex consumer landscape and helping Bajaj Electronics stay ahead in a market increasingly defined by data-driven decision-making. In the vibrant and fast-paced world of consumer electronics, understanding what influences a customer's decision to make a purchase

goes far beyond product features or price points. It requires a deep dive into the social and psychological fabric of the consumer landscape—where demographic characteristics quietly, yet powerfully, shape choices. This study embarks on a journey to unravel the threads of influence that demographic factors exert on consumer purchasing behaviour, with a focused lens on Bajaj Electronics, one of India's prominent electronics retail chains.

Every customer who walks into a Bajaj Electronics store brings with them a unique background shaped by their age, gender, income level, educational attainment, occupation, and more. These demographic attributes do not just inform what consumers buy—they influence how they think about brands, how they assess value, and how they prioritize needs versus desires. By peeling back the layers of these demographic dimensions, this research seeks to identify the patterns and preferences that drive purchasing decisions.

For Bajaj Electronics, which serves a diverse and ever-expanding customer base, the stakes are high. As competition intensifies and consumer expectations evolve, relying on generic marketing approaches is no longer sufficient. Businesses must now tailor their strategies to meet the nuanced demands of specific consumer segments. This study is rooted in the belief that data-driven insight into demographic behaviour can serve as a strategic compass—guiding everything from inventory selection to advertising tone to in-store experience design.

Through surveys, data analysis, and empirical insights, this research aims to shed light on the demographic undercurrents shaping consumer behaviour in the electronics retail sector. In doing so, it not only contributes to the academic understanding of consumer psychology but also offers practical implications for brands like Bajaj Electronics that are looking to build deeper, more profitable relationships with their customers.

Furthermore, the digital transformation in the retail sector has added a new layer of complexity to consumer behaviour. With the rise of e-commerce and Omni channel shopping experiences, understanding the demographic preferences of online versus offline shoppers has become more critical than ever. Bajaj Electronics must not only know what products appeal

to different demographic segments, but also where and how these customers prefer to shop. This study explores such behaviour patterns to support more adaptive and flexible business models.

II. LITERATURE REVIEW

Kotler & Keller (2016)--In *Marketing Management*, Kotler and Keller emphasize that demographic factors such as age, gender, income, occupation, and education significantly influence consumer behaviour. These factors shape preferences, buying capacity, and product perception, especially in durable goods and electronics retail.

Mohd Suki, N. (2013)--In a study on consumer shopping behaviour in Malaysia, Suki examined how demographic variables such as age, gender, income, and education level influence the evaluation of retail marketing mix elements like price, product, place, and promotion. The study found that younger consumers valued variety and promotions, while older consumers prioritized quality and accessibility. The research underscores the importance of demographic segmentation in marketing strategy formulation.

El Hedhli, K., Chebat, J. C., & Sirgy, M. J. (2019)--This research focused on the shopping well-being of consumers in malls across Canada. Findings indicated that demographic variables such as age, gender, income, and family status were significant predictors of shopping experiences. Younger and higher-income shoppers reported higher levels of shopping-related well-being, highlighting the emotional dimension of consumer behaviour influenced by demographic traits.

Rajagopal (2016)--The study in Mexico City analysed the influence of demographics like age, gender, family life cycle, and socioeconomic status on shopping behaviour. Results showed that younger consumers were drawn to malls as social spaces, while older individuals preferred convenience. Demographics also influenced shopping frequency and product choice, emphasizing the need for targeted retail strategies.

Sin, L. Y., & Tse, A. C. (2013)--Investigating online shopping behaviour in Hong Kong, this study found that younger, more educated, and higher-income individuals were more likely to shop online. Gender differences were observed in terms of product

preferences and shopping motivations. The study highlights how even in digital shopping, demographic segmentation remains crucial for effective consumer targeting.

Rao & Reddy (2021)--Their research focused on Consumer Preferences in Multi-brand Retail Stores like Bajaj Electronics and found that purchasing behaviour is increasingly shaped by younger consumers (18–35 age group), influenced by promotional offers and EMI schemes.

Singh & Mehta (2022)--In their recent study, they argue that demographics must be considered alongside psychographics for a holistic understanding of consumer behaviour in modern electronics retail. They suggest that lifestyle and technology adoption rates act as moderators to demographic impact.

Massara, F., Melara, R. D., & Shams, S. M. R. (2017)--This research on Pakistani consumers revealed that age, gender, education, and income were strong predictors of impulsive buying behaviour, especially for apparel products in malls. Young and female consumers with higher disposable income showed a greater tendency to engage in spontaneous purchases, linking demographic traits with behavioural outcomes.

Research Gap:

The existing literature extensively explores the influence of **demographic factors**—such as age, gender, income, education, and occupation—on **consumer behavior**, particularly in **retail and mall environments**. Various studies also highlight the importance of **marketing mix elements**, **shopping motivations**, and **online versus offline preferences** based on these demographic variables. However, the following key research gaps are identified:

1. Limited Integration of Demographics with Emerging Variables: While demographic factors have been widely studied, few studies integrate these with psychographic, behavioral, or technological factors. Singh & Mehta (2022) touch on this by suggesting psychographics as a complement, but empirical integration and modeling of such variables remain limited in the current body of research.

2. Insufficient Focus on Electronics Retail in Indian Context: Although some studies (e.g., Rao & Reddy, 2021) have looked into electronics retail in India, comprehensive, segment-specific insights are still

lacking, especially considering rapidly evolving consumer preferences, digital exposure, and financing schemes (e.g., EMI options) in the Indian electronics retail sector.

3. Underexplored Emotional and Experiential Aspects in Indian Consumers: El Hedhli et al. (2019) discuss shopping well-being and emotional satisfaction in malls, but similar studies focused on Indian consumers, especially in electronics retail, are sparse. Understanding how demographics influence emotional dimensions of shopping (e.g., satisfaction, excitement, stress) remains an underdeveloped area.

4. Static vs. Dynamic Consumer Behavior: Most existing studies offer a static snapshot of demographic influences. However, longitudinal or post-pandemic studies capturing changes in consumer behavior patterns over time (due to technological advancement, digital adoption, or socio-economic shifts) are missing or insufficiently explored.

5. Lack of Segment-Specific Behavioral Analysis (e.g., Gen Z, Millennials): Although younger demographics are mentioned (Rao & Reddy, 2021; Massara et al., 2017), deep-dive segment-level analysis (like Gen Z vs. Millennials) in terms of device preferences, channel choices, or brand loyalty in electronics retail is largely absent.

6. Regional and Tier-Based Market Differences: There is limited research comparing consumer behavior across Tier I, II, and III cities or urban vs. semi-urban areas in India. Given India's demographic diversity, such comparative studies are critical for localized marketing strategies.

7. EMI and Promotional Impact on Buying Decisions: Although Rao & Reddy (2021) mention EMI schemes and offers, quantitative models measuring the exact impact of financing and promotional tools on different demographic groups are still underexplored.

Future research should aim to develop a more holistic, multi-dimensional model that includes demographics along with psychographics, emotional drivers, financing behavior, and regional variables, particularly in the context of India's evolving electronics retail landscape. This would fill a significant gap in both academic literature and practical marketing strategy formulation.

Statement of the Problem:

Despite extensive research highlighting the influence of demographic factors on consumer behaviour in retail settings, there remains a significant gap in understanding how these variables interact with emerging dimensions such as psychographics, emotional experiences, financing behaviour, and technological adoption. In the context of India's rapidly evolving electronics retail sector, existing studies offer limited insights into how diverse demographic groups—especially Gen Z and Millennials—differ in their preferences, motivations, and purchase decisions. Moreover, research seldom accounts for regional and tier-based market differences or assesses the dynamic, post-pandemic shifts in consumer behaviour.

The lack of integrated, segment-specific, and regionally contextualized studies restricts the development of effective, data-driven marketing strategies tailored to India's heterogeneous consumer base. Therefore, a comprehensive investigation that incorporates both traditional demographic variables and contemporary influencing factors is essential to better understand and predict consumer behaviour in the Indian electronics retail sector.

Need For the Study:

In today's highly competitive and rapidly evolving retail landscape, understanding consumer behavior has become a strategic imperative for electronics retailers like Bajaj Electronics. With increasing product variety, technological advancements, and easy financing options such as EMIs, consumers are no longer influenced by product features alone. Instead, factors such as age, gender, income, education, occupation, and family structure significantly shape their buying decisions.

While numerous studies have examined the role of demographics in general retail or online contexts, **there is a limited understanding of how these factors influence purchasing decisions specifically in organized multi-brand electronics retail environments in India.** Bajaj Electronics, being a prominent player in this segment, offers an ideal context to explore these patterns. Additionally, consumer preferences are continuously shifting—particularly post-pandemic—with younger, tech-savvy, and financially-aware customers becoming

dominant influencers. Recognizing how different demographic groups respond to promotions, product categories, pricing strategies, and financing schemes is crucial for developing targeted marketing strategies, improving customer satisfaction, and driving sales.

Thus, this study is essential to:

- Identify which demographic segments are most influential in purchasing behavior at Bajaj Electronics.
- Understand how demographic traits impact consumer preferences, brand choices, and payment methods.
- Assist marketers and retail managers in designing more effective, data-driven, and personalized marketing strategies based on demographic insights.
- Bridge the gap between academic research and practical retail strategy in the context of consumer electronics in India.

Objectives of the Study:

- 1. To identify and categorise the key demographic factors—including age, gender, income, education and occupation- that influence consumer purchasing decisions at Bajaj electronics.
- To examine the relationship between specific demographic variables and product preferences within the electronics category, such as home appliances, mobile devices, and entertainment systems.
- To analyze the extent to which income and education levels affect consumers' brand sensitivity, price consciousness, and perceived value when shopping at Bajaj Electronics.

Scope of the Study:

This study focuses on evaluating the influence of key demographic variables—such as age, gender, income, education, occupation, and family size—on the purchasing decisions of consumers at **Bajaj Electronics**, a leading multi-brand retail chain in India specializing in consumer electronics and appliances.

The scope of the study includes:

1. **Geographical Scope:** The study will be conducted across selected Bajaj Electronics outlets, primarily in urban and semi-urban regions, to capture a diverse consumer base.
2. **Demographic Segmentation:** The research will analyze how different demographic groups (e.g., Gen Z, Millennials, working professionals, homemakers) differ in their product preferences, brand choices, budget constraints, and response to promotional offers and financing schemes like EMIs.
3. **Product Categories:** The study will cover a range of product categories including smartphones, televisions, laptops, home appliances, and accessories to assess if demographic factors influence the type of electronics purchased.
4. **Consumer Decision-Making Behavior:** It will examine aspects such as frequency of purchases, buying motivations (need-based vs. impulse), influence of family members, and sensitivity to price and offers based on demographic attributes.
5. **Retail-Specific Insights:** Unlike broader market studies, this research is specifically focused on **Bajaj Electronics' retail environment**, including in-store promotions, financing options, and customer service experiences that might be differently perceived across demographics.
6. **Time Frame:** The study will consider recent trends and behaviors, particularly **post-pandemic shifts** in consumer attitudes and purchasing habits.
7. **Strategic Implications:** The findings aim to assist Bajaj Electronics' management and marketers in crafting **targeted marketing strategies, store layouts, product assortment, and promotional campaigns** tailored to different demographic groups.

Hypotheses of the Study:

- **H₀:** There is no significant impact of demographic factors on the purchasing decisions of consumers at Bajaj Electronics.

- **H₁:** There is a significant impact of demographic factors on the purchasing decisions of consumers at Bajaj Electronics.

Limitations of the Study:

While the study aims to provide valuable insights into how demographic factors influence consumer purchasing decisions at Bajaj Electronics, several limitations must be acknowledged:

Geographical Limitation: The study may be confined to selected outlets of Bajaj Electronics, primarily in urban or semi-urban areas. As a result, findings may not fully represent consumer behavior in rural regions or across all geographical locations in India.

Time Constraint: The study is conducted within a limited time frame and may not capture long-term changes or seasonal variations in consumer purchasing behavior.

Sample Size and Representation: The research may be based on a limited sample size, which could restrict the generalizability of the findings to the broader population of Bajaj Electronics customers.

Exclusion of Non-Demographic Variables: While the focus is on demographic factors, other influential factors like psychographics (lifestyle, values), emotional triggers, brand perceptions, peer influence, and social media impact are not deeply explored.

Self-Reported Data Bias: The study relies on primary data collected through surveys or questionnaires, which are subject to respondent bias, exaggeration, or misunderstanding of questions.

Retail Format-Specific Focus: The findings are specific to Bajaj Electronics' multi-brand retail format and may not be applicable to other retail formats such as online-only platforms, single-brand stores, or e-commerce environments.

Technological and Economic Shifts: Rapid technological advancements, economic fluctuations, or changes in EMI schemes and product offerings during or after the study period may affect the relevance of the results over time.

Pandemic or External Event Influence: Post-COVID behavioral shifts or other unforeseen socio-economic events may skew consumer responses, making it difficult to isolate the effects of demographics alone.

III. RESEARCH METHODOLOGY

The research methodology outlines the systematic approach adopted to collect, analyze, and interpret data for understanding how demographic factors influence consumer purchasing decisions at Bajaj Electronics.

1. Research Design: The study follows a **descriptive research design**, aiming to systematically describe the relationship between demographic variables (such as age, gender, income, education, occupation) and purchasing behavior (product choice, frequency, payment mode, brand preference, etc.).

2. Type of Research: This is a **quantitative research** study, using structured data collection tools and statistical analysis to test hypotheses and identify patterns.

3. Sampling Method:

- **Sampling Technique:** Non-probability convenience sampling
- **Sample Size:** Approximately 150 consumers visiting selected Bajaj Electronics stores
- **Sampling Location:** Selected urban and semi-urban branches of Bajaj Electronics

4. Data Collection Methods:

Primary Data:

- Collected through **structured questionnaires** administered to customers at Bajaj Electronics.
- The questionnaire includes both **closed-ended** (multiple choice, Likert scale) and **demographic** questions.

Secondary Data:

- Gathered from company reports, industry publications, academic journals, and previous research studies to support the literature review and context.

5. Data Analysis Tools:

- **Chi-square test** (to examine the relationship between demographic variables and purchasing decisions)

6. Variables Studied:

Independent Variables (Demographic Factors):

- Age

- Gender
- Income
- Educational Qualification
- Occupation
- Family Size

Dependent Variables (Purchasing Behavior):

- Product category preference
- Frequency of purchases
- Payment method (e.g., EMI, cash, credit)
- Sensitivity to promotions/discounts
- Brand choice

7. Time Duration of the Study:

The research will be conducted over a period of **2 to 3 months**, including time for data collection, entry, analysis, and interpretation.

8. Limitations & Ethical Considerations:

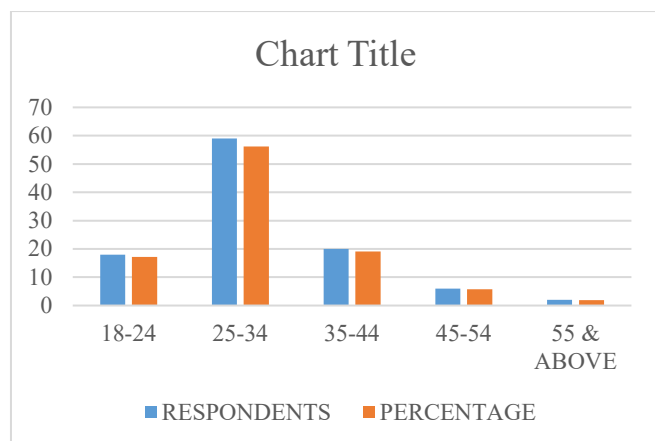
- Participants will be informed of the study's purpose and their responses will be kept **anonymous and confidential**.
- Data collection will be limited to the stated time frame and sample size.

This methodology ensures a structured and evidence-based approach to assess how demographic factors influence consumer purchasing behavior, helping Bajaj Electronics tailor marketing and sales strategies accordingly.

IV. DATA ANALYSIS & INTERPRETATION

1 AGE:

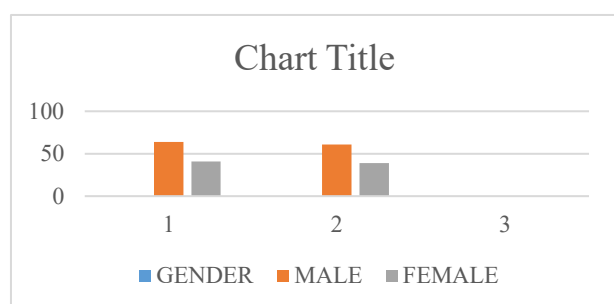
AGE	RESPONDENT	PERCENTAG
18-24	18	17.14%
25-34	59	56.19%
35-44	20	19.047%
45-54	6	5.714%
55 &	2	1.904%
TOTAL	105	100



The above graph shows the age-wise distribution of 105 respondents. Most of the respondents (56.19%) are in the age group of 25-34 years, followed by 19.05% in the 35-44 age group. Young adults aged 18-24 make up 17.14% of the total respondents. Only a small percentage belongs to the 45-54 (5.71%) and 55 & above (1.90%) age groups. This indicates that the majority of participants are young to middle-aged adults.

2 GENDER:

GENDER	RESPONDENTS	PERCENTAGE
MALE	64	60.95238095%
FEMALE	41	39.04761905%
TOTAL	105	100

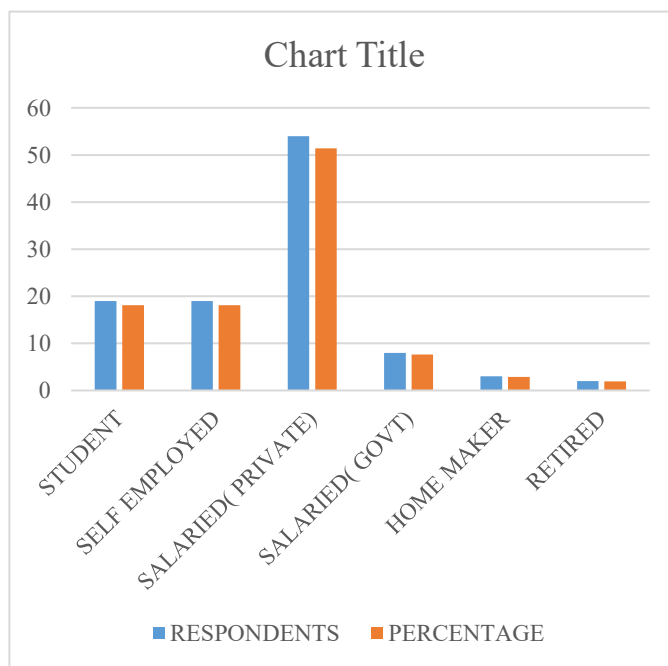


The graph shows the gender distribution of 105 respondents. Out of these, 64 are male, with percentage about 60.95% of the total. Females account for 41 respondents, which is approximately 39.05%. This means there are more male respondents than female respondents in the group. Overall, males form the majority in this sample.

3 OCCUPATION:

OCCUPATION	RESPONDE	PERCENTA
STUDENT	19	18.0952381%
SELF EMPLOYED	19	18.0952381%

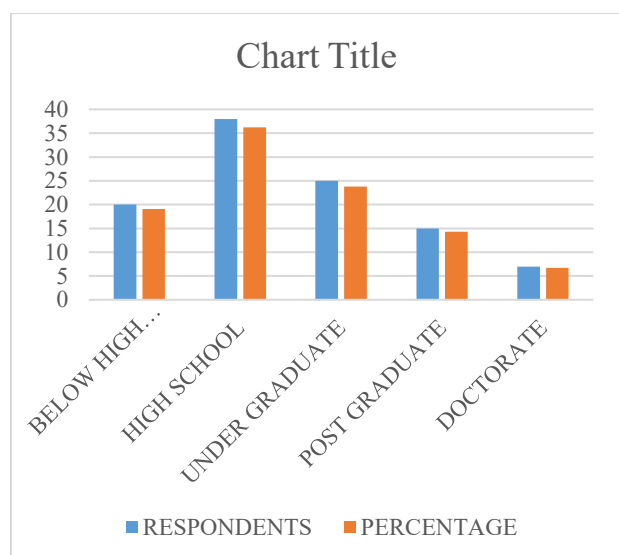
SALARIED(PRIV	54	51.42857143
SALARIED(GOV	8	7.619047619
HOME MAKER	3	2.857142857
RETIRED	2	1.904761905
TOTAL	105	100



The graph presents the occupation details of 105 respondents. The majority, 51.43%, are salaried employees in the private sector. Both students and self-employed individuals make up an equal share of 18.10% each. Government salaried respondents account for 7.62%, while homemakers and retired people represent smaller portions at 2.86% and 1.90% respectively. This shows most respondents are working professionals, mainly in private job.

4 EDUCATIONAL QUALIFICATION:

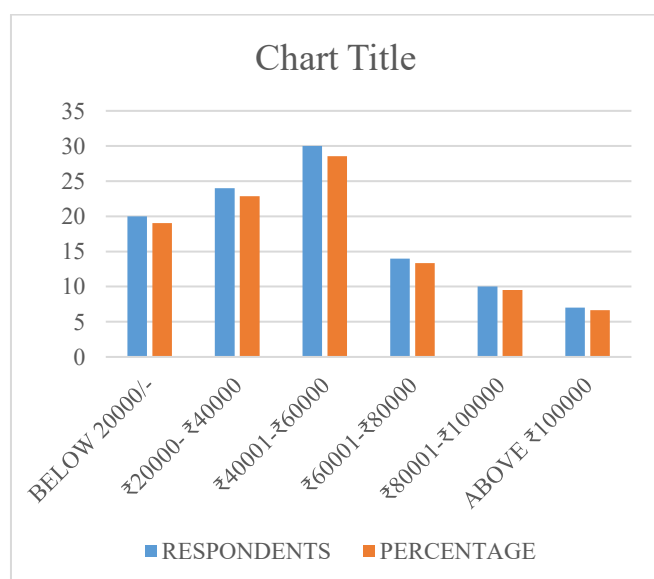
EDUCATIONAL	RESPOND	PERCEN
BELOW HIGH	20	19.047619
HIGH SCHOOL	38	36.190476
UNDER GRADUATE	25	23.809523
POST GRADUATE	15	14.285714
DOCTORATE	7	6.6666666
TOTAL	105	100



The graph shows the educational qualifications of 105 respondents. Most respondents, 36.19%, have completed high school, followed by 23.81% who are undergraduates. Those with education below high school make up 19.05%. Postgraduates account for 14.29%, while 6.67% hold a doctorate degree. This indicates a diverse mix of education levels, with the majority having at least completed high school.

5 MONTHLY INCOME:

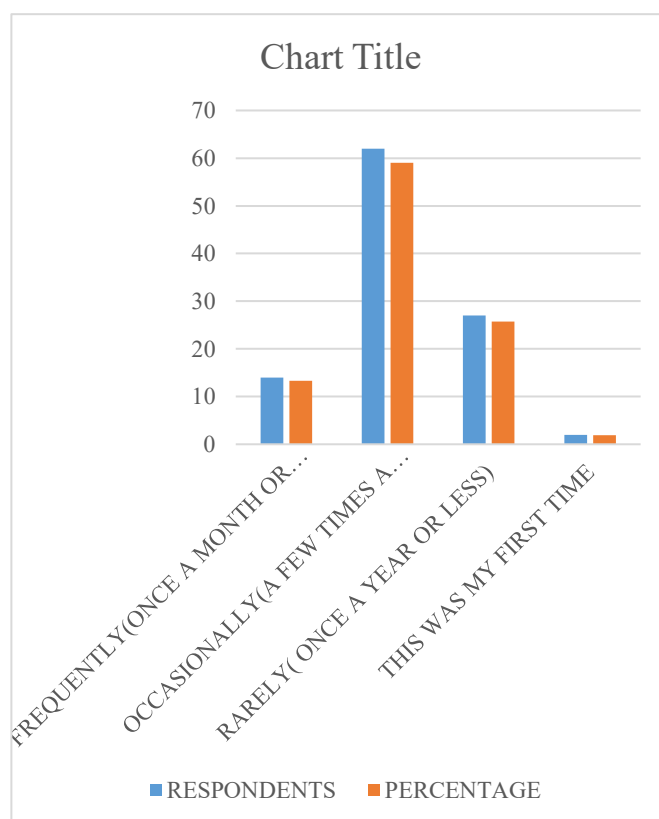
MONTHLY	RESPONDE	PERCENTA
BELOW 20000/-	20	19.04761905
₹20000- ₹40000	24	22.85714286
₹40001-₹60000	30	28.57142857
₹60001-₹80000	14	13.33333333
₹80001-₹100000	10	9.523809524
ABOVE ₹100000	7	6.666666667
TOTAL	105	100



The graph shows the monthly income distribution of 105 respondents. The largest group, 28.57%, earns between ₹40,001 and ₹60,000. Those earning between ₹20,000 and ₹40,000 make up 22.86%, while 19.05% earn below ₹20,000. Smaller percentages earn higher incomes, with 13.33% earning ₹60,001 to ₹80,000, 9.52% earning ₹80,001 to ₹100,000, and 6.67% earning above ₹100,000. This shows most respondents fall in the middle-income range.

6 HOW OFTEN DO YOU SHOP AT BAJAJ ELECTRONICS?

HOW OFTEN DO YOU	RESPON	PERCE
FREQUENTLY(ONCE A	14	13.33333
OCCASIONALLY(A FEW	62	59.04761
RARELY(ONCE A YEAR	27	25.71428
THIS WAS MY FIRST	2	1.904761
TOTAL	105	100

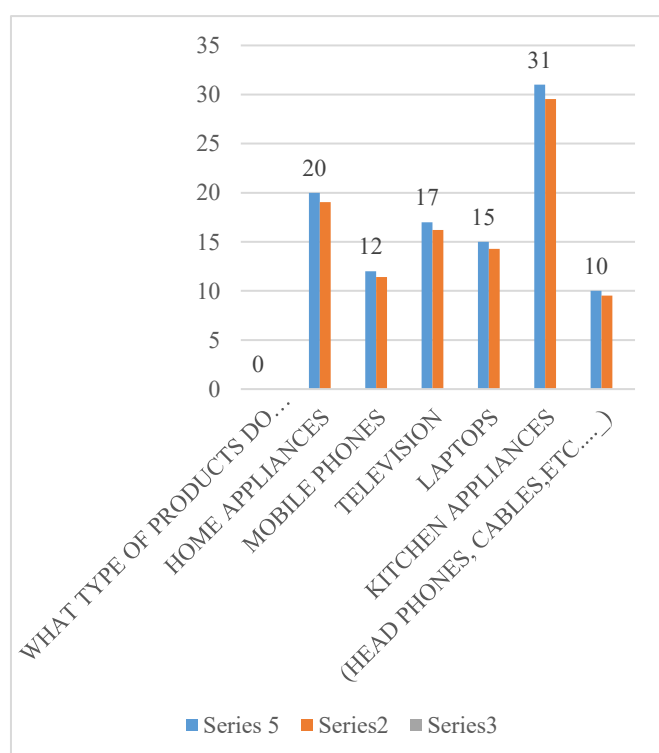


The graph shows how often 105 respondents shop at Bajaj Electronics. Most respondents, 59.05%, shop occasionally, a few times a year. About 13.33% shop frequently, meaning once a month or more. Around 25.71% shop rarely, only once a year or less. A small number, 1.90%, are first-time shoppers. This suggests

that most customers visit Bajaj Electronics occasionally rather than regularly

7 WHAT TYPE OF PRODUCTS DO YOU USUALLY PURCHASE AT BAJAJ ELECTRONICS?

WHAT TYPE OF	RESPOND	PERCEN
HOME APPLIANCES	20	19.047619
MOBILE PHONES	12	11.428571
TELEVISION	17	16.190476
LAPTOPS	15	14.285714
KITCHEN	31	29.523809
(HEAD PHONES,	10	9.5238095
TOTAL	105	100

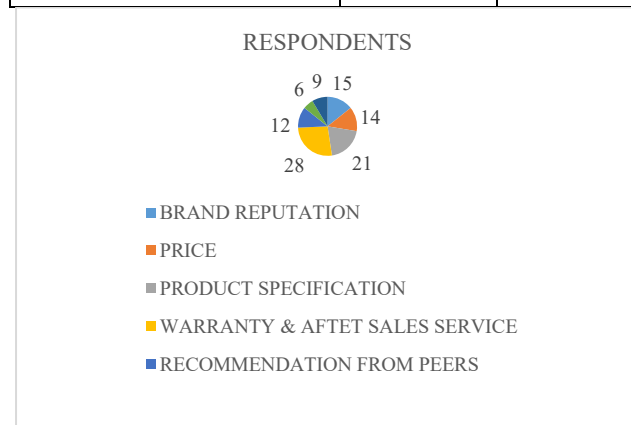


The graph shows the types of products that 105 respondents usually purchase at Bajaj Electronics. Most respondents, 29.52%, buy kitchen appliances. Home appliances are purchased by 19.05%, and televisions by 16.19%. Laptops are bought by 14.29%, while mobile phones account for 11.43%. Accessories like headphones and cables make up 9.52%. This indicates that kitchen and home appliances are the most popular product categories among customers.

8 WHAT FACTORS INFLUENCE YOUR DECISION TO PURCHASE BAJAJ ELECTRONIC GOODS?

WHAT FACTORS	RESPON	PERCEN

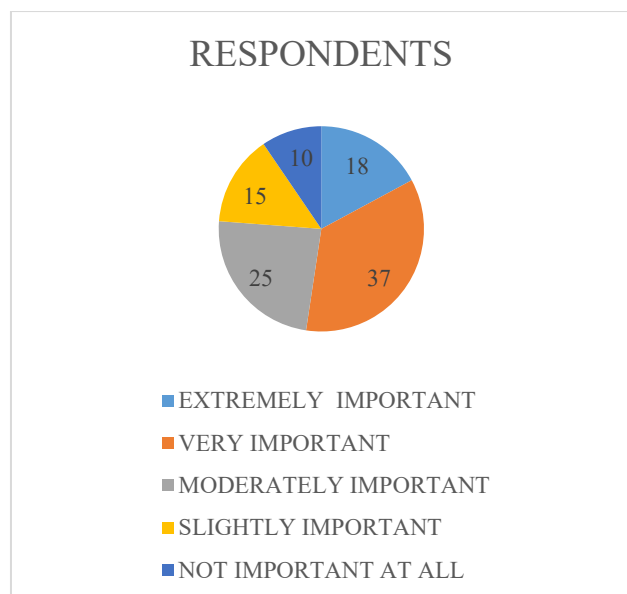
BRAND REPUTATION	15	14.285714
PRICE	14	13.461538
PRODUCT	21	20%
WARRANTY & AFTET	28	26.666666
RECOMMENDATION	12	11.428571
ONLINE RATINGS	6	5.7142857
PREVIOUS	9	8.5714285
TOTAL	105	100



The graph shows the factors that influence 105 respondents when purchasing Bajaj Electronics goods. The most important factor is warranty and after-sales service, chosen by 26.67% of respondents. Product specifications influence 20%, followed by brand reputation at 14.29% and price at 13.46%. Recommendations from peers affect 11.43%, while previous experience and online ratings have smaller impacts at 8.57% and 5.71% respectively. This shows that customers value service and product details the most when buying electronics

9 HOW IMPORTANT IS BRAND REPUTATION WHILE PURCHASING BAJAJ ELECTRONIC GOODS?

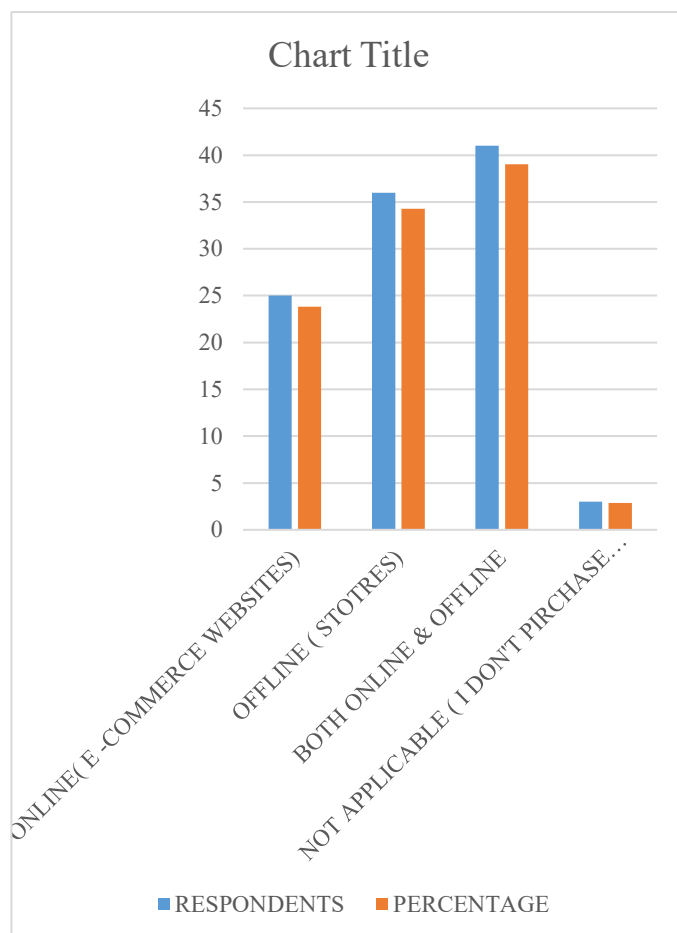
HOW IMPORTANT	RESPOND	PERCENT
EXTREMELY	18	17.1428571
VERY IMPORTANT	37	35.2380952
MODERATELY	25	23.8095238
SLIGHTLY	15	14.2857142
NOT IMPORTANT	10	9.52380952
TOTAL	105	100



The graph shows how important brand reputation is to 105 respondents when purchasing Bajaj Electronics goods. A majority, 52.38%, consider it extremely or very important. About 23.81% find it moderately important, while 14.29% say it is slightly important. Only 9.52% feel that brand reputation is not important at all. This indicates that brand reputation plays a significant role in most customers' buying decisions

10 WHAT IS YOUR PREFERRED MODE OF PURCHASING BAJAJ ELECTRONIC GOODS?

WHAT IS YOUR	RESPON	PERCEN
ONLINE(E -	25	23.809523
OFFLINE (STOTRES)	36	34.285714
BOTH ONLINE &	41	39.047619
NOT APPLICABLE (I	3	2.8571428
TOTAL	105	100



The graph shows the preferred mode of purchasing Bajaj Electronics goods among 105 respondents. Most respondents, 39.05%, prefer buying both online and offline. Offline stores are preferred by 34.29%, while 23.81% choose to shop online through e-commerce websites. A small group, 2.86%, do not purchase Bajaj Electronics products. This indicates that many customers like having the flexibility to shop both ways.

11 WHATS SOURCES DO YOU USUALLY CONSULT BEFORE MAKING A PURCHASE DECISION?

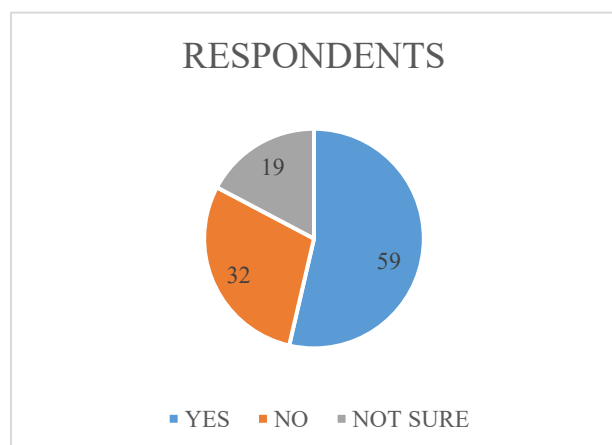
WHATS SOURCES	RESPOND	PERCEN
OFFICIAL BRAND	17	16.190476
CUSTOMER	25	23.809523
SOCIAL MEDIA	18	17.142857
FRIENDS & FAMILY	20	19.047619
IN-STORE	10	9.5238095
PRICES	15	14.285714
TOTAL	105	100



The graph shows the sources respondents consult before making a purchase decision for Bajaj Electronics goods. The most popular source is customer reviews, used by 23.81% of respondents. Friends and family influence 19.05%, while social media is consulted by 17.14%. Official brand websites are checked by 16.19%, and price comparison websites by 14.29%. In-store representatives are the least consulted, at 9.52%. This suggests that customers rely mostly on reviews and personal recommendations before buying.

12 DOES YOUR AGE INFLUENCE YOUR PREFERENCE FOR SPECIFIC BAJAJ ELECTRONIC GOODS?

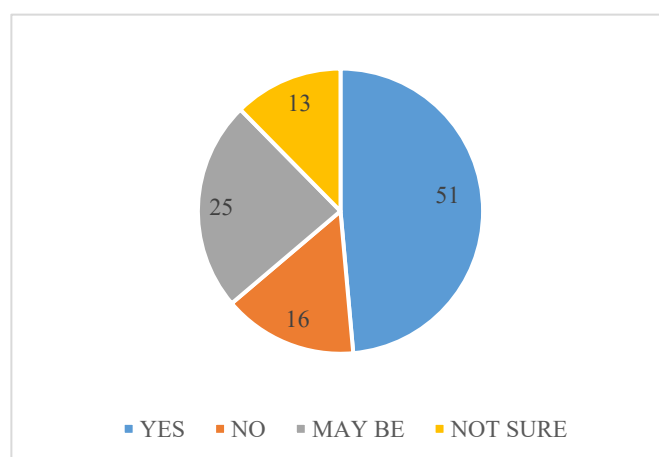
DOES YOUR	RESPONDENT	PERCENTAG
YES	59	56.19047619%
NO	32	30.47619048%
NOT SURE	19	18.0952381%
TOTAL	105	100%



The graph shows whether age influences respondents' preferences for specific Bajaj Electronics goods. A majority of 56.19% said yes, age does influence their choice. About 30.48% said no, while 18.10% are not sure. This indicates that for most customers, age plays an important role in deciding which electronic products to buy.

13 DOES YOUR MONTHLY INCOME IMPACT YOUR PURCHASING DECISION OF BAJAJ ELECTRONIC GOODS?

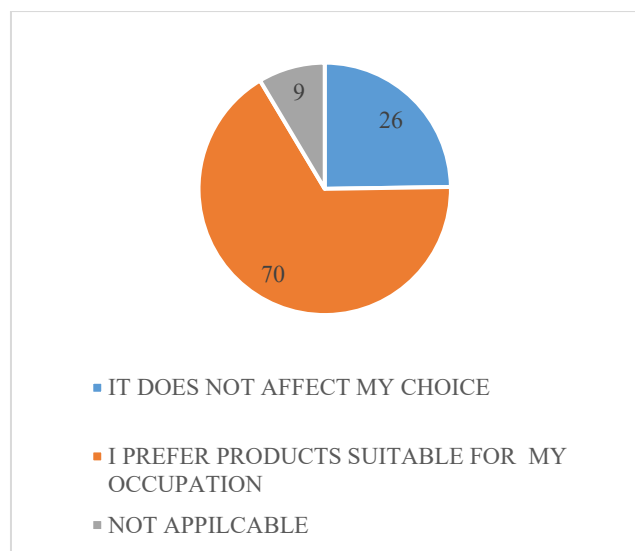
DOES YOUR	RESPONDENT	PERCENTAG
YES	51	48.57142857%
NO	16	15.23809524%
MAY BE	25	23.80952381%
NOT SURE	13	12.38095238%
TOTAL	105	100%



The graph shows whether monthly income impacts respondents' purchasing decisions for Bajaj Electronics goods. Nearly half, 48.57%, said yes, their income affects their buying choices. About 15.24% said no, while 23.81% responded maybe, and 12.38% were not sure. This suggests that income is an important factor for many customers when deciding what to purchase.

14 HOW DOES YOUR OCCUPATION AFFECT YOUR CHOICE OF BAJAJ ELECTRONIC GOODS?

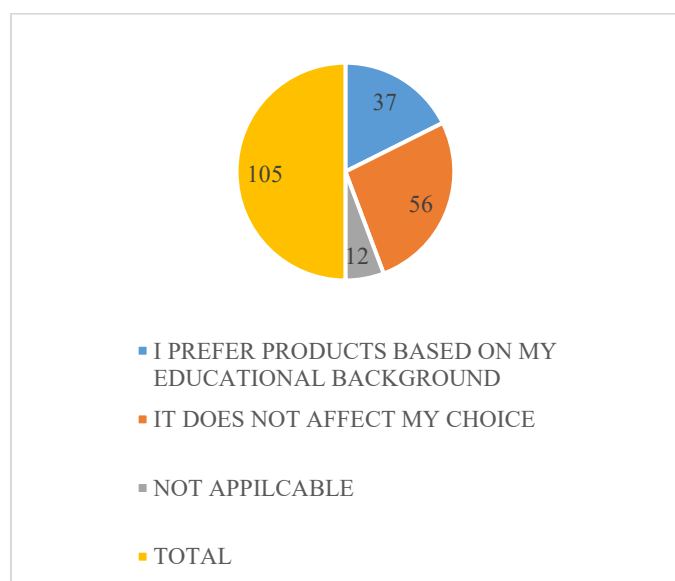
HOW DOES YOUR	RESPOND	PERCEN
IT DOES NOT AFFECT	26	24.761904
I PREFER PRODUCTS	70	66.666666
NOT APPLICABLE	9	8.5714285
TOTAL	105	100



The table shows how respondents feel their occupation affects their choice of Bajaj Electronics goods. A majority, 66.67%, prefer products that are suitable for their occupation. About 24.76% said their occupation does not affect their choice, while 8.57% said it's not applicable. This means most customers consider their job needs when buying electronic products.

15 HOW DOES YOUR EDUCATIONAL QUALIFICATION INFLUENCE YOUR CHOICE OF BAJAJ ELECTRONICS?

HOW DOES YOUR	RESPOND	PERCENT
I PREFER PRODUCTS	37	35.238095
IT DOES NOT AFFECT	56	53.333333
NOT APPLICABLE	12	11.428571
TOTAL	105	100



The graph shows how educational qualification affects respondents' choice of Bajaj Electronics goods. More than half, 53.33%, said their education does not affect their choice. However, 35.24% prefer products based on their educational background. About 11.43% said it's not applicable. This indicates that while education influences some buyers, most do not consider it a major factor in their purchase decisions.

STATISTICAL TOOL FOR ANALYSIS:

HYPOTHESIS TESTING:

- **H0:** There is no significant relationship between income and consumer purchasing decisions for Bajaj electronics products.
- **H1:** There is a significant relationship between income and consumer purchasing decisions for Bajaj electronics products.

Chi-Square Calculation			
Impact	Observed value	Expected Value	X ²
Yes	51	26.25	23.33571
No	16	26.25	4.002381
May be	25	26.25	0.059524
Not Sure	13	26.25	6.685095
			34.08571

X ² table value	X ² calculated value
9.488	34.08571
H0 Rejected	H1 Accepted

As a table value is less than calculated value, we reject H0(Null Hypothesis and Accept H1(Alternative

Note:-
X ² = chi square
O = Observed value
E = Expected value
Formula:- $(O-E)^2/E$
Degree of freedom:-4
E = Expected value
Significance:-0.05

- Since the table value is less than calculated value, H0 is rejected and H1 is accepted. So there is a significant relationship between income and consumer purchasing decisions for Bajaj electronics products.

V. FINDINGS

- Most of the respondents are between 25 and 34 years old, showing that young adults are the main customers of Bajaj Electronics. Very few older people (above 45) took part in the survey. This suggests that Bajaj Electronics mainly attracts a younger audience.
- There are more male customers (about 61%) than female customers (39%). This shows that men are

more likely to shop at Bajaj Electronics, or at least more represented in this survey.

- Most respondents are private sector employees, showing that working professionals form a large part of Bajaj Electronics' customer base. Students and self-employed individuals also form a good share, while homemakers and retirees are fewer.
- A large number of customers have completed high school or undergraduate education. This shows that Bajaj Electronics appeals to people with a moderate level of education, though it also has customers from both lower and higher educational backgrounds.
- Most respondents earn between ₹20,000 and ₹60,000 per month, suggesting that Bajaj Electronics mainly caters to middle-income groups. Higher-income groups are fewer but still present.
- Most customers shop at Bajaj Electronics only a few times a year, which means they visit occasionally. Very few customers shop regularly, and even fewer are first-time buyers.
- Kitchen and home appliances are the most commonly purchased products. This shows that Bajaj Electronics is popular for household electronics more than for gadgets like mobiles and laptops.
- Warranty and after-sales service are the most important factors for buyers, followed by product specifications and brand reputation. This means that customers value long-term support and detailed product features.
- More than half the respondents think brand reputation is very or extremely important. This shows that the company's image and trustworthiness matter a lot to customers.
- Most people prefer both online and offline shopping, showing that customers like flexibility. However, a slightly larger number still prefer visiting stores compared to shopping only online.
- Customers mostly rely on reviews and advice from family and friends before buying. Social media and official websites are also used, but in-store staff have the least influence. This means digital and personal opinions shape buying decisions the most.
- More than half of the respondents feel that their age affects what products they prefer. This suggests that different age groups may be interested in different types of electronics.
- Almost half of the respondents believe their income affects what they buy. This indicates that price and affordability play an important role in choosing products at Bajaj Electronics. Most respondents choose products that fit their job needs. This means occupation plays a strong role in deciding which electronics to purchase.
- Over half of the respondents feel their education does not affect their product choices. However, a good number still think it does. This shows mixed opinions, but overall, education level may not be a strong influence.

VI. SUGGESTIONS

- Introduce promotions or campaigns that appeal more to female shoppers to balance gender participation and increase reach.
- Create job-based bundles or recommendations (e.g., home office setup for professionals, student-friendly laptops) to cater to occupation-specific needs.
- Offer simple, informative product descriptions and in-store guidance to cater to all education levels, especially those with less technical knowledge.
- Introduce EMI options, festive discounts, and mid-range product lines to target the middle-income group, which is the majority.
- Launch loyalty programs or periodic deals to encourage occasional and rare buyers to shop more frequently.
- Highlight kitchen and home appliance deals more prominently in advertisements, since they are the most purchased items.
- Emphasize warranty policies, product specs, and after-sales service in-store and online to align with what matters most to customers.
- Strengthen brand image through customer testimonials, consistent quality, and partnerships with trusted brands.

- Maintain a strong presence both online and offline. Offer seamless integration (e.g., buy online, pick up in-store) to attract customers who prefer both options.
- Improve presence on review platforms and social media. Encourage satisfied customers to leave reviews and share experiences online.
- Segment marketing by age group and promote age-relevant products (e.g., gadgets for youth, health appliances for older adults).
- Provide clear pricing options and emphasize value for money to attract price-sensitive customers.
- Use targeted advertising showing how products meet specific work-related needs, like business laptops for professionals or compact devices for travelers.
- Use visuals, product demos, and easy-to-understand guides to appeal to customers across different educational backgrounds.

VII. CONCLUSION

The study demonstrates that the majority of Bajaj Electronics' customers are young adults, mainly between the ages of 25 and 34, and most of them are male. Customers are mostly working professionals, especially in the private sector, and belong to middle-income groups. Many have completed at least high school, showing a moderately educated customer base. People usually shop occasionally, preferring to buy kitchen and home appliances.

Warranty, after-sales service, and product features are major factors that influence purchases. Brand reputation also matters to most buyers. Customers like to shop both online and offline and rely heavily on reviews and personal recommendations before purchasing. Age, income, and occupation often influence buying decisions, while education has a mixed impact. Overall, Bajaj Electronics serves a diverse but largely young, working, and value-conscious customer base

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An Evaluative Study on Performance Growth Plan of ICICI Mutual Fund and SBI Mutual Fund

Umamaheswararao Gobbilla¹, Devani Keerthi²

¹Associate Professor, Department Of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

orcid.org/0000-0002-4467-4600.

²Student of MBA, CMR Institute of Technology, Hyderabad, Telangana, India.

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Abstract— This study evaluates the performance of Growth Plans offered by ICICI Mutual Fund and SBI Mutual Fund to inform investor decision-making. Employing a quantitative approach, the research analyzes secondary data over a five-year period using performance metrics such as Sharpe Ratio, Treynor Ratio, Jensen's Alpha, and NAV trends. The findings indicate that most schemes exhibit risk-adjusted returns below market expectations, with SBI schemes generally outperforming ICICI in long-term growth and stability. The analysis highlights differences in risk profiles, return consistency, and fund management strategies between the two fund houses. These results provide valuable insights for investors, financial advisors, and policymakers seeking to optimize long-term investment strategies. Overall, the study underscores the importance of comparative performance evaluation in mutual fund selection, contributing to more informed financial planning and enhanced investment outcomes.

Keywords— Mutual Funds, Growth Plan, Fund Performance, Risk and Return, NAV (Net Asset Value), Financial Performance, Portfolio Evaluation, Asset Management Companies (AMCs)

I. INTRODUCTION

In the contemporary financial landscape, mutual funds have emerged as one of the most popular investment avenues for individual and institutional investors alike. Their ability to provide diversified portfolios, professional management, and relatively lower risk compared to direct equity investments has made them an attractive option. Among the various schemes offered by mutual fund houses, growth plans particularly appeal to investors seeking long-term capital appreciation rather than regular income. These plans reinvest returns to enhance the net asset value (NAV) over time, aligning with the wealth creation goals of long-term investors.

In India, ICICI Prudential Mutual Fund and SBI Mutual Fund stand out as two of the most prominent players in the mutual fund industry. Both institutions offer a wide range of schemes under their growth

plans, catering to various risk appetites and investment goals. While ICICI Prudential is known for its strong private sector backing and innovation in fund offerings, SBI Mutual Fund benefits from a trusted public sector image and a wide distribution network.

This study aims to evaluate and compare the performance of growth plans offered by ICICI Mutual Fund and SBI Mutual Fund over a specified period. The evaluation focuses on key performance indicators such as returns, risk-adjusted returns, NAV trends, fund management strategies, and consistency. By analysing these parameters, the study seeks to provide valuable insights for investors, financial analysts, and policymakers regarding the effectiveness and competitiveness of these two leading mutual fund houses.

Ultimately, the goal is to help investors make informed decisions by understanding the comparative strengths and weaknesses of the growth-oriented mutual fund schemes offered by ICICI and SBI, thereby contributing to improved investment strategies and financial planning.

II. LITERATURE REVIEW

1. Sahil Jain (2012) - Analysis of Equity Based Mutual Funds in India.

The last decade has seen a tremendous growth in the mutual fund industry. As per the latest data the assets under management in this industry is more than Rs 6.8 thousand billion. Today the Indian market is flooded with more than a thousand mutual fund schemes, promising better returns than others. In this paper an attempt has been made to analyse the performance of equity based mutual funds. A total of 45 schemes offered by 2 private sector companies and 2 public sector companies, have been studied over the period April 1997 to April 2012 (15 years). The analysis has been made using the risk-return relationship and Capital Asset Pricing Model (CAPM). The overall analysis finds that HDFC and ICICI have been the best performers, UTI an average performer and LIC the worst performer which gave below-expected returns on the risk-return relationship.

2. Josheena Jose, Nivya Unni (2016) -- A Study on Performance Evaluation of ICICI Prudential Mutual Fund With Special Reference to Equity Products (Both Direct And Regular Plan)--

Mutual fund is not an alternative investment option to stocks and bonds; rather it pools the money of several investors and invests this in stocks, bonds, money market instruments and other types of securities. Buying a mutual fund is like buying a small slice of a big pizza. The owner of a mutual fund unit gets a proportional share of the fund's gains, losses, income and expenses. There fore the aim of study is to evaluate the performance of ICICI Prudential mutual funds with special reference to Equity products (Both Direct and Regular plan).

3. Dr. Kalyan (2018) -- A Study on Performance of SBI Blue Chip Fund at SBI Mutual Funds in India--

A mutual fund comprising investments in blue-chip stocks, these funds are measured low risk since the underlying securities are from well established, stable

companies with a history of paying dividends and maintaining value despite fluctuations in the adjoining market. Blue chip funds may be chosen as part of a conservative investment strategy. The manuscript highlights to identify risk and returns involved in the blue-chip fund. The most important objective of all mutual funds is to provide better returns to investors by minimizing risk associated with the capital market investment. State Bank of India Mutual Fund (SBI MF) is one of the largest mutual funds in the country with an investor base of over 5.4 million. With over 20 years of rich experience in fund management, State Bank of India Mutual Fund brings forward its expertise in consistently delivering value to its investors.

4. Lubna Ghazal Sapana Shaw (2019) -- An Empirical Study to Analyze the Risk and Return of selected Equity Mutual Fund of India --

Mutual fund is a trust that pools the savings of the investors to make an incursion into investment in the capital market thereby making investors part owners of the assets. In this paper the study has been made to evaluate the performance of the top five equity diversified mutual fund scheme and their performance are evaluated by selecting 10 years secondary data (2013-2023) Of the top five mutual fund companies' scheme (HDFC top 100, ICICI Pru Blue-chip fund, SBI Blue-chip Fund, Nippon Ind Large Cap Fund, Kotak Blue-chip fund). The performance of the selected schemes is evaluated by comparing the risk and return analysis using annualized return, Deviation, Sharp ratio, alpha factor and beta factor.

5. Manjunath Shivaramu (2019) -- Performance Evaluation of Selected Mutual Funds--

In this paper the authors carried out a detailed evaluation of selected large and small and mid-cap mutual funds in India for period of four years starting from 2011 to 2014. The purpose of this study is to know which the best fund in terms of risk is and return thereby the investors can make investment on those funds. Every investor is worried of risk and return part in their investment especially for the equity mutual funds. For this purpose, the authors used the secondary data collected from various reliable sources to calculate the return and risk. The risk has been measured in terms of standard deviation and beta. The evaluation of the performance the selected mutual funds, we have used the well know models of Sharpe, Treynor and Jensen.

The results reveal that the returns of small and mid-cap funds are better than the large cap funds and the higher total risk was found for the large cap funds. We also tested to know whether there is difference in returns among the selected mutual funds. For this the authors used the one way ANOVA and revealed that there are no differences in returns of funds selected for the study. The results also revealed that the SBI and ICICI large cap and small and mid-cap funds performed well compared to other funds.

6. Margi Choksi (2020)-- A Study on Selected Large Cap Mutual Funds in India--

Mutual Funds were introduced in the Indian financial system with a view to provide comparatively safer investment at the doorstep of the common investors. In this study researcher has tried to understand the performance of selected large cap mutual funds in India. For the study purpose 15 large cap mutual funds has been selected. The Secondary data has been considered for the performance analysis and it was achieved by using various tools and techniques like average return, standard deviation, beta, Sharpe ratio, Jensen ratio and Treynor ratio. The findings depicts that DSP Top 100 Equity Fund, ICICI Prudential Blue-chip Equity Fund and LIC MF Large cap Fund showed highest return among the selected funds.

7. Miss Nisha Chelsia (2022) -- A Study on Performance Evaluation of Top 5 Leading Mutual Fund Schemes in India --

Mutual funds are created as a part of an investment which invest in new financial instruments like stocks and bonds. Investing in them allows an investor to gain, bonds or fixed income securities, commodities, etc. Mutual funds function by pooling the cash together from many investors and that cash gets used to buy the stocks bonds and other securities. among many schemes offered by mutual funds companies blue chip schemes are a type of money equity fund, that primarily finance and equity related securities of large cap companies and even large-cap funds are also coined as the blue chip funds. The blue-chip Fund invests in a company that have a reputation for paying a regular dividend. The disturbing profit consistently over a long period and which has a risk return by investing the blue- chip schemes, which are essentially equity funds are known to be the best mutual fund schemes and safest to invest. The research type is descriptive and data source is collected from secondary data by using the

sample top 5 blue chip funds in India for five years. The technical measures like have been Sharpe's, Treynor's and Jensen's ratio.

8. Dipika, Annu Dalal, Bharat Vashisht (2024) -- Evaluating the Risk and Return Dynamics of ICICI Mutual Funds --

This study analyses the risk and return of 44 ICICI Mutual Fund equity schemes (Direct Plan – Retail and High Net Worth) for the period April 2022 to March 2023. Using metrics like average return and standard deviation, it evaluates fund performance and compares AUMs of retail and HNI investors. The goal is to identify trends, assess investment effectiveness across risk profiles, and support informed decision-making for investors and fund managers.

9. Yashwanth B K (2024) -- A Project Report on "A Comparison Analysis of the Small Cap Mutual Fund Performance of Indian Asset Management Companies"--

This research conducted a comparative analysis of small-cap mutual fund performance among Indian Asset Management Companies (AMCs) – SBI, ICICI, AXIS, HDFC, and KOTAK. Utilizing a descriptive research approach, the study examined historical data from the last five years and employed statistical tools such as correlation and linear regression. Findings revealed strong positive correlations between Nifty returns and NAV returns for all funds, with AXIS and KOTAK showing significant predictive power. The study emphasizes the importance of considering market trends when evaluating fund performance and suggests diversification based on risk-return profiles. Investors are advised to closely monitor market trends and fund performance for informed decision-making.

10. Ellangi Pushpalatha (2024) -- Risk-Return Trade-Off in Blue Chip Mutual Funds: An Evaluation Using Sharpe, Treynor, And Jensen Measures in the Banking Sector --

This study examines the performance of blue-chip mutual funds within the banking sector, focusing on risk-return trade-offs and performance evaluation using measures such as Sharpe Ratio, Treynor Ratio, and Jensen's Alpha. The analysis spans six years of data, covering key mutual funds, including SBI, Canara, Kotak, and others. Findings reveal fluctuations in annual returns, with positive returns observed in favourable market conditions and negative returns during challenging periods. Volatility varies across funds, highlighting

the importance of considering risk in investment decisions. Beta values indicate market sensitivity, while risk-adjusted performance metrics offer insights into the efficacy of fund management strategies. Recommendations are provided for investors, emphasizing diversification, risk-adjusted returns, and informed decision-making. Policymakers are encouraged to prioritize investor protection, transparency, and financial literacy initiatives. Future research directions include exploring long-term performance trends, macroeconomic influences, behavioural finance aspects, and the mutual fund industry technological innovations. Overall, this study contributes to advancing knowledge in finance, investment management, and mutual fund performance evaluation, offering valuable insights for stakeholders navigating the dynamic landscape of financial markets.

III. RESEARCH GAP

The extensive review of literature on mutual fund performance in India highlights several studies that evaluate risk and return, comparative fund analysis, and the use of performance metrics like Sharpe Ratio, Treynor Ratio, Jensen's Alpha, and CAPM. While these studies offer valuable insights, a few key research gaps emerge:

Lack of Comparative Evaluation between Specific Fund Houses:

- Most studies either focus on a single mutual fund house (e.g., ICICI, SBI) or broadly analyze multiple fund schemes across various AMCs.
- Gap: There is limited comparative evaluation between two specific leading fund houses, such as ICICI Mutual Fund and SBI Mutual Fund, particularly in terms of their Growth Plan performance using uniform parameters over the same time frame.

Underrepresentation of Growth Plans as a Focus Area:

- Several studies evaluate equity funds, blue-chip funds, or large-cap/small-cap funds in general.
- Gap: Very few studies explicitly focus on Growth Plans, which are critical for investors

seeking capital appreciation over the long term. The performance dynamics of Growth Plans remain underexplored in the existing literature.

Recent Time Periods and Post-Pandemic Analysis:

- Many studies (e.g., Sahil Jain 2012, Shivaramu 2019) use historical data up to 2014 or 2019. Few incorporate post-COVID-19 financial trends or data from 2022 onwards.
- Gap: A comprehensive post-pandemic evaluation of mutual fund performance is missing, especially during periods of market recovery and volatility.

Limited Inclusion of Investor-Specific Categories (Retail vs HNI):

- Though the study by Dipika et al. (2024) analyzes HNI vs retail segments in ICICI funds, there is no comparative research that integrates such distinctions across fund houses.
- Gap: No study examines how Growth Plans of ICICI and SBI perform across investor segments, i.e., retail vs. HNI.

Neglect of Behavioral and Strategic Fund Management Insights:

- Most studies are quantitative and technical in nature; few analyze qualitative factors like fund management strategies, investor behavior, or decision-making rationale.
- Gap: There is a need for mixed-method analysis that incorporates both quantitative performance metrics and qualitative management strategies influencing growth plan outcomes.

Insufficient Longitudinal Comparative Analysis:

- Many studies focus on 4–5-year spans or use cross-sectional analysis.
- Gap: There is a lack of long-term (10+ years) comparative studies that track the performance trajectory of ICICI and SBI Growth Plans in different market cycles.

A significant research gap exists in conducting a **comparative, long-term, and post-pandemic evaluation of Growth Plans** specifically between **ICICI Mutual Fund and SBI Mutual Fund**. Most

prior studies have focused on broad fund categories or individual fund houses without offering a focused comparative lens. Addressing this gap can help investors, analysts, and policymakers better understand performance patterns, risk profiles, and the strategic approaches of two of India's largest mutual fund players.

Statement of the Problem:

Despite the growing popularity and critical role of mutual funds in India's financial system, there exists a noticeable gap in the literature concerning the **comparative evaluation of Growth Plans** offered by two of the country's leading mutual fund houses – **ICICI Mutual Fund and SBI Mutual Fund**. While numerous studies have assessed mutual fund performance using traditional risk-return metrics and models like Sharpe Ratio, Treynor Ratio, Jensen's Alpha, and CAPM, these evaluations are often either limited to a **single fund house**, generalized across a broad array of schemes, or constrained to **short-term, pre-pandemic data**.

Furthermore, **Growth Plans**, which are instrumental for long-term capital appreciation, remain **underrepresented** in academic research, especially in terms of comparative studies that assess their performance across **retail and HNI investor categories**. Additionally, most existing studies focus predominantly on **quantitative analysis**, overlooking qualitative aspects such as fund management strategies and investor behavior.

In the post-COVID-19 financial landscape—marked by economic volatility, changing investor preferences, and technological advancements—there is a compelling need for a **comprehensive, longitudinal, and comparative evaluation** of the Growth Plans of ICICI and SBI Mutual Funds. Such an investigation would offer critical insights into their risk-adjusted returns, consistency, and fund management effectiveness, thereby filling a significant gap in the existing literature and supporting informed decision-making for investors and policymakers.

Need For the Study:

The Indian mutual fund industry has witnessed rapid growth and diversification over the past decade, offering a wide array of investment schemes to suit the needs of both retail and institutional investors.

Among these, Growth Plans are particularly significant as they focus on long-term capital appreciation by reinvesting profits rather than distributing them as dividends. In this context, ICICI Mutual Fund and SBI Mutual Fund stand out as two of the most prominent and trusted asset management companies in the country, each offering various Growth Plans aimed at different investor segments.

Despite the increasing popularity of these funds, investors often face challenges in selecting the most suitable Growth Plan due to the abundance of schemes, lack of clarity in comparative performance, and varying risk-return profiles. Moreover, existing research on mutual fund performance either focuses on individual fund houses or offers a general analysis of mutual fund schemes without specifically comparing the performance of Growth Plans offered by leading players like ICICI and SBI.

The need for this study arises from the following factors:

1. **Investor Decision-Making:** There is a growing demand for reliable and comparative insights into fund performance to support informed investment decisions, especially in Growth Plans designed for long-term financial goals.
2. **Performance Benchmarking:** A focused evaluation of ICICI and SBI Mutual Fund Growth Plans will help identify which fund house delivers superior risk-adjusted returns and consistency over time.
3. **Post-Pandemic Relevance:** The economic impact of COVID-19 has significantly influenced mutual fund performance and investor behavior. A recent, post-pandemic evaluation can highlight how these funds have adapted to changing market dynamics.
4. **Gap in Existing Literature:** There is limited research comparing the performance of Growth Plans between ICICI and SBI Mutual Funds over a long-term period using standardized evaluation metrics. This study aims to fill that research gap.
5. **Support for Financial Planning:** The findings of this study can benefit retail and HNI investors, financial advisors, fund managers, and policymakers by providing data-driven

insights for investment planning and portfolio optimization.

6. **Encouraging Financial Literacy:** By analyzing and presenting clear, comparable data on mutual fund Growth Plans, the study can contribute to enhancing financial awareness and literacy among new and existing investors.

This study is necessary to bridge the gap between investor needs, market offerings, and academic insight by delivering a focused, comparative, and comprehensive analysis of the performance of Growth Plans from two of India's most influential mutual fund institutions.

Objectives of the Study:

- To achieve a comprehensive understanding regarding the ICICI and SBI mutual fund schemes.
- To estimate the performance of named growth schemes using ICICI and SBI mutual fund.
- To examine the performance of named schemes on the base of trouble and return.
- To study a comparative performance analysis for the named collective finance for five years.

Scope of the Study:

This study aims to provide a comprehensive and comparative analysis of the performance of growth-oriented mutual fund schemes offered by two of India's leading asset management companies – **ICICI Mutual Fund** and **SBI Mutual Fund**. The scope of this study is outlined as follows:

1. Focus of the Study:

- The study specifically evaluates **Growth Plans**, which aim at **long-term capital appreciation** through reinvestment of earnings, rather than income distribution.
- It examines selected equity-based **growth-oriented schemes** from both ICICI and SBI Mutual Funds.

2. Comparative Nature:

- A **comparative evaluation** is conducted between the two fund houses using **standardized performance metrics** such as:
 - Sharpe Ratio
 - Treynor Ratio
 - Jensen's Alpha
 - Standard Deviation
 - Beta
 - Average Returns and NAV movement
- This allows for **objective benchmarking** of performance and risk.

3. Time Frame:

- The study includes **recent and historical performance data** to reflect **pre- and post-pandemic** trends (ideally covering at least the last 5–10 years).
- It captures fund performance across different market cycles to ensure **robust and comprehensive insights**.

4. Data Source:

- The study is based on **secondary data**, including mutual fund reports, AMFI statistics, fact sheets, annual reports, and online investment portals like Value Research and Morningstar.

5. Geographical Scope:

- The research is limited to **Indian mutual fund schemes**, specifically focusing on the operations and offerings of ICICI and SBI Mutual Funds **within India**.

6. Target Groups:

- The study considers the performance of schemes **across investor categories**, such as:
 - **Retail Investors**
 - **High Net-Worth Individuals (HNIs)**

7. Stakeholders Benefited:

- The findings are expected to benefit:
 - **Investors** (seeking better investment options)

- **Fund Managers** (for performance benchmarking)
- **Financial Advisors** (for portfolio planning)
- **Policymakers and Regulators** (for understanding fund behavior)

Hypotheses of the Study:

Null Hypothesis: H0: There is no significant difference in the performance of ICICI and SBI mutual fund schemes.

Alternative Hypothesis: H1: There is a significant difference in the performance ICICI and SBI mutual fund schemes.

Null Hypothesis: H0: There is no significant difference in the risk levels associated with the selected ICICI and SBI mutual fund schemes.

Alternative Hypothesis: H1: There is a significant difference in the risk levels associated with the selected ICICI and SBI mutual fund schemes.

Limitations of the Study:

1. **Limited Time Frame:** The study may consider historical performance data over a specific period (e.g., 3 to 5 years), which may not fully capture long-term trends or recent changes in market dynamics.
2. **Restricted Sample Size:** The study focuses only on the growth plans of ICICI and SBI Mutual Funds, excluding other mutual fund houses that may provide useful comparative insights.
3. **Market Volatility:** Mutual fund performance is significantly influenced by stock market fluctuations and macroeconomic factors, which are beyond the researcher's control and may skew the results.
4. **Dependence on Secondary Data:** The study relies heavily on secondary data (e.g., from AMFI, Value Research, company websites), which may have inherent inaccuracies, reporting delays, or lack real-time updates.
5. **Subjectivity in Performance Metrics:** Though quantitative tools like Sharpe Ratio, Alpha, Beta, and Standard Deviation are used, the interpretation of mutual fund

performance may still involve a degree of subjectivity.

6. **Lack of Consideration for Investor Behavior:** The study does not account for investor-specific factors such as risk appetite, investment goals, or financial literacy, which play a key role in fund performance perception.
7. **Regulatory Changes:** Changes in SEBI regulations, taxation policies, or fund reclassification during the study period may affect the comparability of performance data.
8. **Fund Manager Influence:** The performance of a mutual fund is also influenced by the skills and strategies of fund managers, which are difficult to quantify and compare in an evaluative framework.
9. **Exclusion of Dividend and Hybrid Plans:** The study focuses solely on growth plans, excluding other types such as dividend or hybrid schemes that might offer alternative insights into performance evaluation.

IV. RESEARCH METHODOLOGY

1. Research Design:

The study follows a **descriptive and analytical research design**, aiming to evaluate and compare the performance of growth-oriented mutual fund schemes of ICICI and SBI Mutual Funds. It involves quantitative analysis using financial performance indicators over a specified period.

2. Sources of Data:

- **Secondary Data** is primarily used in this study, collected from:
 - Official websites of ICICI Mutual Fund and SBI Mutual Fund
 - Association of Mutual Funds in India (AMFI)
 - SEBI and RBI publications
 - Value Research Online, Money control, and Morningstar
 - Financial reports, fact sheets, and historical NAV data of selected mutual fund schemes

3. Sample Selection:

- **Mutual Funds Studied:** Selected growth plans under equity schemes from:
 - ICICI Prudential Mutual Fund
 - SBI Mutual Fund
- **Sample Criteria:**
 - Open-ended equity mutual fund schemes with a **Growth option**
 - Minimum **3 to 5 years of performance history**
 - Consistent fund objective and asset allocation

4. Period of Study:

- The evaluation covers the performance of selected schemes over a **5-year**.

5. Tools and Techniques Used:

Performance evaluation is carried out using various **financial and statistical tools**, such as:

- **Sharpe Ratio** – Risk-adjusted return measure
- **Treynor Ratio** – Return relative to systematic risk

- **Jensen's Alpha** – Excess return over the expected CAPM return
- **Standard Deviation** – Measure of total risk/volatility
- **Beta** – Measure of market-related risk
- **Net Asset Value (NAV)** trends – To evaluate fund growth over time
- **Compound Annual Growth Rate (CAGR)** – To understand return consistency
- **Correlation Analysis** – To analyse co-movement with benchmarks

6. Method of Analysis:

- **Quantitative analysis** is used to compute and compare fund performance metrics.
- **Graphical representation and tabulation** are employed for visual comparison.
- The results are interpreted in terms of **risk-return trade-off, consistency, and benchmark outperformance**.

Data Analysis & Interpretation:

TABLE: 1.1 FINANCIAL PERFORMANCE EVALUATION OF MUTUAL FUND SCHMES: Calculated value of balanced fund schemes

Name of the scheme	5 years avg return	Beta	Standard Deviation	Treynor ratio	Jensen' Alpha	Sharpe ratio	Ranking a/β
SBI Multi-Asset Dir Gr	10.93	0.7	0.36	0.07	-2.6	0.14	-3.72
SBI Balanced Adv. Dir	14.65	0.8	1.32	0.11	0	0.07	0
SBI Equity's saving Dir Gr	12.05	0.85	0.65	0.07	-3.1	0.09	-3.64
SBI Hybrid debt Dir Gr	9.85	0.75	0.08	0.05	-4.22	0.5	-5.63
SBI Hybrid Equity Dir Gr	14.84	0.85	1.37	0.1	-0.31	0.06	-0.36
ICICI Prudential balanced advantage Dir Gr	12.94	0.65	0.88	0.11	-0.05	0.08	-0.08

ICICI Prudential regular savings Dir Gr	11.25	0.65	0.44	0.08	-1.75	0.12	-2.68
ICICI Prudential multi-assets	14.52	0.8	1.28	0.11	-0.09	0.07	-0.11
ICICI Prudential Equity saving Dir Gr	10.22	0.85	0.17	0.05	-4.93	0.24	-5.8
ICICI Prudential equity & debt Dir Gr	14.84	0.82	1.37	0.11	0	0.06	0
ICICI Prudential child care study Dir	15.08	0.84	1.43	0.11	0	0.06	0

Evaluation of the performance of balanced fund Schemes:

Table 1.1 displays the average return values for the schemes chosen for the exploration. Out of 15 balanced schemes, the results indicate that all of them produced returns that were less than the market returns. The lowest return on investment is found in the ICICI Prudential Child Care Study Dir of ICICI Prudential Asset Management Company Ltd. Equity Savings Dir Gr. out of 15 schemes, 11 generate double-digit returns. Durable average returns during this period were slightly below the market return of the ICICI Prudential Child Care Study Dir and SBI Hybrid Equity Dir Gr. Based on a risk analysis, the sample fund's return variability was minimal. The director of the ICICI Prudential Child Care Study took a significant risk and was successfully managed by ICICI Prudential Asset Management Company Ltd., producing good returns.

Under the direction of ICICI Prudential Asset Management Company Ltd., ICICI Prudential Care Study Dir and ICICI Prudential Equity & Debt Dir Gr have been demonstrated to be less risky but riskier than the market portfolio of other schemes in this category.

The higher and equal Treynor Index displayed by ICICI Prudential Equity & Debt Dir Gr, ICICI Prudential Child Care Study Dir Gr, Nippon India Balanced Adv. Dir Gr, and SBI Balanced Adv. Dir Gr show that investors who invest in a well-diversified mutual fund portfolio are receiving an adequate return per unit of systematic risk. An advanced positive nascence value indicates better scheme performance. The analysis shows that all 15 schemes have negative alpha values, which indicates that they are all underperforming the market return.

TABLE1.2: PERFORMANCE EVALUATION OF EQUITY DIVERSIFIED FUND SCHEMES: Calculated value of equity diversified fund scheme

Name of the scheme	5 years average return	Beta	Standard Deviation	Treynor ratio	Jensen' Alpha	Sharpe ratio	Ranking α/β
SBI Focused 30 Dir Gr	10.93	0.7	0.36	0.07	-2.6	0.14	-3.72
SBI Small Adv. Dir	14.65	0.8	1.32	0.11	0	0.07	0
SBI Capital Builder value Dir Gr	12.05	0.85	0.65	0.07	-3.1	0.09	-3.64

SBI Mid-cap opportunities Dir Gr	9.85	0.75	0.08	0.05	-4.22	0.5	-5.63
SBI Flexi cap Dir Gr	14.84	0.85	1.37	0.1	-0.31	0.06	-0.36
ICICI Prudential midcap Dir Gr	12.94	0.65	0.88	0.11	-0.05	0.08	-0.08
ICICI Prudential small cap Dir Gr	11.25	0.65	0.44	0.08	-1.75	0.12	-2.68
ICICI Prudential blue-chip Dir Gr	14.52	0.8	1.28	0.11	-0.09	0.07	-0.11
ICICI Prudential focused Equity Dir Gr	10.22	0.85	0.17	0.05	-4.93	0.24	-5.8
ICICI Prudential value discovery Dir Gr	14.84	0.82	1.37	0.11	0	0.06	0
ICICI Prudential banking & finance Dir Gr	15.08	0.84	1.43	0.11	0	0.06	0
ICICI Prudential multicar Dir Gr	17.03	0.98	0.1	0.11	6.49	1.15	6.62
ICICI Prudential infrastructure Dir Gr	13.46	0.94	0.86	0.08	3.35	0.09	3.56

Table 1.2 shows that 10 percent of the equity diversified funds schemes were less than the average return of the market. The findings showed that, with the exception of four, all 22 equity diversified fund schemes produced higher returns than the request. There are no negative values in any scheme. ICICI Prudential Asset Management Company Ltd. shares, which are managed by ICICI Prudential Banking & Fin Services Director, rank first in terms of average return. In terms of risks, the majority of schemes are less hazardous than market risks. The table's 0.03 and 1.03 standard deviations are different. Return variability is lowest for ICICI Prudential Focused Equity Dir Gr and SBI Mid-Cap Opportunities Dir Gr, and highest for ICICI Prudential Banking & Fin Svcs

Dir Gr. Beta ranges from at least 0.07 to 1.08 for the Scheme as it is seen. Likewise, Nippon India was born with the topmost pitfalls. Investors entered acceptable returns in addition to large cap and value tips. Seven plans have multiple beta systems, or beta, which indicates that their portfolios are typically riskier than the market's. Furthermore, I ended up holding portfolios that were comparable in risk to market portfolios. About 15 schemes have a beta-less than one (i.e., market beta) value, indicating that they are generally less risky than market-based schemes. Better performance is indicated by a higher positive alpha value. No alpha scheme displays a negative value, according to the table analysis.

TABLE 1.3: PERFORMANCE EVALUATION OF DEBT FUND SCHEMES: Calculated value of debt fund schemes

Name of the scheme	5 years average return	Beta	Standard Deviation	Trey nor ratio	Jensen' Alpha	Sharpe ratio	Ranking a/β
Banking PSU debt Dir Gr	8.93	1.36	0.36	0.07	-2.6	0.14	-3.72
SBI corporate bond Dir	8.93	0.82	1.32	0.11	0	0.07	0
SBI Credit risk debt Dir Gr	9.16	-0.8	0.65	0.07	-3.1	0.09	-3.64
SBI dynamic debt Dir Gr	7.33	1.13	0.08	0.05	-4.22	0.5	-5.63
SBI floating rate debt Dir Gr	8.15	0.42	1.37	0.1	-0.31	0.06	-0.36
SBI Gilt Dir Gr	7.33	0.52	0.88	0.11	-0.05	0.08	-0.08
SBI Income Dir Gr	8.15	1.23	0.44	0.08	-1.75	0.12	-2.68
SBI Income Dir Gr	8.81	0.44	1.28	0.11	-0.09	0.07	-0.11
SBI low duration Dir Gr	7.96	0.66	0.17	0.05	-4.93	0.24	-5.8
SBI M/T debt Dir Gr	8.12	1.25	1.37	0.11	0	0.06	0
SBI money market Dir Gr	7.28	0.72	1.43	0.11	0	0.06	0
Debit Dir Gr	8.66	1.06	0.1	0.11	6.49	1.15	6.62
ICICI Prudential all	10.82	0.94	0.86	0.08	3.35	0.09	0.56

Table 1.3 displays the average yield values for the chosen schemes. The results are evident from 38 debt fund schemes that were introduced by particular mutual fund companies. All 38 debt fund schemes have below-request when compared to the request return. The average double-number returns were only obtained by 10% of schemes. Nippon India U/ST duration Dir Grind is the only scheme that qualifies as a negative return. There are 38 schemes with a systemic threat (b) in the table. The fact that 50% of systems are beta-low, or request beta, indicates that they are less hazardous than request portfolios. Also, these schemes are less dangerous. Greater average returns in distinction to the other table schemes. You have positive schemes with

negative betas, similar as ICICI Prudential Floating Interest Dir Gr and SBI Credit Risk Debt Dir Gr. The table's beta ranges from -4.8 to 5.24. The table's higher beta of 5.24 for the ICICI Prudential Longterm Bond Dir Gr suggests that the scheme was built to hold riskier portfolios than the requests. According to the Sharp's variability compensation table value, 43% of schemes have inimical issues in terms of trouble. In order for investors to build a properly diversified portfolio, 90% of finances exhibit a positive Tri nor indicator, which indicates the applicable return per unit of systemic trouble assumed. Unexpectedly, 10% of the schemes were worse than trouble-free returns (6 percent).

TABLE 1.4: LIQUID FUND SCHEMES PERFORMANCE EVALUATION: Liquid fund scheme calculated values

Name of the scheme	5 years average return	Beta	Standard Deviation	Trey nor ratio	Jensen' Alpha	Sharpe ratio	Ranking a/β
SBI liquid Dir Gr	8.93	1.36	0.36	0.07	-2.6	0.14	-3.72
ICICI Prudential liquid Dir Gr	8.98	0.82	1.32	0.11	0	0.07	0
Market Index	9.16	-0.8	0.65	0.07	-3.1	0.09	-3.64

Table 1.4 displays the average return values for the liquid scheme selectee for this disquisition. The average return produced by all three schemes was less also their request yield, according to the results. Grater returns when compared to other schemes among these three. There isn't a scheme in the table that offers a negative return. Table 1.4 shows the systemic trouble of three schemes. Two of the systems

have beta values that are lower than the request beta, which suggest that their portfolios are riskier than the request. The Gr was riskier then other schemes in this order. As a result, the above discussion demonstrates that while most sample funds have returns below the request return, all schemes have achieved higher returns than a threat-free security return.

TABLE 1.5: TAX PLANNING FUND SCHEMES PERFORMANCE EVALUATION

Calculated Value of ELSS fund (Tax planning fund) schemes

Name of the scheme	5 years average return	Beta	Standard Deviation	Trey nor ratio	Jensen' Alpha	Sharpe ratio	Ranking a/β
SBI Tax Dir Gr	14.78	0.97	0.32	0.09	-1.66	0.27	-1.71
SBI L/T average Dir Gr	19.23	0.97	1.9	0.13	2.79	0.07	2.88
Market Index	16.57	1					

Table 1.5 lists the average ELSS return levels chosen for the research. Out of the four tax planning schemes, only one scheme has outperformed the market return, according to the results. SBI AMC's L/T Advantage Dr Gr scheme produced the highest and the lowest returns. Each plan generates a double-digit return. The findings indicate that, in comparison to all other schemes, the return on the market was superior. According to the study, sampling schemes outperformed free returns, and one SBI L/T Advantage scheme Dir Gr outperformed the average market return. All sample schemes, with the exception of one, have assumed a lower level of risk than the market. Additionally, the schemes beta ranges from 0.32 to 2.14. Many schemes have betas (also known as market betas) below one, which indicates that their

portfolios are typically less risky than the market portfolio.

V. FINDINGS

- In terms of risks, the majority of schemes are less hazardous than market risks. The table's 0.03 and 1.03 standard deviations are different. Return variability is lowest for ICICI Prudential Focused Equity Dir Gr and SBI Mid-Cap Opportunities Dir Gr, and highest for ICICI Prudential Banking & Fin Svcs Dir Gr. The Scheme's observed beta ranges from a minimum of 0.07 to 1.08.
- According to the Jensen Ranking, SBI Capital Builder Value Dir Gr has outperformed the others

and is ranked first, followed by ICICI Prudential Banking & Fin Svcs Dir Gr.

- According to the Sharp's variability compensation table value, 43% of schemes have unfavorable outcomes in terms of risk. In order for investors to build a properly diversified portfolio, 90% of funds exhibit a positive Tri nor index, which indicates the appropriate return per unit of systemic risk assumed. Surprisingly, 10% of the schemes had lower returns than risk-free returns (6%).
- Table 1.4 displays the average return values for the liquid schemes selected for this investigation. The average return produced by all three schemes was less than their market yield, according to the results. greater return when compared to other schemes among these three. There isn't a scheme in the table that offers a negative return. The risk to the system (b) of three schemes is shown in Table 1.4. Two of the systems have beta values that are lower than the market beta, which suggests that their portfolios are riskier than the request. The Gr was than other schemes in this category.
- The findings indicate that, in comparison to all other schemes, the return on the market was superior. According to the study, one SBI L/T Advantage scheme Dir Gr has outperformed the average market return, and sampling schemes outperformed returns without risk. Except for one, all of the sample schemes have assumed less risk than the market. Additionally, the scheme's beta ranges from 0.32 to 2.14. Betas for many schemes are less than one. (i.e. request betas), indicating that these schemes' portfolios are generally less hazardous than the request portfolio. The findings indicate that, in comparison to all other schemes, the return on the market was superior. According to the analysis, the sample schemes outperformed both the average market return and the return without risk.

VI. SUGGESTIONS

In my study I have found some limitations. For that I can suggest both companies following suggestions or areas of enhancement.

- Compared to SBI, ICICI Bank ought to make an effort to give its investors higher returns. To increase profits, businesses should attempt to invest in better securities.
- By enhancing customer relationship management or providing better customer service, both businesses should aim to please their clients.
- Businesses ought to encourage people to take risks.
- Investors should be fully informed of all terms and conditions as well as the concepts of mutual funds.
- Since it is the most effective way to place a brand in the minds of consumers, it should receive more attention in advertising.
- It is accepted that "SBI mutual funds give higher.

VII. CONCLUSION

In conclusion, we can state that mutual funds are a very profitable investment tool due to their low acquisition costs, tax advantages, and ability to diversify profits and lower risk.

Many mutual fund investors believe that SBI offers superior returns to ICICI.

I was required to compare the mutual funds of SBI and ICICI as part of my study, and I discovered that people think SBI is superior to ICICI.

However, ICICI also has responders, and by improving itself over time, it can attract more investors.

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Computation Fluid Dynamics of Aerodynamics Swirl Low NO_x Burner in Furnace

Asya Abd Alelah Alabdalah

Department of ITE, SVU University, Syria

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Abstract— By using a prototype multi -annular swirl burner, the important aerodynamics features of a typical low Nitrogen Oxides NO_x of internal staging schematic was studied. So by using swirl means the structure of flame is separated to locally fuel-rich environment prior to burn out. Selecting of the optimal swirl burner design is depending on swirl economy and can estimated using hydraulic resistance parameter. Swirl stabilized flames are lifted a few millimeters above the fuel injector and this liftoff allows air to mix with fuel upstream of the flame base , the positions of the primary and secondary air as well as fuel tube were adjusted to produce a particular flow field which Its name Radially Stratified Flame Core Burner. In result NO_x emissions are not more than 120ppmv at 15% excess air and the implement internal staging schematic is effective and promise way to have high furnace efficiency at low NO_x emissions

Keywords— computation fluid dynamics, low NO_x burner, flame stability, internal recirculation zones, Swirl burn

I. INTRODUCTION

Spiral flow is currently used in modern industrial burners, furnaces, and boilers. This reduces pollution from combustion processes, particularly nitrogen oxides (NO_x), both thermal and instantaneous, resulting from fuel.

Adding angular momentum to the flow creates a spiral-shaped core composed of the fuel-air mixture, giving the flame a special shape, making it a vortex. In other words, the molecules in the flame move in a spiral motion along the axis of the burner. This spiral motion has a significant impact on the gas exiting the burner head nozzles, whether in cold flow or hot flow.

This spiral motion is strongly related to the swirl number (S), which is defined as the quotient of the axial flow resulting from the angular momentum divided by the axial flow resulting from the direct momentum. This spiral motion affects the size, shape, and dimensions of the resulting jet or flame.

Swirl flow can be classified according to the swirl number (S) as weak ($S < 0.3$), moderate ($0.3 < S < 0.6$), and strong ($S > 0.6$).

When the torch has a high number of swirl motion, it produces a radial and axial gradient in static pressure. This gradient controls the flame structure, as the reverse pressure gradient on the torch axis produces an internal recirculation zone. This zone makes the flame stable.

The internal recirculation zone is a storehouse of heat and active chemical species that are transferred from it to the blazes (the blazes are a fresh mixture of fuel and air), and also this zone forms an internal recirculation zone for combustion products to the flame, which reduces the local oxygen concentration, lowers the flame temperature and this in turn limits the formation of NO_x.

The helical flow characteristics associated with the dimensionless number of helical motion resulting from the use of guide vanes on the burner periphery,

and a radial flame regulator at the burner axis on the fuel gas tube have been mathematically simulated using the k-epsilon flow model and the wall function to predict the velocity profiles, and to determine the hydraulic energy loss factor resulting from the use of these flow guides in the burner.

The flame is known as subsonic flow associated with combustion reactions. The angular momentum of the flame structure is added by the guides in addition to the direct momentum of the flow, but the total pressure loss must be minimal to obtain an internal circulation area of suitable dimensions, as well as to ensure good mixing and a stable flame.

Diffused gas flames rely on the use of staged combustion techniques to reduce nitrogen oxides during combustion. They are divided into two categories: The first relies on the physical separation of several stages of the combustion reaction (fuel-rich or fuel-poor stages). Air can be supplied in stages. The theoretical basis for this is to make the initial combustion zone air-poor relative to the fuel, which favors the formation of N_2 over NO_x . Despite the high flame temperature, the low oxygen concentration limits the thermal formation of NO_x [1]. According to Chen (1982), NO_x is reduced by 20%–50% when air is used in stages without any negative impact on furnace efficiency [2]. Fuel can also be supplied in stages. This method relies on finding a source of hydrocarbon radicals that reduce nitrogen oxides formed in a previous stage of the combustion reaction to molecular nitrogen [1]. Where 40% to 70% of the fuel is passed to a second stage by a shunt. In the first zone, combustion takes place at a low temperature and in the presence of a high percentage of surplus air, which reduces thermal NO_x . In the second zone, the fuel interacts with the air coming out of the first zone, where combustion is complete due to slow mixing, which requires a smaller amount of surplus air compared to rapid mixing, which reduces NO_x and improves the thermal efficiency of the furnace [2]. According to (Went 1991), NO_x emissions can be reduced by 50% in this way without causing any negative impact on the efficiency of the furnace [2]. If the flue gases are recirculated without the initial air temperature rising above 1300 K and the combustion reaction is completed with an excess oxygen content of no more than 5%, then, according to Katsuki (1998), fuel

efficiency can be increased by 50% at low NO_x emissions [2]. However, the disadvantages of using this method of physical separation between the reaction zones include high operating costs, erosion of the heat transfer surfaces, and difficulty in upgrading or modifying the burner [1]. Therefore, the second type of NO_x emission control has been resorted to, which is controlling the flame structure using the aerodynamics of the burner. This is done using guide blades that add centrifugal forces to the flow, causing slower mixing of the fuel and air and increasing the residence time of the reactants in the reaction zone. The speed of mixing the fuel with the air determines the flame temperature. However, the optimal burner design in this technology, called internal staging schematic, depends on the amount of energy lost in the flow. When air passes through the torch [1], increasing the intensity of the spiral motion in the torch, expressed by the spiral motion number, is essential for the fuel to ignite and for the flame to be stable. However, the efficiency of the torch must be taken into account when choosing the optimal torch design, by determining the hydraulic loss factor, which expresses the amount of flow energy lost resulting from the spiral motion in the torch [3]. Using mathematical simulation of flow (computing fluid dynamics CFD), the various components of the torch were studied, which control the flame structure with the aim of controlling the aerodynamics of the torch (internal staging schematic).

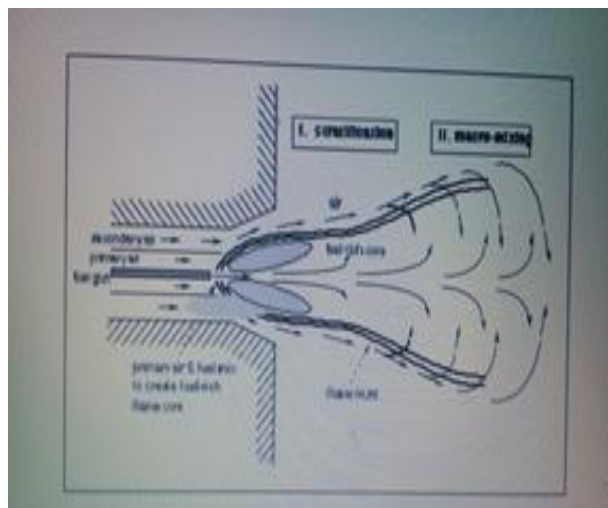


Fig.1: shows the flow field generated by a multi-layered diagonal flame core (internal staging schematic) [1].

All the combustion air is introduced into the torch, but using guide vanes around the torch, the movement and quantity of secondary air are controlled. Using an air deflector in the torch axis on the fuel gas tube, the quantity and movement of the primary air are controlled. That is, by controlling the mixing process in the torch using these guides, we obtain a multi-layered radial flame core (RSFC) Fig.1.

II. RESEARCH OBJECTIVE

The aim of this research is to conduct a simulation of the flow in a torch to determine the internal turbulent flow properties represented by the turbulent kinetic energy (K) and the turbulent dissipation factor (ϵ).

It also aims to observe various flame regions, such as the internal circulation zone and the wake region downstream of the air deflector. These regions are generally characterized by intense turbulence and high stress and deformation rates resulting from the decay and demolition of the spiral motion in this region. The numerical results of the cold flow model are also used, along with determining the dimensionless spiral motion number (S) for the tangent swirls and the air deflector. This is done to determine their effect on the aerodynamics of the torch, creating fuel-rich and fuel-poor zones in the flame structure and controlling the amount of NOx generated by combustion. We also aim to determine the hydraulic energy loss factor associated with torch efficiency, which is known as the result of dividing the loss in total pressure (LTP) by the kinetic energy of the flow at the exit from the torch

$$\frac{v^2}{2g} \quad (1)$$

Where: the amount $\frac{v^2}{2g}$ is known as the result of dividing the mass flow by the product of the density of the fluid entering the torch in the maximum flow area within it [3].

III. RESEARCH METHODOLOGY AND RESOURCES

- Determining the dimensionless number of the spiral motion of the flow guides based on the burner's design data.
- Mathematical simulation of cold flow without combustion using the Siemens NX code.

- Determining the amount of nitrogen oxides produced by combustion using the 7E method according to the U.S. Environmental Protection Agency (EPA).

IV. RESULTS AND DISCUSSION:

4.1 Determining the dimensionless swirl number (S) of the secondary and primary air

The detailed diagram of the burner with a multi-layered radial flame core shows that combustion air enters the burner as a result of natural inhalation through an air box consisting of two cylinders: the first, an internal, immovable cylinder, 2 mm thick and 258 mm in diameter, and the second, an external, movable cylinder, 2 mm thick and 264 mm in diameter. These two cylinders have identical windows, and the movement of the external cylinder relative to the internal one changes the area through which the air flows.

The combustion air enters through the air box windows by natural inspiration, occupying the annular space between the concentric channels. The combustion air is initially divided into two parts using tangential air swirlers, which are longitudinal blades 1 mm thick and 103 x 65 mm in dimensions. These blades are positioned around a cylinder concentric with the burner, 1 mm thick, 251 mm in diameter, and 90 x 788 mm in flat plate dimensions. The first section represents the secondary air, which gains spiral motion using the side air blades and constitutes 70% of the total combustion air volume. The second section represents the primary air, which constitutes 30% of the total combustion air volume. It enters through the central annular space and finally exits through the 120 mm diameter, 2 mm thick air deflector. Its blades are angled 170° x 170° from the radial direction. The flame deflector is positioned on the fuel gas tube, which is coaxial to the burner. The fuel gas exits the 38 mm diameter burner head through 12 holes, each angled 30° from the burner axis, to mix with the air. Together, they exit through a gradually narrowing cone, from which the mixture is distributed throughout the furnace after passing through the primary combustor, which takes the shape of a gradually expanding cone.

Determining the spiral motion number of the guides on the torch circumference

Is derived from expressing the spiral motion number mathematically, which is defined as the ratio of the angular momentum of the flow to the direct momentum of the flow [5]:

$$S = \frac{G_{ang}}{G_x \cdot R_b} = \frac{\int_0^\infty \rho \cdot U \cdot W \cdot r^2 dr}{R_b \int_0^\infty \left(U^2 - \frac{1}{2} W^2 \right) r \cdot dr} \quad (2)$$

G_{ang} the direct flow due to the angular momentum

G_x The direct flow due to the direct momentum

R_b The radius of the cylindrical torch

ρ The density of the working fluid, which we assume to be air in the simulation for non-combustion flow

U The average direct velocity in the plane whose area is $2\pi r dr$

w The average angular velocity in the plane whose area is $2\pi r dr$

r The distance from the torch axis.

Since the necessary data about the speed is practically unavailable, in engineering applications we resort to calculating the dimensionless number of the spiral motion using the geometric dimensions of the structure under study, where we express the relationship between w and U using the angle of inclination of the blades from the direct current lines α according to the relationship

$$\tan \alpha = \frac{U}{w} \quad (3)$$

Where $\alpha = 29.5^\circ$ as a result we find this one

$$G_{ang} = 2\pi \rho \int_{R_c}^{R_b} U_a (U_a \tan \alpha) r^2 dr = 2\pi \rho U_a^2 \tan \alpha \left(\frac{R_b^3 - R_c^3}{3} \right) \quad (4)$$

U_a The average value of the direct velocity in the annulus occupied by the secondary air and including the lateral guides on the burner periphery.

R_c The characteristic dimension of the ring occupied by primary air.

R_b The distinctive dimension of the torch

The direct flow due to the direct momentum of the flow in both the primary and secondary airflow regions is calculated from the relationship

$$G_x = 2\pi \rho \int_{R_c}^{R_b} U_a^2 r dr + \int_0^{R_c} U_c^2 r dr = \pi [\rho U_a^2 (R_b^2 - R_c^2) + \rho U_c^2 R_c^2] \quad (5)$$

Where: U_c the average direct velocity in the ring occupied by the primary air, and R_c the characteristic dimension of the ring occupied by the primary air. Thus, the dimensionless number of the helical motion of the guides around the burner circumference is given by the relation

$$S = \frac{2}{3} \tan \alpha \frac{1 - R^3}{1 - R^2 + \left[m^2 R^2 \left(\frac{1}{R^2} - 1 \right)^2 \right]} \quad (6)$$

R The ratio of the two characteristic dimensions of the space occupied by the primary air to the space occupied by the working fluid in the burner, expressed as

$$R = \frac{R_c}{R_b} \quad (7)$$

m The ratio of the mass flow of the primary air to the secondary air which has the same value as the result of dividing the effective area of the primary air flow at the center of the burner by the effective area of the secondary air flow through the ring occupied by the guides around the burner.

$$S = \frac{2}{3} (\tan 30^\circ) \frac{1 - (0.29)^3}{1 - (0.29)^2 + \left[(0.42)^2 (0.29)^2 \left(\frac{1}{(0.29)^2} - 1 \right)^2 \right]} \quad (7) \quad S = 0.46$$

Hence, the dimensionless number of the spiral motion of the secondary air has an average value.

Determining the spiral motion number of a flame deflector

In 1996, Shee derived an empirical relationship to determine the dimensionless spiral motion number of flow deflectors such as a flame deflector (a radial-type swirl generator). This spiral motion number (S) strongly depends on both the Reynolds number and the angle of inclination of the deflectors from the radial vector Φ , according to the relationship [6]:

$$S = C_1 (Re) \cdot \sigma(\varphi) \quad (8)$$

Where: the value C_1 is a function of the value of the Reynolds number according to the relation

$$C_1 = 0.28[1 - \text{sech}(0.026Re^{0.67})] \quad (9)$$

Hence, when the Reynolds number of the flow is greater than 2200 and the flow is turbulent, the value becomes constant C_1 and equal to 0.28.

The value depends on the geometric structure of the flame σ regulator and is given by the following relationship:

$$\sigma = \frac{1}{1 - \xi} \left[\frac{\tan \varphi}{1 + \tan \varphi \tan(\pi/Z)} \right] \quad (10)$$

Where ξ the blockage factor resulting from the thickness of the flow guides is given by the relationship

$$\xi = ZT/2\pi R_1 \quad (11)$$

Where Z the number of flame directors, T Flame guide thickness and R_1 the exit radius of the flame regulator and by application we find

$$S = 0.28X \frac{1}{1 - (10X2/2\pi X40)} \left[\frac{\tan 10^\circ}{1 + \tan 10^\circ \tan(\pi/10)} \right] = 0.05 \quad (12)$$

In this burner, using flow guides, two zones for combustion reactions are created. The first is the zone characterized by the presence of slip layers, where the mixing process between fuel and air is slower, controlled by the density gradient between the slip layers. This zone is relatively cold, as the spiral-moving combustion air surrounds the hot, fuel-rich flame core. The fuel-rich flame core is created by injecting primary air (30% of the combustion air) into the area surrounding the burner head, which is centered on the burner. Due to the centrifugal forces resulting from the spiral motion of the combustion air surrounding the hot flame core, the mixing process resulting from the turbulent mixing between the hot flame core and the surrounding spiral-moving combustion air is dampened. This zone is called the density stratified zone and may extend for a distance equivalent to five times the diameter of the burner in the furnace [1]. The second zone is characterized by microscopic mixing of the combustion products from the first zone with the secondary combustion air, which constitutes 70% of the combustion air. This completes the combustion reaction at a relatively low temperature and with an optimal excess air ratio, which limits the formation of

nitrogen oxides. Therefore, the amount of NOx produced by combustion is related to the S-number of the spiral motion generated by the flow guides. To observe how nitrogen oxide emissions are controlled based on the aerodynamics of the turbulent, post-mixed flame, the flow was simulated in the region near the burner head, where all the combustion and mixing reactions take place. Using mathematical simulation of fluid flow (computing fluid dynamics) using the Siemens NX code, we provide a set of numerical modeling results that demonstrate the changes in the macroscopic properties of the fluid at every point in the space within which the fluid moves in the burner mounted on the furnace.

4.2 The Physical Model of the swirl -Driven Burner

A mathematical model of cold isothermal flow was developed. To ensure that the numerical results of the flow model match those of the actual burner, a three-dimensional model of the swirl-drive burner was created, identical in geometric structure to the original burner.

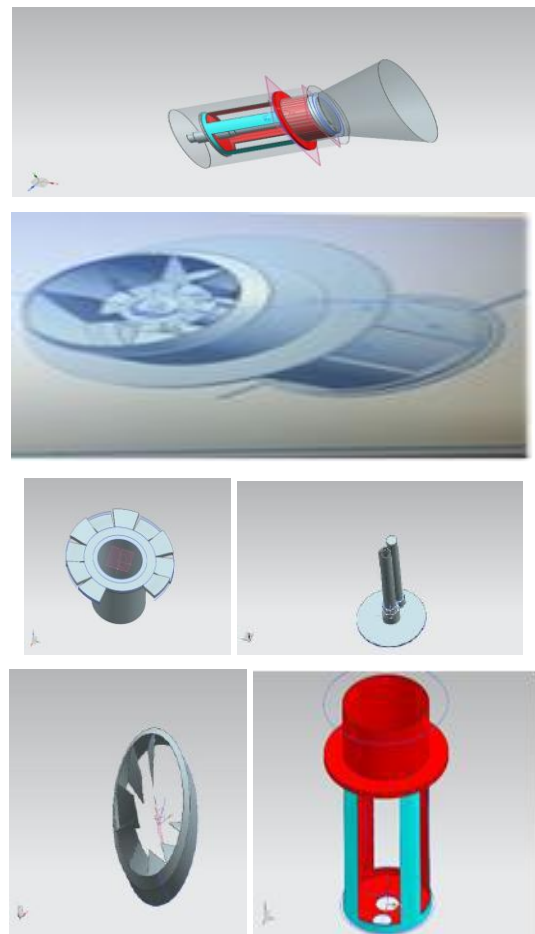


Fig.2: shows the three-dimensional model of the studied torch and its components

The burner under study operates on natural inhalation, with combustion air entering through the fully open air box gates at maximum fuel consumption. Assuming that air is the working fluid and that it is incompressible, and that the relative velocity of the working fluid is zero when in contact with the solid surface, which is assumed to be completely smooth, and taking into account the buoyancy forces, then applying the transition equations for the conservation of mass, momentum, and energy according to the rules for using average values according to Reynolds analysis, we obtain a set of transition equations called the Navier-Stokes equations according to Reynolds analysis, which express the effect of turbulence on the average macroscopic properties at the finite element boundaries of the studied system. The model was then performed in a steady-state frame. Fig. 2 shows the three-dimensional model of the studied torch and its two components: the moving swirl torch, the air box, the flame regulator, and the side guides.

4.2.1 Flow Model and Determination of the Reynolds Number for Wall Friction

The flow model known as K-Epsilon was used, as it is recommended in industries where most flows occur at relatively high speeds.

Given the diverse geometric structure of the system under study, the value of the Reynolds number for wall friction (Y^+) was adjusted according to the wall function to a value less than 5. This avoids entering the buffer region, where no mathematical model or wall function predicts flow in this region.

This model includes two partial differential equations: one expresses the change in kinetic energy (K) of the flow and ϵ the other expresses the turbulent dissipation rate.

Turbulent or Eddy Viscosity μ_t is expressed as a function of both ϵ of K and

This flow model includes five empirical constants.

4.2.2 Generating a Finite Element Mesh

This stage is considered the most difficult in the simulation, because designing a finite element mesh in the studied geometric structure for the fluid-occupied space requires testing multiple mesh sizes to match the desired degree of accuracy for the approximate solution. The desired adjustments were

made by reducing the element density on the axes of the gas flow nozzles and the mixing zone with air in the gradually decreasing cone. Therefore, the solution must be independent of the chosen mesh size and at a reasonable computational cost for the proposed mathematical model. Boundary Conditions of the Model

This burner was designed to generate the required amount of heat over a short distance and within its operational range (turn-down ratio). Therefore, the simulation was performed at maximum fuel consumption and assuming the combustion air intake windows were fully open. The burner burns a gaseous fuel that does not contain any nitrogen compounds, but the hydrogen gas content may reach up to 50%.

The maximum fuel consumption is 69.6 standard cubic meters per hour, where the excess air content is 0.5%. 3%. Since the total pressure drop at the boundaries of a system is less than 3000 Pa, we can consider the average pressure applied to one of its boundaries to be equal to the average atmospheric pressure [4].

This is the case for our spiral-driven torch. Therefore, this is used as one of the boundary conditions applied in the mathematical simulation of flow in the torch. The general design condition was studied without correcting for altitude above sea level.

4.2.3 The numerical results of the mathematical model and their reliability

Ensuring their consistency with reality by utilizing available similar experiments and studies. Consistency in the results with the study presented by the American Standards Board for Mechanical Engineers in 1994 was observed.

(American Society of Mechanical Engineers ASME)

4.2.3.1 Numerical Results of Mathematical Simulation of Air flow as a Working Fluid into the Torch

The most important feature accompanying the spiral flow in a torch with a laminated radial flame core is the presence of an internal circulation region resulting from the velocity dissipation of the spiral motion in the direct direction of the flow, shown in Fig.3: This region helps stabilize the flame by

providing a hot flow region in which the combustion products are recycled and re-enter the slip layers.

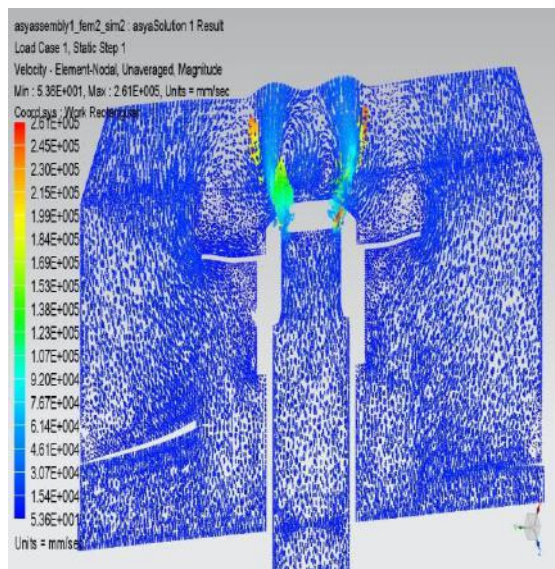


Fig.3: The inner circulation region in the radial laminar flame core.

The boundaries of this region are drawn in the radial plane at points where the mass flow in the direct and reverse directions is equal at any point within the vicinity of the torch axis. In other words, in this region, the flame velocity is equal to the flow velocity, and the reactants are well mixed with the combustion air due to the high turbulence resulting from the high deformation rates. In each axial plate, when the axial velocity is zero at any point, this point falls within the internal circulation region, which results from a reverse pressure gradient along the torch axis. It is observed that ring vortices form within the internal circulation region resulting from the velocity dissipation. The angle in the direct direction of flow, which results from the static pressure gradient in the radial plane as the working fluid exits the nozzles of the burner head, is due to the geometric structure of the studied part of this torch. It is noted that the burner head plays a role similar to a flow-guiding body (BLUFF-BODY), as the nozzles are distributed around the periphery of the burner head at an angle of inclination equal to 30° relative to the direct current lines. Also, the guides, which have a high dimensionless number of spiral motion when $S > 0.6$, cause a radial and axial static pressure gradient sufficient to generate a central toroidal recirculation zone. No central annular

circulation region can be observed when $S < 0.4$. Therefore, when $S < 0.4$, the presence of annular circulation regions is due to the geometric structure of the system, which creates a flame with a low swirl motion number, such as the presence of a flow-guiding body.

4.2.3.2 The relationship between NOx produced by combustion and the aerodynamics of the burner

The amount of NOx produced by dry combustion at 3% excess oxygen was 120 parts per million. This is attributed to the thermal fixation of molecular nitrogen in the air, as the fuel does not contain nitrogen compounds. This low amount of thermal NOx is due to the presence of lateral air guides, which allow the combustion reactions to occur between the bulk of the combustion air and the reaction products of the fuel-rich primary combustion zone (hot radial internal circulation zone + cold radial slip layers).

Despite the high temperature in the fuel-rich zone, this does not stimulate the formation of thermal NOx due to the lack of oxygen. Furthermore, hydrocarbon radicals are formed, which convert nitrogen oxides to molecular nitrogen. Centrifugal forces also prevent combustion air from entering the laminar radial flame core, which is formed by the use of a low-swirl number air deflector. This reduces the intensity of the internal recirculation zone and allows a greater amount of gaseous fuel to enter it. This allows the combustion reaction to occur at a longer residence time, higher temperature, and less oxygen, making the nitrogen oxides' reduction mechanism chemically preferable to their formation in this zone. Meanwhile, in the second stage of combustion, a slow microscopic mixing process takes place between the air and the reaction products of the first zone at a low flame temperature and in the presence of an optimal proportion of excess air, limiting the formation of thermal NOx. The secondary airflow has a greater impact on the amount of nitrogen oxides produced because the greater the angular momentum added to it, the longer and slower the mixing time becomes, increasing turbulence and increasing the efficiency of the combustion process at lower pollutant values than thermal NOx. Note Fig. 4.1: and fig.4.2: which illustrate the basic characteristics of turbulence: one represents the change in the kinetic energy of the

turbulence, and the second represents the rate of dissipation of the turbulence.

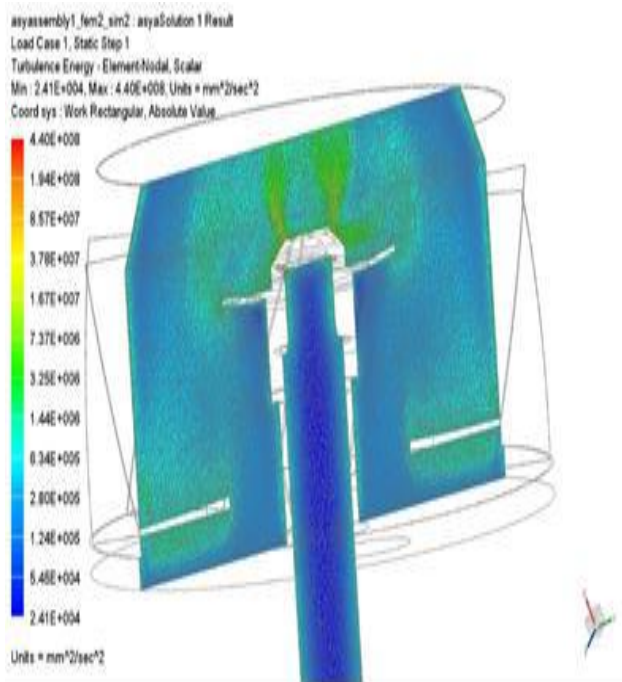


Fig. 4.1: illustrates turbulence.

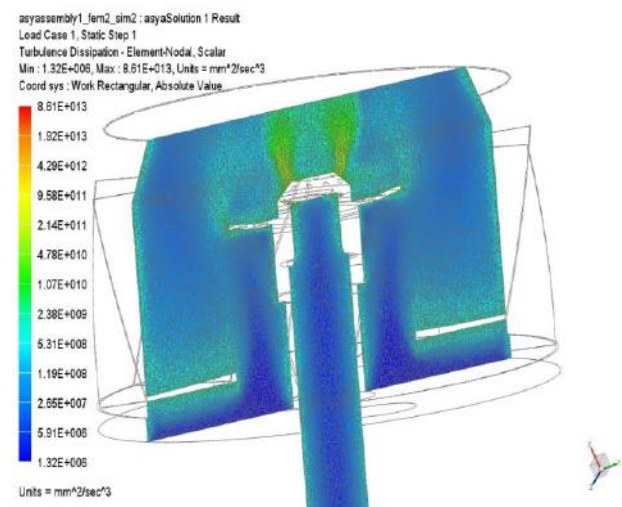


Fig. 4.2: illustrates turbulence.

Weber and Dugue have established a simple relationship to express the amount of change in the value of the dimensionless number of the spiral motion in both the cold and hot flow cases, which is:

$$S_{hot} = S_{cold} \left(\frac{\rho_{hot}}{\rho_{cold}} \right)^B \quad (13)$$

The dimensionless number of the spiral S_{hot} motion of the hot flow

The dimensionless number of the helical S_{cold} motion of the cold flow

ρ_{hot} Density when combustion is present

ρ_{cold} Density without combustion

B constant with a value ranging from 0.5 to 1

This change in the value of the dimensionless vortex number in the flow occurs in the presence of combustion reactions due to the large gradient in temperature and density, which alters the size and intensity of the internal recirculation zone due to the greater direct momentum added to the

flow compared to the case of cold flow. The role of the angular momentum added to the flow is noticeable, as it does not change significantly in the presence of combustion. There is no doubt that the use of flow guides causes a specific pressure loss. The hydraulic pressure loss factor expresses the fluid's resistance to flow as it passes through these guides. However, when designing a torch, it is essential to minimize the hydraulic pressure loss factor to achieve an efficient recirculation zone, a stable flame, and good mixing. Therefore, it is usually preferable not to increase the angle of inclination of the guides, as the blockage factor increases with increasing angle, causing an increase in the hydraulic pressure loss factor. Fig. 5: shows the change in static pressure within the torch under study and fig.6 shows the Y+ value in the model..

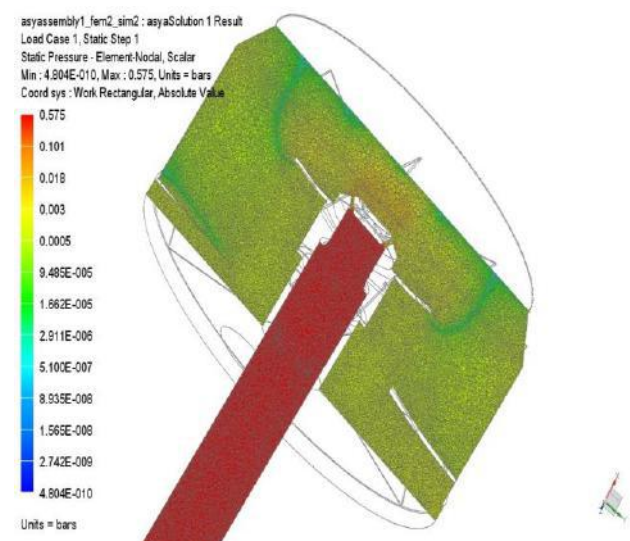


Fig.5 shows the change in static pressure within the torch under study and the Y+ value in the model

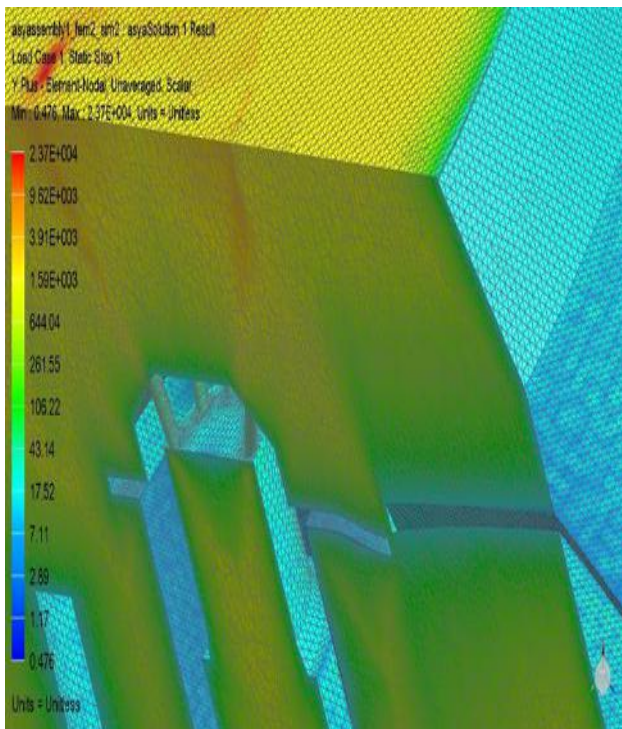


Fig.6: shows the Y+ value in the mode

V. CONCLUSION

From the mathematical simulation of the flow in a spiral burner, we conclude that there are two aspects of momentum that determine the flame structure: angular momentum arising from the geometric structure of the burner and the presence of flow guides, in addition to direct momentum.

This slows the fuel-air mixing process and lengthens the reactant residence time in the multi-structured, layered radial flame core, which includes fuel-rich and fuel-poor regions. The overall combustion reactions are influenced by the quantity and movement of the combustion air available in each region, making the application of dynamic separation to the flame structure a promising and effective method in furnaces for achieving the best combustion efficiency and the lowest nitrogen oxide pollutant levels.

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Enhancement of a solar-tracking concentrator system with multiple conversion mechanisms based on the energy chain principle

Andry Thierry Randrianarinosy², Jaolalaina Arisoa Andrianavoarivelo², Harimalala Razanamampisoa¹, Jean Marc Fabien Sitraka Randrianirina², Rakotoarimanana Liva Graffin¹, Zely Arivelo Randriamanantany¹

¹Department of Physics and Applications of the University of Antananarivo, University of Antananarivo BP 566, Antananarivo 101.Madagascar

²Institute for Energy Management IME, University of Antananarivo, University of Antananarivo BP 566, Antananarivo 101.Madagascar

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Abstract— This article presents the improvement of a construction system adapted to solar tracking. The system integrates multiple energy conversion mechanisms in accordance with the energy chain principle and it is based on high-temperature energy capture. Therefore, it enables the deployment of a field of collectors or storage units that use a heat transfer fluid to perform the functions of energy concentration, heating, storage, and distribution. From a forward-looking perspective, these concentrator systems contribute to enhancing solar energy utilization through the application of advanced signal-based simulation and modeling methods for solar systems.

Keywords— Solar concentrator, Thermal collector, Linear Fresnel field, Form factor, Energy of tomorrow.

I. INTRODUCTION

The use of solar energy represents an alternative based on the implementation of various energy conversion mechanisms, [1]. These mechanisms are classified into two categories of collection, which are conventional solar collection and high-temperature solar collection, [2]. In this context, the study of solar concentration focuses on the application of adaptive technological systems centered around a thermal focal point. This work aims to develop models of active solar systems. Specifically, it seeks not only to establish a field of collectors or thermal storage units using a heat transfer fluid such as water, but also to integrate linear Fresnel collector technology.

The objectives of this article are as follows:

- To determine the shape factor using Gauss approximation and Hottel's string method [3]. This analysis helps evaluate the system's efficiency in terms of economy, ecology, and environmental impact, based on the country's geographical conditions.
- To study the application of a solar concentration system in two and three dimensions. This involves designing a technological model using thermal and dynamic simulations with software such as MATLAB, EnergyPlus, or RetScreen. The goal is to adapt the system's performance to the selected technology, whether cylindrical-parabolic or parabolic.

II. SYSTEM DESIGN AND INSTALLATION TECHNIQUE

2.1 Two-Dimensional Concentration System

The linear Fresnel field technology is based on the use of cylindrical lenses and adjustable reflective surfaces, [4]. These surfaces are arranged in the form of dihedrals with a semi-open angle at the apex.

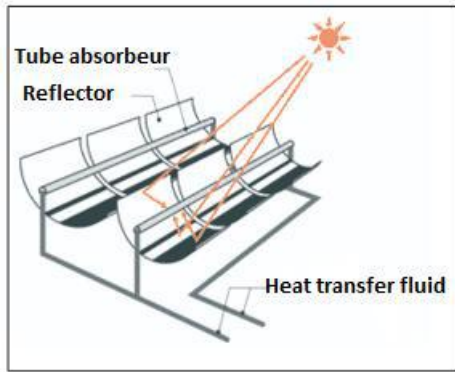


Fig.1 : Two-Dimensional Concentration System

A two-dimensional parabolic flat collector can receive light rays from an entire hemisphere, [5]. The concentrator system used in this study continuously tracks the sun throughout the day. This continuous solar tracking requires a more complex mechanism, and the effective collecting area varies depending on the solar radiation intensity during the day. The two mirrors of the concentrator must be oriented so that their reflected rays intersect at a focal point located at a half-angle at the system's apex. This focal point is equipped with a thermal receiver modeled as a black body, operating at a temperature denoted by T_s .

This configuration can be modeled geometrically. Assuming negligible transient solar shading, the half-angle at the apex is taken as $\theta_s = 16^\circ$, which allows for an effective distribution of solar radiation within the system. The incoming radiation is captured by a concentrating system with an aperture area A_a , and the absorber is placed on a surface A_c . The absorber is considered a gray body operating at temperature T_c , [6]. During the experiment, it is important to ensure that the space between the source and the aperture remains completely empty.

The maximum geometric concentration is given by the following ratio:

$$C = \frac{A_a}{A_c} \quad (1)$$

The power emitted by the source and absorbed by the receiver can be expressed as:

$$q_{sc} = \mathcal{F}_{sc} A_s \sigma T_s^4 \quad (2)$$

where $\mathcal{F}_{sc} \leq \nu$ represents the fraction of the emitted power that reaches the absorber, either directly or after reflections or refractions.

Similarly, the energy emitted by the absorber and received by the source can be written as:

$$q_{cs} = \mathcal{F}_{cs} A_s \sigma T_c^4 \quad (3)$$

According to the second law of thermodynamics, when there is no net heat exchange between two bodies at the same temperature:

$$\text{If } T_s = T_c, \text{ then } q_{sc} = q_{cs}$$

$$\text{which implies } \mathcal{F}_{sc} A_s = \mathcal{F}_{cs} A_c \quad (4)$$

Additionally, we also have:

$$\mathcal{F}_{sa} A_s = \mathcal{F}_{as} A_a \quad (5)$$

The geometric concentration ratio is then defined as:

$$C = \frac{A_a}{A_c} = \frac{\mathcal{F}_{sa} \mathcal{F}_{cs}}{\mathcal{F}_{as} \mathcal{F}_{sc}} \quad (6)$$

In an ideal concentrator, all radiation entering through the aperture should reach the absorber, which leads to the condition:

$$\mathcal{F}_{sa} = \mathcal{F}_{sc} \quad (7)$$

Here, $\mathcal{F}_{sa}$ represents the fraction of power emitted by

the aperture that directly reaches the source. Based on radiative transfer theory and geometric modeling, the following relationship holds:

$$C_{[3]} \leq \frac{1}{F_a} \text{ and } \frac{1}{F_a} = \frac{1}{\sin \theta_c} \quad (8)$$

where:

- θ_c is the half-apex angle;
- F_a is the form factor obtained using Hotel's crossed-string method, [7].

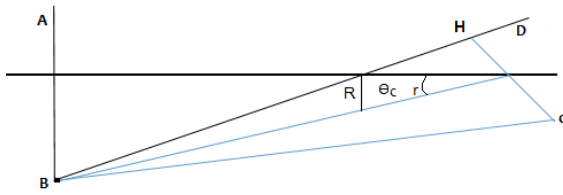


Fig.2 : Configuration of Form Factor Calculations for an Enhanced Two-Dimensional

2.1.1 Calculation of the form factor F_a

using a mathematical model

The formula is as follows:

$$F_a = \frac{BD-BC}{CD} \quad (9)$$

When

$CD \ll AB$ et $BD - BC \approx HD \approx CD \sin \theta_c$, $F_a = \sin \theta_c$, avec θ_c , it follows that:

$$F_a = \sin \theta_c, \text{ avec } \theta_c$$

where θ_c is the half-angle at the vertex of a dihedron.

The maximum geometric concentration of an improved two-dimensional system [8] is then expressed as:

$$C_{max} = \frac{1}{\sin \theta_c} = C_{ideal\ 2D} \quad (10)$$

2.2 Three-dimensional concentrator systems

This system is inspired by a compact cylindro-parabolic concentrator used in solar applications. To reach temperatures above 150°C [9], it is necessary to concentrate solar rays using two appropriate sets of reflective elements or lenses.

Solar thermal energy enables the production of domestic hot water in a three-dimensional concentrator configuration. This system offers an effective alternative to electric water heaters (see Figure 3).

The Fresnel linear technology, developed through a thermodynamic concentration approach, is currently considered a promising solution for energy production, [10]. Available thermal storage technologies can ensure energy supply even during periods without sunlight.

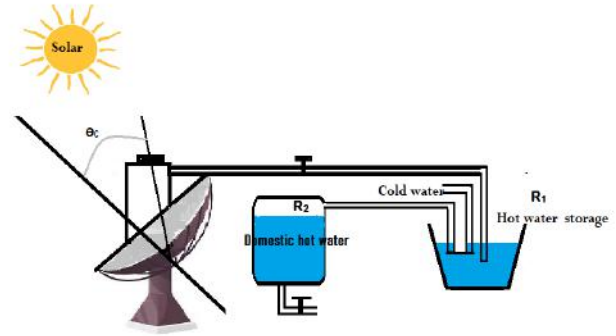


Fig.3: Active three-dimensional (3D) solar system

The flux received by the collector is reflected by the concentrator lenses and then passes through a glazing designed to thermally insulate the focal point, where it is absorbed by a suitable surface (see Figure 3). Reflection, transmission through the glazing, and absorption result in optical losses denoted as $\dot{P}$, which are globally characterized by an energy efficiency.

For the active system shown in Figure 3, only the direct component of solar radiation can be directed to the focal point, as the diffuse component cannot be concentrated.

The main constraint, besides the higher cost compared to flat plate collectors, lies in the need to install a tracking system that follows the sun's movement. In solar cooling applications, this technology is combined with double or triple-effect absorption cycles, which require operating temperatures above 150 °C.

III. THERMAL MODELING OF APPLIED SYSTEMS

For the geometric model, the equation characterizing the steady-state operation per unit surface area of the absorber or receiver is [11]:

$$P_a = P_u + \dot{P} \quad (11)$$

Where:

- P_a is the incident radiation power absorbed per unit area,
- P_u is the useful power of the collector,
- $\dot{P}$ represents thermal losses.

During the system startup phase, thermal inertia cannot be neglected. However, before reaching the collector, the incident radiation may undergo various modifications.

The direction and power of the observed radiation is expressed as [12]:

$$P_a = E \cdot C \cdot \rho \cdot \tau \cdot \alpha \quad (12)$$

where:

- $E = I_{bn} \cos \theta_i$ with θ_i the angle of incidence [°],
- E is the irradiance at the collector level,
- I_{bn} is the direct solar radiation,
- C is the geometric concentration ratio of the collector,
- ρ is the reflectivity of reflective surfaces (galvanized sheet in this case),
- τ is the transmissivity of protective glazing,
- α is the absorptivity of absorbing surfaces.

The instantaneous overall efficiency of the collector η is given by:

$$\eta = \frac{P_u}{E \cdot C} \quad (14)$$

At night, the heat transfer fluid (hot water) is stored in a tank that ensures the distribution of unstable power [13]. The energy transported is in the form of sensible heat and the useful power is:

$$P_u = Q C_f (\theta_s - \theta_e) \quad (15)$$

where:

- Q is the mass flow rate of the heat transfer fluid per unit surface,

C_f is the specific heat capacity of the fluid [J kg⁻¹°C⁻¹],

- θ_s and θ_e are the fluid temperatures at the outlet and inlet of the collector, respectively.

Thermal losses of the pipe are:

$$\dot{P} = C_p (\theta_{moy} - \theta_a) \quad (16)$$

where:

C_p is the apparent conductance of losses at temperature θ_{moy} [Wm⁻²°C⁻¹]

θ_{moy} is the temperature of absorbing surfaces,

θ_a is the ambient temperature.

The instantaneous internal efficiency η_i is:

$$\eta_i = \frac{P_u}{P_a} \quad (17)$$

During the experiment, the following values were used: $\rho = 0.80$; $\tau = 0.85$ and $\alpha : 0.95$

IV. RESULTS AND DISCUSSION

A black spherical body with radius R, placed isotropically at a distance R from the aperture, is used in a cooking system in contact with surface R1 (see Figure 3). This surface absorbs heat and transfers it to surface R2. When a relatively low temperature is adopted (such as cold water temperature), the temperature of R1 must be limited to 50 °C to maintain an acceptable performance coefficient.

Distributing a fluid to R2 at low temperature appears to be an effective solution. The combination of R1, R2, R3, and a heat pump creates an active system with three complementary functions: cooking, water heating, and electric energy production.

The ideal maximum concentration for a three-dimensional system is given by:

$$F_a = F_s \frac{S_a}{S_c}, \text{ where}$$

$$F_s = \frac{S_a}{4\pi r^2} \quad (18)$$

and

$$R = r \sin \theta_c \quad (19)$$

which leads to

$$F_a = \frac{R^2}{r^2} \quad [3] \quad (20)$$

and

$$C_{idéal\ 3D} = \frac{1}{\sin^2 \theta_c} \quad (21)$$

The performed models allowed the plotting of the following curves .

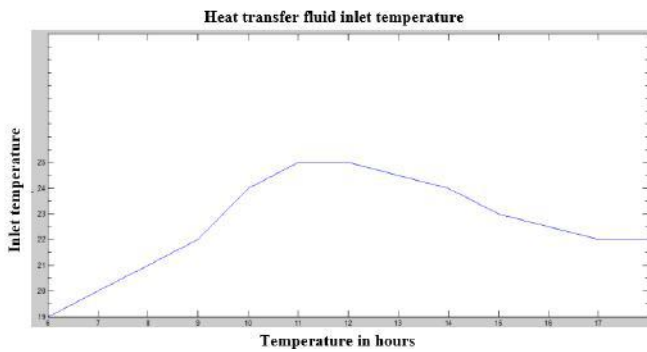


Fig.4 : Heat transfer fluid inlet temperature in °C

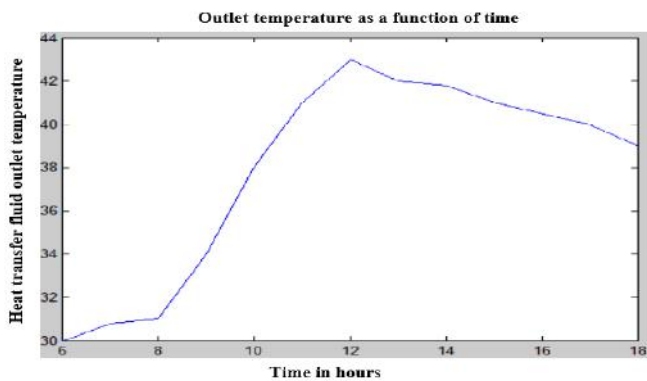


Fig.5 : Outlet fluid temperature in °C

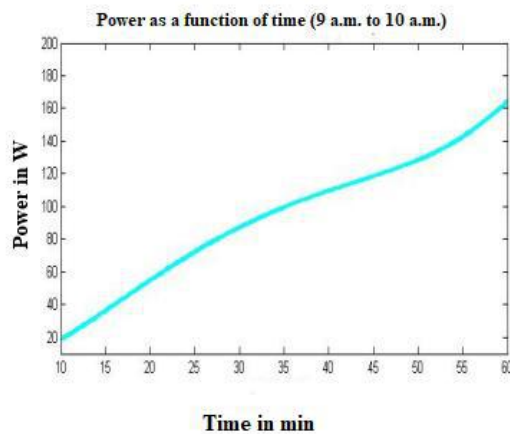


Fig.6 : Overall power received by the sensor between 9 a.m. and 10 a.m.

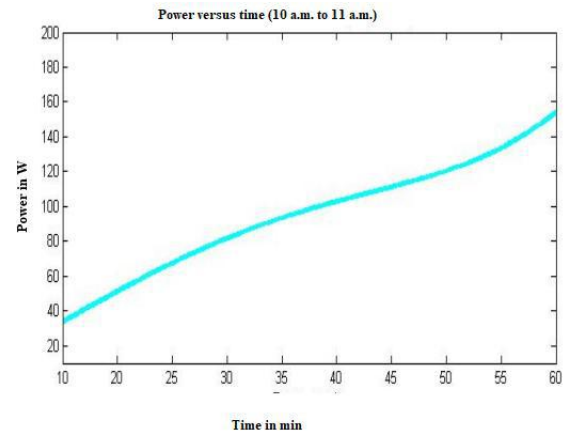


Fig.7 : Overall power received by the sensor between 10 a.m. and 11 a.m.

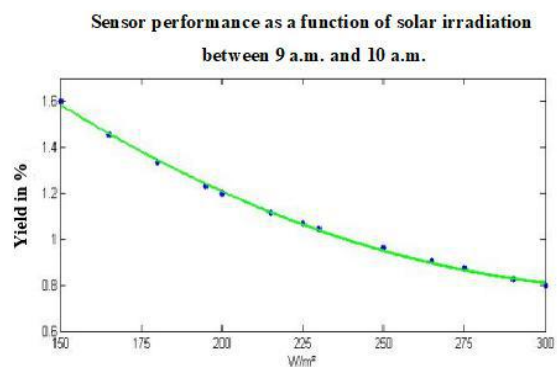


Fig.8 : Overall yield received by the sensor between 9 a.m. and 10 a.m.

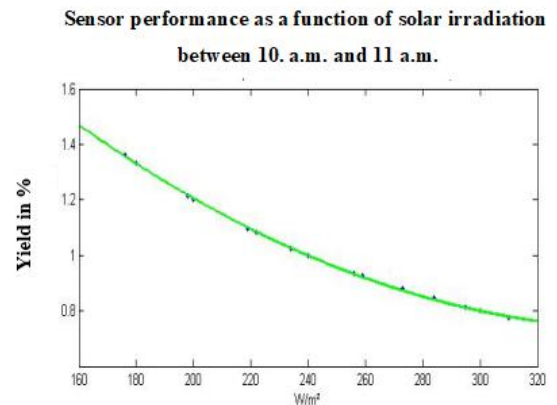


Fig.9 : Overall yield received by the sensor between 10 a.m. and 11 a.m.

These results define the maximum concentration achievable for a given linear field. Using a single-axis concentrator implies that the maximum achievable concentration factor is:

$$C_{max} = \frac{n^2}{\sin^2 \theta_c} \quad (22)$$

Where n is the refractive index and θ_c is the entrance angle of the optical system.

The optical system used is immersed in air, so the refractive index is $n = 1$, and the exit angle is approximately $\pm 90^\circ$.

Compound parabolic concentrators were originally developed in high-energy physics to detect Cherenkov radiation, but their usefulness for solar radiation concentration was only recognized recently, notably by Winston in 1974. They are especially efficient in two-dimensional systems, where they achieve ideal concentration.

For example, considering a half-angle at the apex $\theta_c = 16^\circ$, the results are:

- Low concentration: $1 < C = \frac{S_c}{S_r} < 10$ with an operating temperature around 150°C
- Medium concentration: $10 < C < 100$ with an operating temperature around 300°C
- High concentration: $C \geq 10$ with an operating temperature above 500°C

For a 2D low-concentration system, $C_{max} = 3.7$ corresponds to a concentrator temperature close to 150°C . For a 3D medium-concentration system, $C_{max} = 13.172$ corresponds to a concentrator temperature around 300°C .

V. CONCLUSION

The goal of this work was achieved by significantly improving the solar concentration system using Fresnel technology to refine fixed and targeted orientation of two- and three-dimensional concentrator systems. An East-West axis was selected for the studied location to maximize the power of direct solar energy.

Significant concentrations on the order of 10 were obtained for the systems studied. The increased simplicity of the mechanism reduces maintenance costs over the system's lifetime and allows the design of a lighter solar tracking system. This lightweight design facilitates installation in locations where weight is a critical factor, such as commercial and industrial rooftops.

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Handover and Call Drop Optimization Techniques

Pa Malick Badjie¹, Goueye Bi Vanie², Alemu Betelhem Zerfu³ and Majid Youssouf Hassan⁴

¹Radio Network Planning and Optimization Engineer, Qcell Ltd, Qcell House, Kairaba Avenue, The Gambia
Msc Student in Engineering Physics, Ca' Foscari University of Venezia, Italy

²Radio Network Planning and Optimization Engineer, Qcell Ltd, Qcell House, Kairaba Avenue, The Gambia

³Msc Student in Electronic Engineering, University of Padova, Italy

⁴Msc Student in Artificial Intelligence and Data Engineering, Ca' Foscari University of Venezia, Italy

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Abstract – Optimization initiatives typically involve leveraging advanced technologies and enhancing existing network systems to improve Quality of Service (QoS). These efforts may include eliminating redundant data, implementing data compression, enhancing application delivery, and applying traffic shaping techniques to reduce packet loss. This article aims to support on-site engineers in addressing handover and call drop issues. Handover-related challenges continue to pose significant problems for telecommunications providers in The Gambia and globally. Although researchers have made considerable progress in the field of wireless communications, many issues remain unresolved. Handover is closely associated with call drops, as handover failures often result in dropped calls. Therefore, addressing handover-related call drops is a key component of optimizing handover success rates. This paper outlines methods for evaluating network handover and call drop performance, as well as testing and troubleshooting techniques.

Keywords – Handover, call drop, optimization, QoS.

I. INTRODUCTION

- 1.1 As GSM technology continues to evolve with remarkable advancements particularly in data-driven technologies like LTE and 5G. The need to establish effective and seamless interfaces between these newer generations and legacy systems such as the Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS), which primarily support voice services, becomes increasingly critical to ensure uninterrupted service continuity [4].
- 1.2 One of the key features of 3G networks is their integration with 2G networks. The current deployment of Circuit-Switched (CS) networks enables interoperability and flexibility in managing handovers, thus supporting continuous service delivery.

- 1.3 Wireless Local Area Network (WLAN) coverage, on the other hand, provides additional support in areas with low signal strength [1]. When a User Equipment (UE) initiates a call in one UMTS Terrestrial Radio Access Network (UTRAN) Registration Area (URA) and moves into another URA particularly in a handover region. The UE measures and compares the signal strength from newly detected cells through Inter-Radio Access Technology (IRAT) reselection processes. It then attempts a successful handover, provided the serving cell has defined neighbor relations with the strongest measured cell and that the required signal quality thresholds-such as minimum Energy per Chip over Interference (E_c/I_o) and Received Signal Code Power (RSCP)-are satisfied [6]. If this handover attempt fails, it can result in a call drop.

1.4 This document aims to assist on-site engineers in addressing handover and call drop issues by outlining optimization methodologies, performance evaluation techniques, and effective testing and troubleshooting methods.

This paper is organized as follows:

Section I provides a brief introduction to the concepts of handover and call drops, highlighting their close relationship.

Section II presents a flowchart that outlines the necessary steps for detecting, evaluating, analyzing, and addressing handover and call drop issues.

Section III discusses the design and implementation of the Drive Test (DT) procedures and optimization systems.

Section IV focuses on network optimization strategies for improving handover success rates and reducing call drops, including a detailed description of the network operation flow. It also analyzes common problems encountered during network optimization.

Section V concludes the paper, acknowledgement and provides references.

II. DRIVE TEST (CALL QUALITY TEST) OPTIMIZATION FLOW

Drive Test and Call Quality Test are essential tools for network evaluation and optimization. The Key Performance Indicators (KPIs) derived from Drive Tests and Call Quality Tests serve as benchmarks for verifying network performance. Overall, Drive Testing enables the assessment of network coverage, identification of cells with missing neighbors, and detection of cross-cell coverage issues.

Hard Handover (HHO) and Inter-Radio Access Technology (IRAT) handovers are particularly useful for resolving coverage issues in special scenarios where Call Quality Testing is also appropriate. In this section, we briefly describe the optimization flow of Drive Testing and Call Quality Testing, specifically in the context of Soft Handover (SHO), Hard Handover (HHO), and IRAT handovers.

While incorrect or missing configuration data can lead to various types of handover failures, IRAT handover failures often involve more complex factors—such as challenging radio conditions, mismatches between

network technologies, and ping-pong reselection behavior. Special attention should be given to configuration parameters at the Radio Network Controller (RNC) level, including the Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC), and Base Station Color Code (BCC), among others.

However, handover failures are rarely caused by configuration mismatches alone, as such issues typically trigger alarms visible on network monitoring tools. Consequently, this section focuses on Soft Handover (SHO) optimization, where certain failures may not be reflected in monitoring systems and must instead be identified through on-site Drive Test data collection.

The flowchart depicting the proposed Soft Handover Drive Test detection and analysis process is shown in **Figure 2.1** below. The sequence of events is explained as follows:

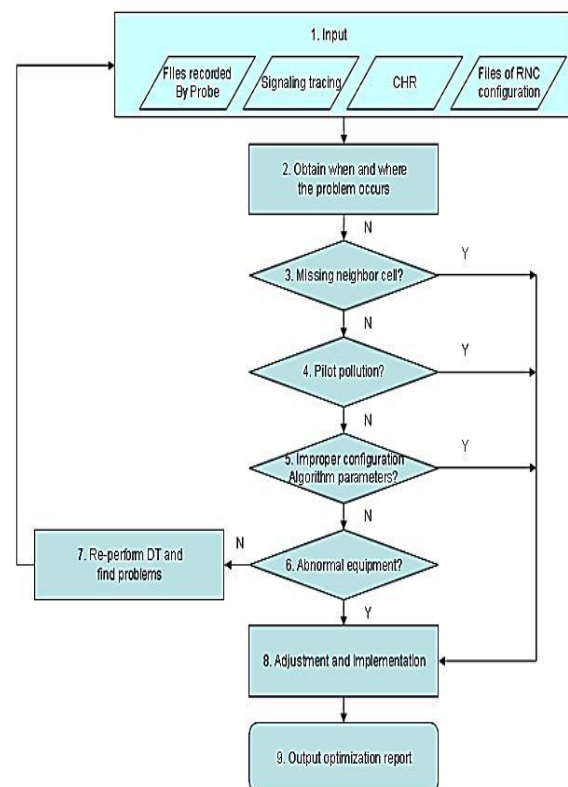


Fig.2.1 SHO DT data analysis flow

2.1 Inputting Analysis Data:

During the detection and evaluation of handover and call drop problems, a drive test is essential for understanding UE behavior in connected and idle

modes by collecting data, correlating signaling traces, and retrieving Radio Network Controller (RNC), Call History Records (CHR) and RNC MML scripts. While testing, a Soft-Handover (SHO), related call drop may occur, or the SHO itself may fail. Each such occurrence must be logged, with the precise location and timestamp recorded for subsequent analysis.

2.2 Missing Neighbor Cell:

During the initial stages of optimization, a common assumption is that call drops are often caused by missing neighbor relations. To confirm the presence of inter/intra-frequency missing neighbor cells, the following methods should be employed:

✓ Check the active set Ec/Io recorded by the UE before the call drop and the Best Server Ec/Io recorded by the scanner.

Determine whether the Best Server's scrambling code recorded by the scanner is included in the inter/intra-frequency neighbor cell list from the measurement control message before the call drop. A missing inter/intra-frequency neighbor cell is likely if **all** the following conditions are met:

- The Ec/Io recorded by UE is poor.
- The Best Server's Ec/Io is strong (good).
- The scrambling code of the Best Server is not present in the intra-frequency neighbor cell list.

✓ Observe UE reconnection behavior after the call drop

- If the UE reconnects immediately after the call drop and camps on a cell with a different scrambling code than the one at the time of the drop, then a missing neighbor cell is suspected between the cells.
- Confirm this by reviewing the most recent inter/intra-frequency measurement control message before the drop (trace back through signaling messages). Then check whether the scrambling code of the post-reconnection cell was included in the neighbor cell list of that measurement control message.

Neighboring relations between cells are crucial for ensuring the continuous delivery of services within a

network. While missing neighbor cells can lead to call drops, redundant neighbor cells can also negatively impact network performance. They increase the signaling overhead and the UE's intra/inter-frequency measurement load. If this issue becomes severe, it may prevent essential neighboring cells from being properly listed, thereby compromising handover success and overall service quality.

2.3 Pilot Pollution:

Another factor contributing to call drops and handover failures is **pilot pollution**. Pilot pollution typically occurs in areas where multiple strong pilot signals are present, but none is strong enough to serve reliably as the primary pilot. This results in interference and confusion for the UE during cell selection or handover processes.

To define rules for identifying pilot pollution, confirm the following criteria

- ✓ **Definition of strong pilot:** A pilot (CPICH) is considered *strong* if its (RSCP) is above a predefined absolute threshold:

$$CPICH\_RSCP > Th_{RSCP\_Absolute}$$

This threshold determines whether a signal is strong enough to be considered useful.

- ✓ **Definition of "excessive":** the number of strong pilots at a location is evaluated. If the number exceeds a defined limit (Th_N) it's considered excessive:

$$CPICH\_Number > Th_N$$

- ✓ **Definition of "No best server strong enough":** This is where your image fits. It refers to a **lack of a clearly dominant pilot**, even though many are strong. It uses the difference between the RSCP of the strongest pilot and that of the $(Th_N + 1)^{th}$ strongest pilot:

$$(CPICH\_RSCP_{1st} - CPICH\_RSCP_{(Th_N+1)th}) < Th_{RSCP\_Relative}$$

Following the descriptions, pilot pollution exists if the following conditions are met:

- ✓ The number of pilots satisfying $CPICH\_RSCP > Th_{RSCP\_Absolute}$ is more than Th_N .
- ✓ $(CPICH\_RSCP_{1st} - CPICH\_RSCP_{(Th_N+1)th}) < Th_{RSCP\_Relative}$

Set $Th_{RSCP\_Absolute} = -95$ dBm, $Th_N = 3$, and $Th_{RSCP\_Relative} = 5$ dB, the judgement standards for pilot pollution are:

- The number of pilots satisfying $CPICH\_RSCP > -95dBm$ is greater than 3.
- $(CPICH\_RSCP_{1st} - CPICH\_RSCP_{4th}) < 5dBm$

2.4 Improper Configuration of SHO Algorithm Parameters:

To address call drops and handover failures, two major problems must be resolved by fine-tuning the Soft Handover (SHO) algorithm parameters:

✓ Delay handover

In CS (Circuit Switched) services, the User Equipment (UE) may fail to receive the *Active Set Update* command due to timing issues. After the UE reports a measurement message, the Ec/Io of the original cell may drop sharply. By the time the Radio Network Controller (RNC) sends the *Active Set Update* message, the UE may have already powered off its transmitter due to synchronization loss, preventing it from receiving the update.

In PS (Packet Switched) services, the UE may either fail to receive the *Active Set Update* message or perform a Traffic Radio Bearer (TRB) reset prematurely before the handover is completed.

Common scenarios leading to delayed handover include:

- **Turnng corner effect:** The Ec/Io of the serving cell drops sharply, while that of the target cell increases rapidly resulting in a temporarily high measurement value.
- **Needlepoint effect:** The Ec/Io of the original cell drops and momentarily recovers, while the Ec/Io of the target cell spikes for a brief period.

In both cases, the UE typically sends Event 1a and 1c measurement reports before the call drop. The RNC receives these events and issues an *Active Set Update* message, which the UE fails to process due to timing or synchronization issues.

✓ Ping-pong Handover

Ping-pong handovers occur when the UE repeatedly switches between two or more cells within a short time. This instability can be caused by two main conditions:

- **Frequent Best Server Changes:** The best server alternates quickly between multiple cells. Each cell may appear as the best server for only a short duration, despite having a strong RSCP.
- **Multiple Cells with Similar RSCP and Poor Ec/Io:** Several cells exist with nearly equal RSCP values, but all have poor Ec/Io, meaning no clearly dominant serving cell exists. As a result, the UE cannot identify a reliable primary pilot.

Signaling Analysis:

When one of the cells is deleted from the active set, the UE immediately reports Event 1a again. The rapid transitions prevent the UE from receiving the *Active Set Update* command in time, leading to a failed handover or potential call drop.

2.5 Abnormal Equipment:

Failures or abnormal functionalities can always be troubleshot by starting with the alarm console for abnormal alarms. Meanwhile, the trace messages should be analyzed to locate the SHO problem by checking the failure message.

2.6 Reperforming Drive Test and Locating Problems:

If the problem is not caused by any of the previously identified issues, perform the Drive Test (DT) again and collect DT data along with supplementary data from problem analysis.

After confirming the cause of the problem, adjust the network using the following appropriate methods:

- **For handover problems caused by pilot pollution:** Adjust the engineering parameters of the antenna so that a best server forms around the antenna. Also, adjust the engineering parameters of other antennas to weaken their signals and reduce the number of pilots. If these measures fail, construct a new site to cover the area (if conditions permit) or combine the two cells as one if the interference originates from two sectors of the same NodeB.
- **For abnormal equipment:** Consult the customer service engineer regarding abnormal equipment and the transport layer on the alarm console. If alarms are present on

the alarm console, cooperate with customer service engineers.

- **For call drops caused by delayed handover:** Adjust antennas to expand the handover areas, set the handover parameters for the 1a event, or increase the Cell Individual Offset (CIO) to enable handover to occur earlier.
- **For needle effect or turning corner effect:** Setting the CIO to 5 dB is recommended, but this may increase the handover ratio.
- **For call drops caused by Ping-pong handover:** Adjust the antenna to form a best server or reduce Ping-pong handovers by setting the handover parameters of the 1B event, including the 1B event threshold, 1B hysteresis, and 1B delay trigger time.

III. HARDWARE, DESIGN AND IMPLEMENTATION OF DRIVE TEST USING GENEX

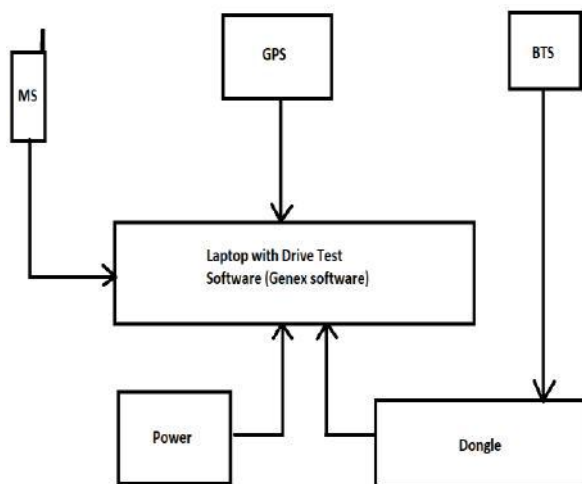


Fig.3.1 Drive Test System

To conduct a successful drive test, the drive test engineer must ensure that the engineering parameters are up to date to have accurate records of UE events during the test. These parameters include antenna azimuths, heights, mechanical and electrical tilting, frequency bands on site, and more. The data collected helps identify and analyze the causes of call drops, handover failures, and other network issues.

The basic Genex drive test tool consist of the following components:

- A laptop with drive test software and GPS connection capability, data cables and multi-connector port.
- A GPS tracker,
- A Drive test mobile phone (e.g. Huawei MT7-L09)
- An inverter or an AC/DC Power source

3.1 Laptop:

A Genex software is installed on the laptop as a tool to collect and visualize data during the drive test. It records the route taken and stores the data for later analysis using another software called "Genex Assistant"

3.2 GPS Tool:

GPS tracker monitors the movements of the drive test vehicle on a map to ensure the target route is fully covered.

3.3 Drive Test mobile phone:

One of the most important tools is the mobile station (MS), as the drive test aims to understand its behavior in both idle and connected modes. The tool captures the events the MS experiences during the test, such as attempted calls, successful and unsuccessful calls, handover success rates, and call drop rates. It also measures threshold settings (coverage, offset, etc.) to minimize unnecessary handovers.

3.4 The Inverter:

The inverter used is a DC-to-AC inverter. Its purpose is to keep the laptop charged during the drive test, preventing interruptions or data loss caused by the laptop shutting down if its battery is completely discharged before the drive test is completed.

IV. NETWORK OPTIMIZATION OF CALL DROP RATE AND HANDOVER

Call drops are typically related to the signaling flow leading up to the drop. These drops can also be observed during drive test analysis using tools like Genex Assistant, as illustrated in Figure 4.1

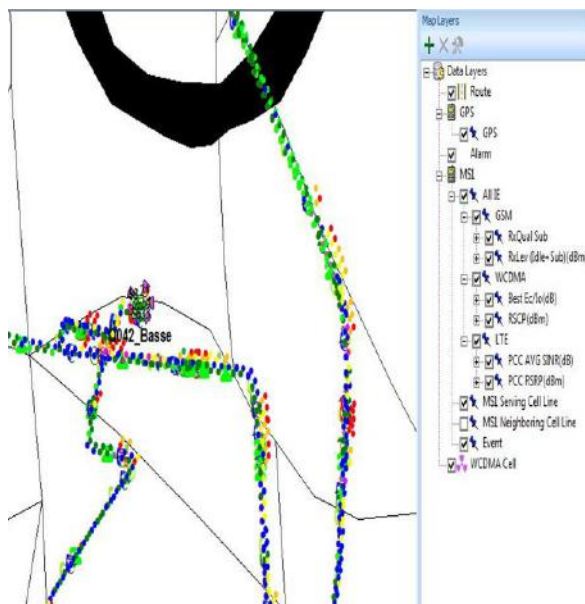


Fig.4.1 Short Call drive test to determine handover and call drop

4.1 Analysis

Check the pilot test data from both the UE and the scanner at the call drop points. Then, examine the scrambling codes recorded by the UE's active set and the scanner prior to the call drop. In the analysis, we observed that the measurement results from the UE active set and the scanner are inconsistent - the scanner detected a scrambling code that does not exist in the UE's active set.

This discrepancy may be caused by a missing neighbor cell configuration or delayed handover, as the scrambling code is not even present in the UE's monitor set, as shown in Figure 4.2 below.

If only the UE recorded information during the test, without scanner data, then call drops due to a missing neighbor cell can be investigated using the following methods:

- ✓ **Confirm the scrambling codes** of all cells in the active set, as well as those in the monitor set measured by the UE before the call drop.
- ✓ **Compare the scrambling code** of the cell that the UE camps on after reselection (i.e., after the call drop) with the scrambling codes in the UE's active set and monitor set before the call drop. If the post-drop scrambling code is not found in either the active or monitor sets before the drop, then the call drop is likely due to a missing neighbor cell.

- ✓ **Check the neighbor cell list** to verify whether the target neighbor is correctly configured. This is essential for resolving call drops caused by missing neighbor cell configurations at the site.

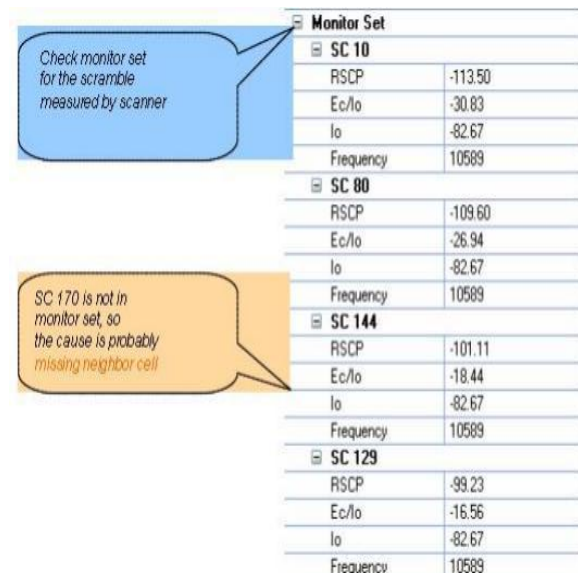


Fig.4.2 Analysis of short Call drive test to determine handover and call drop

4.2 Solution:

When a call drop is caused by a missing neighbor cell, the missing neighbor should be added to the neighbor cell list. This is because the RNC (Radio Network Controller) updates the measurement control information based on the best cell, which is determined through intra-frequency measurement reports specifically, those triggered by the 1D event before the measurement control is sent.

In the post-drive test analysis, after adding the missing neighbor cells, another call drop was observed. However, this time the drop was not due to a Radio Frequency (RF) issue. The scrambling codes of all cells in the active set and the monitor set, measured by the UE both before and after the call drop, were confirmed to be valid neighbor cells, as shown in Figure 4.3



Fig.4.3 Post drive test result

V. CONCLUSIONS

In this paper, we have demonstrated that handover is closely related to call drops. The call drop minimization techniques employed here effectively reduce the number of call drops and improve handover performance in mobile cellular networks, proving to be both efficient and reliable.

However, these techniques should not be considered exhaustive, as call drops and handover failures can also result from various other issues such as transmission failures, faulty channels, and more. For a network optimization engineer, conducting a drive test remains essential to accurately identify the root causes of call drops or handover degradation.

ACKNOWLEDGEMENT

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Analyzing Impact of Pakistan Economic Corridor on Import and Export in Pakistan and China

Muhammad Haseeb Arif

haseeb.arif93@gmail.com

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Abstract— China and Pakistan, among other countries, have a pressing need for a quicker, safer, and more cost-effective commerce route heading to the west, which encompasses Europe and the Middle East. This study's main goal is to determine whether the China-Pakistan Economic Corridor (CPEC) is a viable, long-term option for future market penetration and company growth. With an emphasis on shipping costs and transit times, it examines how the China-Pakistan commerce is affected by the China-Pakistan Economic Corridor (CPEC). The report also contrasts the effectiveness of the proposed CPEC route with that of the existing trade route. For this analysis, a qualitative and descriptive research style was used. The results show that significant cost reductions can result from following the suggested CPEC path. The cost of shipping between Gwadar, Pakistan, and Kashgar, China, might drop by 69% for Oman, 49% for Jeddah and Kuwait, and 38% for European ports. Additionally, transit times for ports in Europe, Jeddah, Kuwait, and Oman might be shortened by 10–11 days, 11–13 days, and 15–18 days, respectively.

Keywords— China Pakistan Economic Corridor (CPEC), Pakistan Economic Corridor. Import/Export, Project.

I. BACKGROUND

Pakistan is strategically located in a geographic threshold zone that is vital to global trade. As we all know, China relies on Middle Eastern countries to meet its energy requirements. With this in mind, it has committed to investing 46 billion dollars in the CPEC project, which will eventually help it lower transportation costs and delivery times.

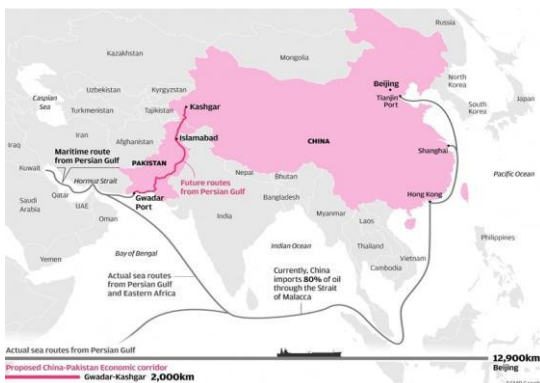


Figure 1.1: China-Pakistan Economic Corridor

(Source: <https://www.dawn.com/news/1177116>)

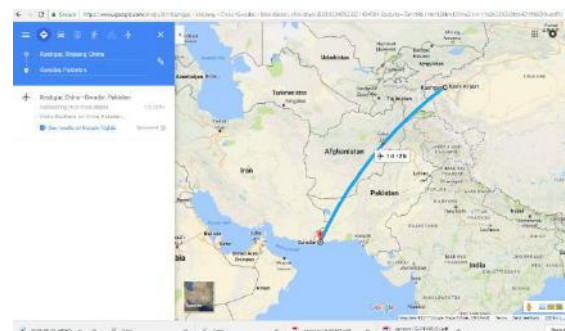


Figure 1.2: Google Maps

(Source: <https://www.google.com/maps/>)

- China Pakistan Economic Corridor (CPEC)

Four components of this project are:

1	Gwadar (Port city & Gwadar region's socio economic development)
2	Energy (Coal, Hydel, Wind, Solar, Liquid Natural Gas, Transmission)
3	Transportation Infrastructure (Road, Rail, Aviation)
4	Investment & Industrial Cooperation (Gwadar Free Zone & other industrial parks)

CPEC should be viewed more than network of roads, highways & rail linkages but a comprehensive package & integration of many projects that will meet Pakistan's and China's energy and other requirements. It is being dubbed a "Game Changer" in both China and Pakistan. China's total investment is approximately \$46 billion. The following table shows the breakdown of the CPEC project portfolio investment.

Sr. No.	Sector	No. of Projects	Estimated Cost (Million \$)
01	Energy	21	33,793
02	Transport Infrastructure	4	9,784
03	Gwadar	8	792.62

Table 1.1: Project Portfolio Investment

(Source: Board of Investment, Pakistan)

- Projects under CPEC

In this section of the research work gives the details of each individual project coming under CPEC i.e.

1. Energy Projects
2. Transport Infrastructure Sector Projects
3. Gwadar Port related Projects
4. Other Projects

Energy Projects

Energy is a critical component for Pakistan's economic growth. Pakistan has battled electrical shortages for the past decade, with little improvement evident thus far. Long periods of load shedding are causing the demise of numerous enterprises. Because of the increased demand for electricity, energy projects are crucial to CPEC initiatives.

Total energy produced under these energy priority projects will be 10,400 MW with a total investment of US\$ 15,506 Million. Apart from that there will be actively promoted projects which will provide 6,645 MW of energy with an investment of US\$18, 287. Hence in the long run, 17,045 MW energy will be produced with a total cost of US\$33,793 Million.

Sr. No	Projects	MW	Cost (US\$ M)
1	Port Qasim Electric Company Coal Fired, 2X660, Sindh	1320	1,980
2	Sahiwal 2x660MW Coal-fired Power Plant, Punjab	1320	1,600
3	Engro thar 2x330MW Coal-fired, Thar, Sindh	660	1,000
	Surface mine in Block II of Thar Coal field, 3.8 mtpa, Thar Sindh		860
4	Gawadar Coal Power Project, Gwadar	300	360
5	Muzaffargarh Coal Power Project, Punjab	1320	1,600
6	Rahimyar Khan Coal Power Project, Punjab	1320	1,600
7	SSRL Thar Coal Block 6.5mtpa & CPIH Mine Mouth Power Plant, Thar, Sindh	1320	1,300
8	Quaid-e-Azam 1000MW Solar Park, Bahawalpur, Punjab	1000	1,350
9	Dawood 50MW wind Farm, Bhambore, Sindh	50	125
10	UEP 100MW wind Farm, Jhimpir, Sindh	100	250
11	Sachal 50MW Wind Farm, Jhimpir, Sindh	50	134
12	Sunnec 50MW wind Farm, Jhimpir, Sindh	50	125
13	Suki Kinari Hydropower Station, KPK	870	1,802
14	Karot Hydropower Station, AJK & Punjab	720	1,420
Total (Priority)		10400	15,506

Table 1.2: CPEC Energy "Priority" Projects

(Source: China Pakistan Economic Corridor. (CPEC). 5th November, 2015. Board of Investment, Pakistan)

Transport Infrastructure Sector Projects

We will look at the transportation infrastructure sector projects under CPEC.

Sr. No	Projects	Length (km)	Cost (US\$ M)
Roads			
1	KKH Phase II (Raikot – Islamabad Section)	440	3,500
2	Peshawar-Karachi Motorway (Multan-Sukkur Section)	392	2,600
Rail Sector Projects			
1	Expansion and reconstruction of existing Line ML-1	1736	3,650
2	Haveelian Dry port (450 M. Twenty Foot Equivalent Units)		40
TOTAL			9,790

Table 1.3: CPEC Transport Infrastructure Projects

(Source: China Pakistan Economic Corridor. (CPEC). 5th November, 2015. Board of Investment, Pakistan)

The total cost involved will be US\$ 9,790 Million.

Gwadar Port Projects

Before the CPEC is completed, Gwadar requires significant infrastructural enhancements to meet future demand. The Gwadar city's projects will be listed here.

1	Eastbay Expressway	140.00
2	Gwadar International Airport	230.00
3	Construction of Breakwaters	130.00
4	Dredging of berthing areas & channels	27.00
5	Infrastructure for Free Zone & EPZs port related industries	35.00
6	Necessary Facilities of Fresh Water Treatment and Supply	114.00
7	Hospital at Gwadar	100.00
8	Technical and Vocational Institute at Gwadar	10.00
Total Gwadar Port Projects		786.00

Table 1.4: CPEC Gwadar Port Related Projects

(Source: China Pakistan Economic Corridor. (CPEC). 5th November, 2015. Board of Investment, Pakistan)

The total cost involved will be US\$ 786 Million.

Other Projects

As previously stated, the CPEC comprehensive package consists of multiple projects rather than a single route.

Sr. No	Projects	Length (km)	Cost (US\$ M)
1	Mass transit Lahore		1,600
2	Cross Border Optical Fiber Cable		
	Total	44	
	Total Cost of CPEC Projects		1,644

Table 1.5: CPEC Other Projects

(Source: China Pakistan Economic Corridor. (CPEC). 5th November, 2015. Board of Investment, Pakistan)

The total cost involved will be US\$ 1,644 Million.

- CPEC Route

CPEC has the potential to be a game-changing project for Asia. It includes massive infrastructure and transportation projects, including as 3,000 kilometers of pipelines, roads, and railroads that connect the port of Gwadar in southern Pakistan with the dry port of Kashgar in northern Xinjiang, China. The quickest route to the Arabian Sea and the Indian Ocean is via this corridor. China now uses the 5,153-kilometer route from Kashgar to Shanghai for the transportation of products.

On the other hand, it is only 2,800 kilometers from Kashgar to Gwadar, which is almost half the length of the current route. In order to restore historic trade routes linking Asia, Africa, and Europe, Chinese President Xi Jinping suggested the revived Silk Road in 2013, which includes this corridor (Inp, 2015). Beyond bilateral collaboration, CPEC is likely to benefit other nations as too, particularly Afghanistan, which will allow trade through Pakistan to adjacent regions.

Because of its strategic advantages, China, whose economy is expanding at the quickest rate in the world, wants to extend CPEC. Shanghai is 5,153 kilometers west of Kashgar, whereas Gwadar is only 2,800 kilometers away, making it a more practical option. The quickest path (2,600 kilometers) from Central Asian nations—Afghanistan, Kyrgyzstan, Kazakhstan, Tajikistan, Turkmenistan, and Uzbekistan—to Iran (4,500 kilometers) and Turkey (5,000 kilometers) is via Pakistan, which is a vital gateway to Central Asia due to its strategic location.



Figure 1.3: Highway Network of CPEC

(Source: <http://cpec.gov.pk/>)

CPEC Gwadar and Kashgar rail network is vital to transportation and is regarded as the economy's backbone. A railway map is shown below. The green and white lines depict the anticipated future construction of a 1,059-kilometer railway line connecting Havelian & Kashi.

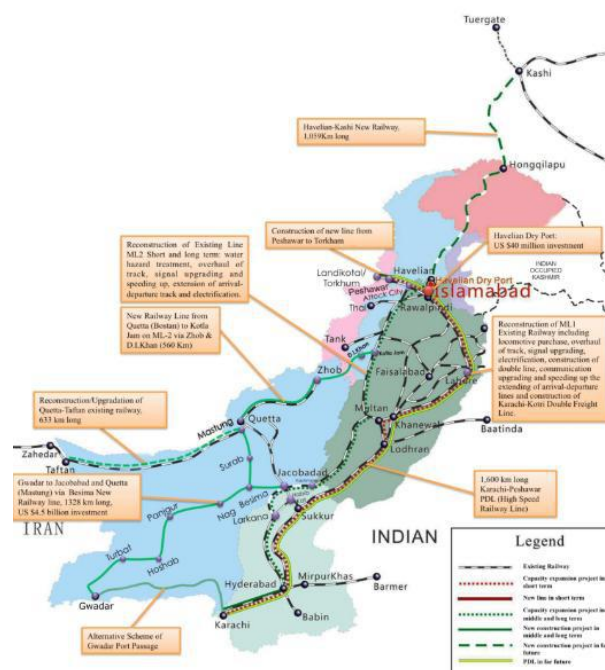


Figure 1.4: Railway Network of CPEC

(Source: <http://cpec.gov.pk/>)

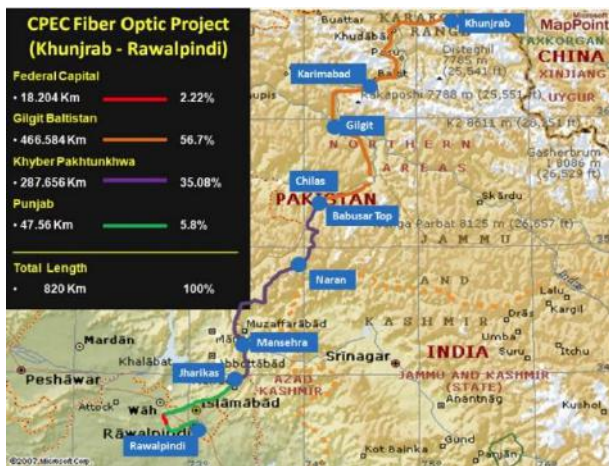


Figure 1.5: Fiber Optic Project of CPEC

(Source: <http://cpec.gov.pk/>)

Gwadar to Khunjerab is 2,688 kilometers long, including mountainous areas. For the CPEC project, two to six lanes are envisioned, with each lane measuring around 3.65 meters wide. The projected speed for CPEC route will be b/w 70 & 120 km/hr. The road map for CPEC is displayed below.

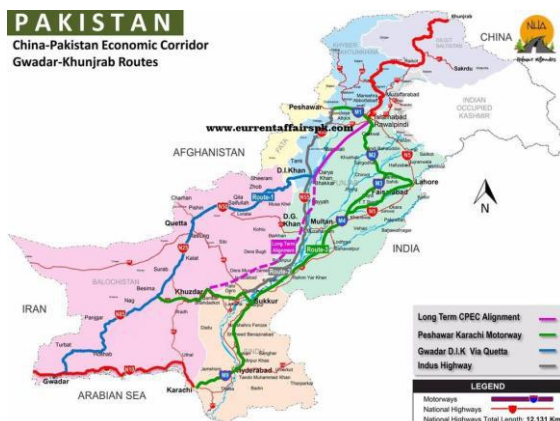


Figure 1.6: CPEC Routes

(Source: <http://www.currentaffairspk.com/detail-of-cpec-china-pakistan-economic-corridor-routes-fiber-optics/>)

The economic corridor three routes are;

The Western Route

Starts from Gwadar and passes through different cities of Baluchistan including Torbat, Panjgur, Nag, Basimeh, Sorab, Qalat, Quetta, Qila Saifullah and Zob, reached Dera Ismail Khan and continued to Islamabad.

The Central Highway

Starts from Gwadar and passes through several cities in the provinces of Punjab, Sindh and Balochistan before reaching Dera Ismail Khan. Basima, Khuzdar, Sukkur, Rajanpur, Liah, Muzaffargarh and Bakar are among the towns.

Eastern Route

Gwadar, Basime, Khazdar, Sukkur, Rahim Yar Khan, Bahawalpur, Multan, Lahore/Faisalabad and Islamabad are all located on the Eastern Route.

- General Impact of CPEC

China & Pakistan's economies would be significantly impacted by this CPEC investment. Due to severe energy shortages in Pakistan, the majority of the investment is in the energy industry. More than 15,000 MW of power will be produced by planned and proposed energy projects, which might stimulate business and draw in private investment. For the past ten years, Pakistan has seen little investment from the private sector.

The expected investment will also have an impact on the stock market. There is every probability that the revenues and the share prices will increase for various industrial units. This will lead to the increase in productivity of the manufacturers. China benefits equally from this project. CPEC will reduce distance b/w China's Kashgar, located in Xinjiang province, 5,153 kilometers from Beijing, and Persian Gulf, which is currently 13,000 kilometers away. Delivery time will be shortened from 45 days to 10 days for distances up to 2,500 km. China will be able to import commodities like oil in ten days and save money on freight thanks to the new channel. CPEC will significantly cut down China's current commercial routes to Middle East, Africa, and Europe.

- Overview

Delivering completed goods to clients is the focus of logistics. It involves a number of tasks, such as order processing, storage, and transportation. This activity falls under the "supply chain management" network, which is built on the integration of several industries, such as information, material handling, warehousing, transportation & inventory, and packaging. This activity plans the troops, supplies, equipment, and mobility, among other things. Two primary components of logistics are:

- Transport (vehicles i.e. trucks, vans, rail, ships, airplanes)
- Infrastructure (roads, highways, sea ways, air ways)

Both aspects of logistics are referred to as the backbone, lifeline, or critical levers of trade in this communications-driven era and aid in cutting down

on delivery times and shipping costs.

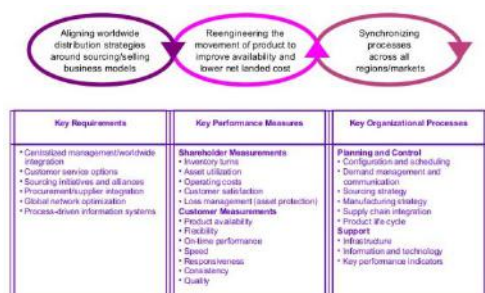


Figure 1.7: Global Logistics Strategy

(Source: Coopers & Lybrand Consulting)

One of the most important logistics activities, if we examine any global logistics strategy, is transportation. Choosing the appropriate means of transportation is essential. In order to choose a mode, organizations attempt to assess many aspects of transportation. Out of all the variables that are available, cost and travel time are regarded as the two main or primary qualities. Norbis and Meixell (2008).

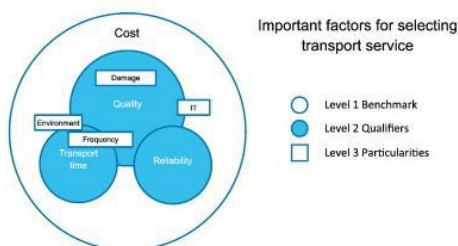


Figure 1.8: Important factors for selecting transport service

(Source: Research in Transportation Business & Management Volume 23, June 2017, Pages 35–45)

Objectives

The primary goal of the study is to determine how transit time and shipping costs affect trade. The study suggests an optimal path that is both economical and time-efficient. China is searching for a more efficient and cost-effective commerce route to reach the nations of Europe and the Middle East. Verifying whether CPEC is feasible and sustainable substitute for the current routes is the goal of this research project. Without a doubt, CPEC can offer a quicker route between China and the Middle East and Europe.

Research Question

- Is there a -ve/+ve effect on imports & exports in terms of transportation costs & delivery (transit) time?

- Which route (currently/CPEC, including road & sea components) is better in shipping costs and shipping / delivery time?

II. THEORETICAL FRAMEWORK & LITERATURE REVIEW

- Supply Chain & Logistics

Supply chain is made up of manufacturers, suppliers, distributors, retailers, and wholesalers who are all connected by some form of transportation. The provision of goods and services to final consumers is the main objective of a supply chain network. The effective integration and connectivity of all business divisions and supply chain management network stakeholders influence network's performance (Sahin, 2002). The term "supply" can be used as a verb or as a noun when discussing "supply chain management." As a verb, this word means "to provide for," and as a noun, it implies "the act of filling a want or need (Merriam-Webster. 1973).

Keith Oliver, an executive at Booz Allen Hamilton, originally used the term "supply chain management" in 1982 (InformationWeek, 2003). The administration of the operations or activities that cooperate in a synchronized chain is referred to as supply chain management.

In recent years, companies have attempted to enhance their supply chain operations and have begun to recognize that the supply chain is the primary source of competitive advantage over rival businesses. Businesses are spending a lot of money developing specialized software to guarantee that supply chain operations run efficiently. Numerous software companies have marketed supply chain management (SCM) systems, including software and licensing, for billions of dollars. These expenses are in addition to the expenditures of installation and upkeep. In 2003, Kanaka-medala et al.

Service to end users/customers is the main goal of supply chain management. According to Christopher (1998), a supply chain is a collection of many businesses united by the goal of getting goods and services into the hands of consumers. As various procedures and activities are carried out, this process involves numerous upstream-downstream links.

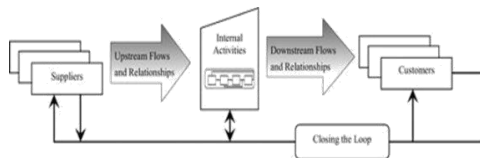


Figure 2.1: Supply Chain Network, Stages & Relationships

(Source: Christopher, 1998)

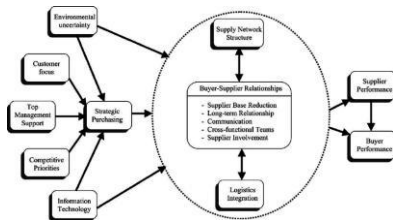


Figure 2.2: Framework of Supply Chain Management

(Source: Towards a Theory of Supply Chain Management by Iraj F. Ghomi & Armin Pajand, Apr 2004 - Journal of Operations Management)

The term logistics was coined in the 1960s and has been widely used ever since. However, they are constantly changing over time and are not static. (McGuinness, 1992). It is the combination of various activities that are involved in moving products. Information, storage, warehousing, warehousing, asset management and many other important functions are included in this process. It is an activity that links and combines several supply chain operations. It is significant activity that affects how well the supply chain operates. The development of organizational networks and infrastructure determine how efficiently logistics are carried out. Logistics centers, warehouses, stations, docks, and aircraft ports are examples of sites or activities that make up an infrastructure network. Other channels include railroads, highways, canals, flight paths, and pipelines.

The components, resources, supply and transport businesses, and target clients make up logistics corporations. (Zhang and others, 2011). Infrastructure determines logistics efficiency, as stated by Shan et al. (2011). Any company can now use logistics as a competitive advantage in the current globalized era. Bowersox and associates (2000).

By creating new logistics capabilities, businesses add value for their clients. (Esper and others, 2007; Mentzer and others, 2001). A strategic resource, logistics is used by many businesses to obtain a competitive edge. In 2004, Mentzer et al.

Transportation on the other hand has a critical role to play in the manipulation of logistics. As logistics has advanced through 1950s (nationalization and globalization).

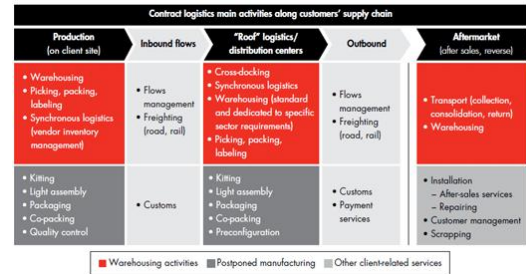


Figure 2.3: Challenges and winning Models in Logistics

(Source: Table 8. Crapoz, Challenges and winning models in logistics by François Boussois, François Martineau and François Thibault, November 07, 2012)

- Supply Chain

It starts from supplier & ends at customer. It has different functionalities, activities & flows. It is divided into Upstream, Internal Organization & Downstream.



Figure 2.4: Simplified Supply Chain

(Source: <https://www.slideshare.net/bosp1/lecture-iii-september-2014the-information-system-and-procurement>)

The main roles in a supply chain and their connections are depicted in the above diagram. According to Joseph (2012), procurement and purchase are two of the main upstream operations. Other features fall into the following categories: inbound transportation, management/selection, supplier partnership & development, outsourcing, vendor auditing, and material movement. Obtaining the raw materials needed for production is the special focus of the upstream function.

Production and operational management functions are part of the internal organizational activities. R&D, quality, inventory, materials, and technology implementation and management are some of these activities.

The various activities that make up downstream flow include marketing, distribution, packaging,

warehousing, and outbound transportation. The downstream function transports the final products from the manufacturing plant or process to the final consumers. Information, demand, and funds are transferred from the final consumer (right) to the supplier (left) during this process.

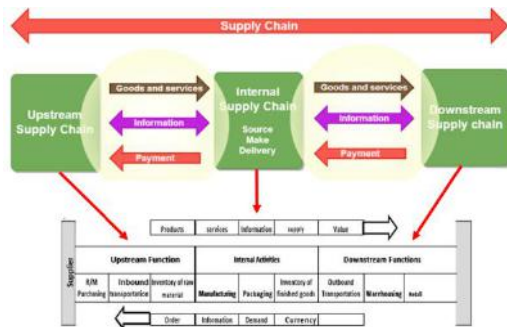


Figure 2.5: Flow of Supply Chain Network

(Source: This work is revised by Mr. M. Ahmer Aamer, Dated 1st June, 2017)

Choosing the best method of transportation is the most important task that needs to be completed in the transportation industry. This choice is influenced by numerous things. In order to prevent delays, organizations want the raw materials to arrive on time for production, and they also want the final products to reach end users or consumers as soon as possible. Only an efficient transportation system and the ensuing infrastructure will make this feasible. Reducing transit times and shipping costs can be greatly aided by improved road infrastructure or the maritime route.

It is important to remember that every action in the supply chain network affects the national economy. But out of all the supply chain activities, transportation has the biggest influence.

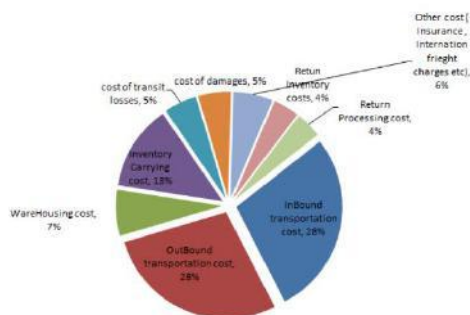


Figure 2.6: Breakup of Supply Chain Costs

(Source: "State of Retail E-Commerce in India", NGHM 2017. Break-up of typical supply chain costs)

- Importance of Shipping Costs

Transportation is an important economic activity in

industrial systems. The money spent on logistics is 1/3 or 2/3 of the costs. According to (Chang, 1988), total transportation cost is forty-four percent of the total input costs and six point five percent of the total. Car rental is offered. Market products.

Furthermore, planning the containership route and timetable is a crucial component that is very challenging to alter in the near term (Ting Shih Chan, 2003). Managers are constantly looking for dependable and reasonably priced forms of transportation. Choosing a form of transportation involves numerous complex decisions and challenges. Finding the pertinent transportation performance characteristics is one of the many criteria that must be evaluated in order to choose the best carrier and the most practical mode. Rate negotiations, service standards, transit durations, shipping expenses, and carrier performance are some of these variables and determinants (Monczka et al., 2005). According to Russell and Taylor (2003), these are the most crucial considerations for any business because, in the industrial sector, transportation expenses are quite high and typically account for 20% of total production costs.

As a result, businesses are constantly looking for more cost-effective transportation choices. Companies do their best to reduce transportation expenses. If raw material transportation expenses are high, the finished goods' pricing will reflect this. Many businesses and organizations strive to reduce shipping costs, resulting in lower-cost end products. According to Pedersen (1998), a survey of transportation costs was undertaken in Norwegian enterprises, and the results revealed that transportation accounts for more than half of total logistics costs for items (Reimann1989).

China Pakistan Economic Corridor (CPEC)

- Pakistan

As route runs through Pakistan, it is critical to comprehend the country's topography, politics, and climate. Climatic circumstances have a significant impact on CPEC. Heavy snowfall, rain, or flooding may have an impact on the projected trading route.



Figure 3.1: Map of Pakistan

(Source: <http://www.ezilon.com/maps/images/asia/Pakistan-physical-map.gif>)

South Asia is home to Pakistan. Afghanistan, Iran, India, China, and the Arabian Sea are some of its neighbors. China to the north, India to the east, Iran and Afghanistan to the west, and the Arabian Sea to the south. Pakistan's location at the intersection of Asia makes it unique geographically. Pakistan's terrain is made up of mountain ranges, deserts, forests, and green spaces. Pakistan is made up of the Balochistan Plateau in the west, the mountains in the north and west, and the Indus Plain in the east. K2 (Mt. Godwin-Austen) is the highest point at 8,611 meters, while the Indian Ocean is the lowest at 0 meters. Some of the highest peaks in the world, such as K2 (28,250 feet, 8,611 meters) & Nanga Parbat (26,660 feet, 8,126 meters), are located in Pakistan's northern region. To south is Arabian Sea (2017, CIA Global Factbook). The landscape of Pakistan is incredibly varied. The high mountains are located in Pakistan's northern region, across the Sahara and Arabian Sea. There are numerous well-known mountain summits in Pakistan. Ahmad, Kazi S. (1951).

Climate information is critical, particularly for the locations through which the corridor passes. Pakistan's climate is predominantly hot. Pakistan is blessed with four seasons. During the winter, Pakistan has temperatures ranging from -10 to -20 in the north and +10 to +20 in the south. (CIA World Factbook, 2017). Pakistan's weather is naturally diverse. Extreme weather is unusual, yet it does occur on occasion.

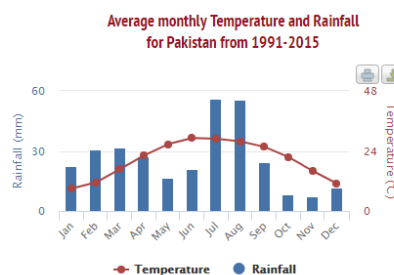


Figure 3.2: Average Monthly Temperature and Rainfall Pakistan (1991-2015)

(Source: Climate change knowledge portal, The World Bank Group)

Heavy snowfall and terrain sliding can have a negative impact on the CPEC in Pakistan's northern provinces. The Shahrah-e-Karakoram route, which connects Pakistan with China, becomes impassable during the winter and rainy season.



Figure 3.3: Shahrah-e-Karakoram landslide blockade

(Source: <http://dunyanews.tv/en/Pakistan/328851-Kohistan-KKH-blockade-continues-on-eighth-day-due>)

Pakistan is blessed with 4 seasons.

Seasons	Average Temperature (Fahrenheit Degrees)
Winter	20 to -25
Spring	25 to 35
Summer	32 to 53
Autumn	18 to 5

Table 3.1: Average Temperatures (4 Seasons)

(Source: World Bank, 2017)

- Effects of CPEC on Pakistan's Economy

Pakistan had a population of 30 million and a GDP per capita of \$100 in 1947 (Dr. Hafez A. Pasha, 2013).

Meanwhile, Pakistan's GDP has increased by 4.71% in 2016 compared to the previous year, 2015. Pakistan's GDP growth from 1952 to 2016 was 4.91%. The following charts show the economic situation in Pakistan.

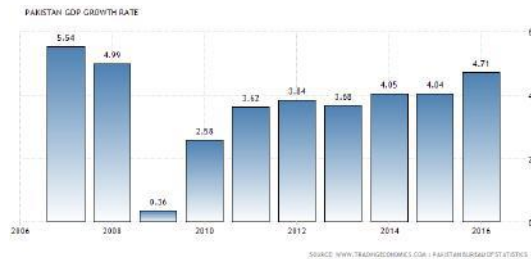


Figure 3.4: Pakistan GDP Growth Rate

(Source: Pakistan Bureau of Statistics)

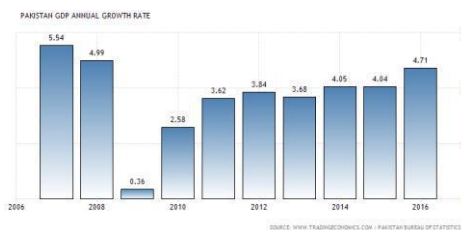


Figure 3.5: Pakistan GDP Annual Growth Rate

(Source: Pakistan Bureau of Statistics)



Figure 3.6: Pakistan GDP

(Source: Pakistan Bureau of Statistics)

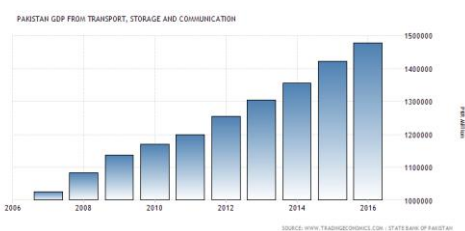
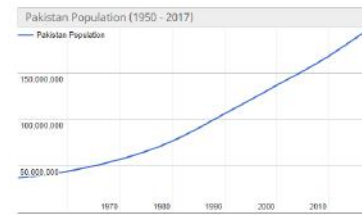


Figure 3.7: Pakistan GDP from Transport, Storage & Communications

(Source: Pakistan Bureau of Statistics)



Population of Pakistan (2017 and historical)

Year	Population	Yearly % Change
2017	196,744,376	2.03 %
2016	192,826,902	2.07 %
2015	188,624,874	2.13 %
2010	170,043,918	2.09 %

Figure 3.8: Population of Pakistan

(Source: <http://www.worldometers.info/world-population/pakistan-population/>)

Imports & export details of Pakistan are shown below;



Figure 3.9: Exports Pakistan

(Source: Pakistan Bureau of Statistics)



Figure 3.10: Imports Pakistan

(Source: Pakistan Bureau of Statistics)

CPEC is expected to produce over 700,000 new jobs in Pakistan, thus bringing our youthful people into the mainstream. It should be noted, however, that this initiative will save thousands of kilometers of transit between China and other countries.

The study also confirms that economic and social development relations between China and Pakistan have entered a new phase in recent years, and the two countries have established "multiple wheels" to promote in double bonds. CPEC begins in Kashgar, Xinjiang, China, and travels via the Khunjrab Pass and other nodal sites to Karachi and Gwadar, two

southern Pakistani coastal cities. in the cement sector. economic ties between Pakistan and China.

III. METHODOLOGY

Travel time and expenses are the main topics of this investigation. Companies and organizations weigh the pros and downsides of several car models before choosing one. The two most crucial elements are delivery time and freight cost. In the context of the CPEC project, both of these factors are significant. A 50-foot container used to import and export commodities from the Middle East and Europe to Kashgar (West China) via Gwadar Port is the subject of this study, which attempts to ascertain the change or variation in transit time and transportation costs.

- Research Design & Data Collection

The research plan includes detailed information about available data and sources, the research approach used, data analysis methods and data interpretation to answer the research questions. Resources are secondary data obtained from various sources, including the Internet, articles, newspapers, and books. freight lines provide the essential data, which includes delivery time and current freight charges. Road and maritime travel are the suggested present and future routes. Road freight prices are computed using information gathered from the Internet and shipping, while ocean freight rates are obtained from different shipping companies. The shipping businesses and management provide the first piece of information (shipping cost) by email. The official shipping timetables of the French shipping company CMA CGM (Compagnie Maritime d'Affrètement Compagnie Générale Maritime) are used to calculate sea freight times (<https://www.cma-cgm.com/>). Google Maps is used to calculate the distances to highways.

Primary Data	Obtained from shipping companies such as CMA-CGM, MSC, China Shipping and Hapag Lloyd, and carriers such as AW Logistics and Combined Transport.
Secondary Data	Collected from the Internet (such as Google Maps), research studies, newspapers and books.

- Analysis of Data

The research used in this work is Qualitative and descriptive in nature for answering the research questions. Comparative analysis is done for existing

and proposed routes. The variables used for the comparative research work include total distance, shipping costs & transit time. Statistical Test is based on mathematical analysis.

IV. LIMITATIONS

Shipping companies offered shipping charges for a 50-foot container (only for one month). Depending on various variables such as oil prices and product demand, prices may rise or fall. The current and proposed approach consists of two parts:

- Road Transportation
- Transportation by Sea

Research makes it easy to determine shipping costs and shipping times by sea. However, doing so is difficult for road transport. Road charges may vary as local carriers have different rates. The research has assessed the average costs of road transport to meet research needs.

The research methodology is based on the following Calculations/stages/parts;

A	Present transit time & shipping costs
B	Proposed route transit time & shipping costs
C	Comparison of both routes' shipping costs & transit time

Impact on China

- Present Transit Time & Shipping Costs

The researcher chooses the three Middle Eastern ports that China depends on to meet its urgent demands and the three European ports that import and sell the most to China in the first step or phase. Following port selection, this study examines the shipping costs and transit duration for a 50-foot container from these ports to Kashgar, Western China. The following is journey from chosen ports to Kashgar, West China:

- Sea

- Highway

For clarity, routes are divided as:

A	Distance between Kashgar (West China) and Port of Shanghai (China Road)
B	The sea distance from Shanghai to the ports of entry (China Sea)A



Figure 5.1: China Road and China Sea Present Routes

(Source: This work is revised by Mr. M. Ahmer Aamer by plotting on the map. Dated 10th May, 2017)

Products from Kashgar are being shipped to Shanghai Port via the China route if China wishes to export them to the designated nations. Once the products reach the port, they are loaded onto ships and transported by sea to the China Sea, which is their final destination (designated country). Additionally, things will alter if China decides to import goods from other nations. As we can see, a road has two parts: the road and the sea. It is possible to calculate the China Sea route's passage time and shipping expenses. Online resources (the ferry lines' precise timetable page) provided the delivery time information for this investigation. The shipping charge was sent by the shipper. The average cost per kilometer is multiplied by the total distance of the China road to determine the transportation cost for the China highway. By dividing the total road distance in China by the average truck speed, the study determines the road transport time. Road conditions, altitude, traffic, and driver rest are other elements to take into account. In order to calculate the current freight rates and transit time for 50-foot containers that are intended for import or export to China from certain ports of entry, China will combine the freight rates with the transit time by land and sea.

- Proposed Route

The study assesses transit time and transportation costs for the proposed new CPEC route. This approach also focuses on the sea and roads. The road connecting Kashgar and Gwadar is known as "Pakistan Road".



Figure 5.2: New Proposed Route

(Source: This work is revised by Mr. M. Ahmer Aamer by plotting on the map. Dated 12th May, 2017)

If China wants to transport products from the proposed new route, the cargo will reach Gwadar from Kashgar (Western China) via Pakistan route. It is then brought from Gwadar port by loading on a barge and sent to the final destination through Pakistani waters.

- Chinese Exports

The statistics shown below depicts this picture.



Figure 5.3: Chinese Exports

(Source: Trading Economics)

Shown below is the exports volume to various countries.

Country	Exports (%)
India	17.9
Japan	6.9
South Korea	14.3
Taiwan	9.9
ASEAN Countries	11.6
EU Countries	7.1
South Africa	12.8
Brazil	32.4
Russia	22
US	11
Australia	10.4
New Zealand	9.4

Table 5.1: Chinese Exports to different countries

(Source: Trading Economics)

- Chinese Imports

China stands 2nd in world imports. Shown below are the imports statistics.



Figure 5.4: Chinese Imports

(Source: Trading Economics)

Country	Exports (%)
Japan	45.5
ASEAN Countries	25
US	19.9
EU Countries	12.3
South Korea	11.1
Taiwan	12.1
Australia	69.8

Table 5.2: Chinese Imports to different countries

(Source: Trading Economics)

- Present Route

Researcher evaluated transportation cost/transit time for 50-foot container shipped from dry port of Kashgar (western China) to the destination ports. Today's transportation consists of roads and waterways. Cargo from Kashgar will arrive at Shanghai port via China route. It travels from Shanghai (port) to designated ports throughout the China Sea. As a result, this study estimates the transportation cost/delivery time from source port to destination by simply adding values of China Road & China Sea. Delivery times & delivery times are available from shipping companies. Shipping costs & delivery time will be determined later. To begin with, the research study evaluates the cost of China's road sections and their transportation times.

- China Road Cost

Overall distance of China Road is 5,153 kilometers. Average cost per kilometer is US\$0.50, according to AW Logistics Company (AW Logistics, 2017). Cost of inland haulage (price for commercial transport of

goods) differs amongst local transporters, hence an average cost is used to meet the requirements. China Road portion inland transport charges are computed by multiplying the China Road distance and the average per kilometer cost.

China Road Haulage Charges		
China Road Distance (Km)	Per Km Cost (US\$)	Total (US\$)
5,153	0.50	2,576.5

Table 5.3: Road Transport Cost (China Road Segment)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 20th May, 2017)

- China Road - Transit Time

The average truck or rail speed divided by total distance of China Road section yields travel time. The average truck/rail speed is obtained from the local transporters, such as AW logistics & distance of China Road section is obtained from Google Maps (AW logistics, 2017). The truck's speed can reach 85 km/h in certain areas, although it falls to 25 km/h or less in mountainous areas. In light of this, an average speed of 55 km/h, or $(85+25)/2$, is chosen.

China Road Transit Time		
China Road Distance (Km)	Average (Truck/Rail) Speed (Km Per Hour)	Total (Hours)
5,153	55	93.69

Table 5.4: Transit Time (China Road Segment)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 20th May, 2017)

To obtain correct findings, each voyage at the China road segment is subjected to an average of 24 hours of transit time delays caused by the aforementioned causes. In the computation below, an average 12-hour delay is added to the China Road transit time. The 12 hours are based on our assumptions.

China Road Transit Time		
China Road Transit Time (Hours)	Average Delay's (Hours)	Total (Hours)
93.69	12	105.69 or 4.4 Days

Table 5.5: Total Transit Time (China Road Segment)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 20th May, 2017)

- Present Route Shipping Costs

The port of origin in all the cases is Kashgar. The shipment will first reach through the China The road will lead to the Shanghai port, from whence it will be delivered to its final destination across the China Sea. To calculate current shipping expenses, we shall sum the shipping costs of the China Road and China Sea parts. China Road costs have already been computed above.

Present Route Shipping Cost = China Road Cost + China Sea Freight

Origin Port	Destination Ports	China Road Freight (Kashgar-Shanghai)	China Sea Freight (Shanghai-Destination Ports)	Total Freight
Kashgar	Hamburg	\$1,900 - \$2,200	\$1,800 - \$1,900	\$3,700 - \$4,100
	Le Havre	\$1,900 - \$2,200	\$1,800 - \$1,900	\$3,700 - \$4,100
	Rotterdam	\$1,900 - \$2,200	\$1,800 - \$1,900	\$3,700 - \$4,100
	Jeddah	\$1,900 - \$2,200	\$1,300 - \$1,500	\$3,200 - \$3,700
	Kuwait	\$1,900 - \$2,200	\$1,300 - \$1,500	\$3,200 - \$3,700
	Oman	\$1,900 - \$2,200	\$1,200 - \$1,300	\$3,100 - \$3,700

Table 5.6: Present Route Freight

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 22nd May, 2017)

- Present Route Transit Time

The current travel time for a 50-foot container is calculated by adding the transit time on the China Road and the transit time on the China Sea. Shipping times for China roads are determined, transit times to China seas are based on CMA Line's official shipping schedules.

Current Route Transit Time = China Route Transit Time + China Sea Transit Time

Origin Port	Destination Ports	China Road Transit Time (Kashgar-Shanghai)	China Sea Transit Time (Shanghai-Destination Ports)	Total (Transit Time)
Kashgar	Hamburg	4 – 6 Days	29 – 34 Days	33 – 40 Days
	Le Havre	4 – 6 Days	29 – 34 Days	33 – 40 Days
	Rotterdam	4 – 6 Days	29 – 34 Days	33 – 40 Days
	Jeddah	4 – 6 Days	14 – 19 Days	18 – 25 Days
	Kuwait	4 – 6 Days	14 – 19 Days	18 – 25 Days
	Oman	4 – 6 Days	11 – 14 Days	15 – 20 Days

Table 5.7: Present Route Transit Time

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 22nd May, 2017)

Marine transit times are derived from the CMA line's online schedules. The time spent in other ports throughout the travel will not be counted.

Impact on Pakistan

- Proposed Route

This cargo is going from Kashgar to Gwadar port via Pakistan route. After that they are transported from Gwadar port to other destination ports through Pakistani sea route. Shipping companies provide information on freight rates and transit times for Pakistan's maritime sector. Pakistan taxes and duties and transit time are calculated after collecting the necessary data.

- Pakistan Road Cost

According to Google map, the road width in Pakistan is 2800 km. According to Combined Freight International (2017), the average cost per kilometer is \$0. 26. Prices vary for different carriers in the area, so the average price is used to meet requirements.

Pakistan Road Haulage Charges		
Pakistan Road Distance (Km)	Per Km Cost (US\$)	Total (US\$)
2,800	0.26	728

Table 6.1: Pakistan Road Cost

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 28th May, 2017)

- Pakistan Road Transit Time

The transport time of the road section of Pakistan is determined truck can reach speeds of up to 85 km/h in some sections, although it drops to 25 km/h or less in mountainous areas. Average speed of 55 km/h (25+85)/2 is used.

Pakistan Road Transit Time		
Pakistan Road Distance (Km)	Average (Truck/Rail) Speed (Km Per Hour)	Total (Hours)
2,800	55	50.9

Table 6.2: Pakistan Road Segment Transit Time

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 28th May, 2017)

The road transport between Kashgar and Gwadar takes 50. 9 hours. However, other factors such as weather conditions, traffic congestion, strikes, law and order and drivers resting after long journeys must also be considered. The reasons mentioned above mean an average of 12 hours of delivery delay. These 12 hours are based on the assumptions we made earlier.

Pakistan Road Transit Time		
Pakistan Road Transit Time (Hours)	Average Delay's (Hours)	Total (Hours)
50.9	12	62.9 or 2.62 Days

Table 6.3: Pakistan Road Total Transit Time

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 28th May, 2017)

50-foot container will take 62.9 hours (2.62 days) to reach from Kashgar - Gwadar through Pakistan Road.

- Shipping Cost

The cargo will first go to Gwadar port via Pakistan route. In addition, it is shipped to other ports of destination by sea in Pakistan. To calculate the cost of transporting a 50-foot container through CPEC, we add the road costs of Pakistan's road sector and the sea transport of Pakistan's sea sector. Pakistan sea freight rates for Europe are obtained from CMA and MSC lines, sea freight rates for Middle East countries are obtained from CMA, MSC, China Shipping and Hapag Lloyd. Fees will be collected for the month of April 2017 and will be valid for one month. Prices change monthly. (CMA, MSC, Hapag Lloyd, China Shipping, 2017). To calculate shipping cost for 50 feet container, add Pakistan road and Pakistan sea shipping cost.

CPEC Proposed Route Shipping Cost = Pakistan Road Cost + Pakistan Sea Freight

Origin Port	Destination Ports	Pakistan Road Freight (Kashgar-Gawadar)	Pakistan Sea Freight (Gawadar-Destination Ports)	Total Freight
Kashgar	Hamburg	\$700 - \$800	\$1,700 - \$1,800	\$2,400 - \$2,600
	Le Havre	\$700 - \$800	\$1,700 - \$1,800	\$2,400 - \$2,600
	Rotterdam	\$700 - \$800	\$1,700 - \$1,800	\$2,400 - \$2,600
	Jeddah	\$700 - \$800	\$800 - \$900	\$1,500 - \$1,700
	Kuwait	\$700 - \$800	\$800 - \$900	\$1,500 - \$1,700
	Oman	\$700 - \$800	\$250 - \$350	\$950 - \$1,150

Table 6.4: CPEC Route Shipping Cost

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 28th May, 2017)

- CPEC Proposed - Transit Time

Pakistan road shipping time is pre-determined, but the Pakistan sea shipping time is based on the CMA live shipping schedule. By adding the Pakistan road transport time and the sea transport time in Pakistan, we can calculate total transit time through

new CPEC route.

Origin Port	Destination Ports	Pakistan Road Transit Time (Kashgar-Gawadar)	Pakistan Sea Transit Time (Gawadar-Destination Ports)	Total (Transit Time)
Kashgar	Hamburg	2 - 4 Days	22 - 26 Days	24 - 30 Days
	Le Havre	2 - 4 Days	22 - 26 Days	24 - 30 Days
	Rotterdam	2 - 4 Days	22 - 26 Days	24 - 30 Days
	Jeddah	2 - 4 Days	6 - 9 Days	8 - 13 Days
	Kuwait	2 - 4 Days	3 - 5 Days	5 - 9 Days
	Oman	2 - 4 Days	4 - 7 Days	6 - 11 Days

Table 6.5: Transit Time (CPEC)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 30th May, 2017)

Ocean loading times are taken from the online CMA Line Schedules. The transit time starts from the time the ships dock until their final destination. Time spent in various ports is not included.

V. FINDINGS

- Impact on Imports & Exports

Based on our analysis, the total traffic from the selected sites is in the billions. The analysis shows that the shipping cost for a 50-foot container imported from European countries will decrease. Also, the transit time from European countries is reduced. For countries in the Middle East, which China relies heavily on for energy, shipping costs will be reduced in addition to the delivery time. This addresses the primary research question in the study. The table below shows the overall impact of CPEC on savings.

Ports	Exports (Billion Dollars)	Imports (Billion Dollars)	Total Trading Volume (Billion Dollars)	10% Saving (Billion Dollars)
Germany	\$92.5	\$87.4	\$179.9	\$17.9
France	\$50.4	\$20.0	\$70.4	\$7.0
Netherlands	\$44.7	\$10.3	\$55.0	\$5.5
Saudi Arabia	\$19.8	\$48.0	\$67.8	\$6.7
Kuwait	\$3.8	\$8.9	\$12.7	\$1.2
Oman	\$1.2	\$18.9	\$20.1	\$2.0
Total	\$212.4	\$193.5	\$405.9	\$40.5

Table 7.1: Impact of CPEC

(Source: This work is revised by Mr. M. Ahmer. Dated 2nd June, 2017)

The table above shows that the supply chain may save approximately US\$40.5 billion on all exports/imports transported from the specified

destinations. The CPEC route will not only cut transportation expenses, but it will also shorten the distance from 10,000 to 11,000 kilometers, resulting in shorter trade transit times. The shorter route means faster delivery of the shipped goods.

- Comparisons

Shipping - Costs Comparison

The table indicates a favorable impact (green hue) in terms of transportation costs. China should be able to save at least \$1,300 for each 50-foot container imported/exported from Europe. The new route shipping cost is approximately 36.0% cheaper than the current route shipping cost. According to research findings, China should pay about half of the current shipping costs for each 50-foot container (originating in Jeddah and Kuwait). In other words, China can cut shipping costs by up to 50% on all oil imports.

Origin Port	Destination Ports	Current Route Shipping Cost	CPEC Route Shipping Cost	Difference
Kashgar	Hamburg	\$3,700 - \$4,100	\$2,400 - \$2,600	\$1,300 - \$1,500
	Le Havre	\$3,700 - \$4,100	\$2,400 - \$2,600	\$1,300 - \$1,500
	Rotterdam	\$3,700 - \$4,100	\$2,400 - \$2,600	\$1,300 - \$1,500
	Jeddah	\$3,200 - \$3,700	\$1,500 - \$1,700	\$1,700 - \$2,000
	Kuwait	\$3,200 - \$3,700	\$1,500 - \$1,700	\$1,700 - \$2,000
	Oman	\$3,100 - \$3,700	\$950 - \$1,150	\$2,150 - \$2,550

Table 7.2: Shipping Costs Comparison (Present & Future CPEC route)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 2nd June, 2017)

Transit Time Comparison

The green color indicates a positive impact on delivery time. The results show that China can save 9-10 days for all imports and exports to/from Europe. Likewise, China can reduce transit times to Middle Eastern countries because it depends on them for its energy needs.

Origin Port	Destination Ports	Present Route Transit Time	CPEC Route Transit Time	Difference
Kashgar	Hamburg	33 - 40 Days	24 - 30 Days	9 - 10 Days
	Le Havre	33 - 40 Days	24 - 30 Days	9 - 10 Days
	Rotterdam	33 - 40 Days	24 - 30 Days	9 - 10 Days
	Jeddah	18 - 25 Days	8 - 13 Days	10 - 12 Days
	Kuwait	18 - 25 Days	5 - 9 Days	13 - 17 Days
	Oman	15 - 20 Days	6 - 11 Days	9 - 9 Days

Table 7.3: Transit Time Comparison (Present & Future CPEC route)

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 2nd June, 2017)

- Comparison of Distance

Present Distance

Today's route is a combination of road and sea elements. The distance of the new route is calculated by adding the China route and the China Sea distances to the current route. Nautical distance is measured in nautical miles. However, we have converted it to kilometers. To convert nautical miles to kilometers, multiply the nautical distance by 1.852.

Total Present Route Distance = China Road Distance + China Sea Distance

Origin Port	Destination Ports	China Road Part Distance (Kashgar to Shanghai)	China Sea Part Distance	Total Present Route Distance (Km)
Kashgar	Hamburg	5,153	10,778nm x 1.852 = 19,961km	25,114
	Le Havre	5,153	10,320nm x 1.852 = 19,113km	24,266
	Rotterdam	5,153	10,320nm x 1.852 = 19,113km	24,645
	Jeddah	5,153	6,558nm x 1.852 = 12,145km	17,298
	Kuwait	5,153	6,558nm x 1.852 = 11,227km	16,380
	Oman	5,153	5,389nm x 1.852 = 9,980km	15,133

Table 7.4: Present Route Distance

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 2nd June, 2017)

Route Distance

CPEC route distance = Pakistan Road Distance + Pakistan Sea Distance

Origin Port	Destination Ports	Pakistan Road Part Distance (Kashgar to Gawadar)	Pakistan Sea Part Distance	Total CPEC Route Distance (Km)
Kashgar	Hamburg	2,800	6,386nm x 1.852 = 11,827km	14,627
	Le Havre	2,800	5,928nm x 1.852 = 10,979km	13,779
	Rotterdam	2,800	6,133nm x 1.852 = 11,358km	14,158
	Jeddah	2,800	2,166nm x 1.852 = 4,011km	6,811
	Kuwait	2,800	1,087nm x 1.852 = 2,013km	4,813
	Oman	2,800	467nm x 1.852 = 865km	3,665

Table 7.5: CPEC Route Distance

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 2nd June, 2017)

Distance Comparisons

The research work demonstrates how much the distances increase or decrease as a result of the CPEC route by estimating the difference between the current and CPEC route lengths.

Origin Port	Destination Ports	Present Route Distance	CPEC Route Distance	Difference (Km)
Kashgar	Hamburg	25,114	14,627	10,487
	Le Havre	24,266	13,779	10,487
	Rotterdam	24,645	14,158	10,487
	Jeddah	17,298	6,811	10,487
	Kuwait	16,380	4,813	11,567
	Oman	15,133	3,665	11,468

Table 7.6: Current & CPEC Routes Distances Comparison

(Source: This work is revised by Mr. M. Ahmer Aamer. Dated 4th June, 2017)

VI. RECOMMENDATIONS

It is simple to conclude, after reading the research findings, that businesses should take the CPEC route because it is very cost-effective and time-efficient. Production plants must receive raw materials on schedule and provide completed goods to consumers or clients in a timely manner. Only the supply chain management network's increased speed, effectiveness, and dependability make this feasible. Transporting commodities or products is a supply chain network's primary role. A good delivery system ensures that raw materials are delivered on time and finished goods are delivered to users or customers on time. Transportation thus plays a critical part in the supply chain network. Transportation mechanisms transport raw materials to the manufacturing site before moving finished products to users/customers. An effective transportation infrastructure allows for speedy, affordable, and efficient delivery.

VII. CONCLUSIONS

This study's primary goal is to determine whether CPEC will have an impact on travel times and transportation expenses. This study focused on delivery time and transportation costs in an effort to assess importance of logistics in supply chain management. Any supply chain network's base or backbone is thought to be logistics. As a result, it serves as both an inbound and outward transit mechanism. The most important and valuable aspects of transportation are freight costs and transit times. Every business organization aims to cut logistical expenses and delivery time. Every corporate entity desires less expensive transportation

services that deliver on schedule.

China is the biggest importer and consumer of products and services worldwide. These days, China sells goods worth billions of dollars. It thus advanced to the world's top level. The world's second-largest importer is China. China's main commercial partners are the destination nations chosen for this study. To meet its energy needs, China imports a lot of oil from eastern nations. Another quick, effective, secure, and dependable method is critically needed in China. This might reduce shipping expenses for China by billions of dollars. This study's primary goal is to ascertain how China's imports and exports are affected by the China-Pakistan Economic Corridor (CPEC).

Results show that avoiding these bottlenecks can save the supply chain billions of dollars in imports and exports. The CPEC route will undoubtedly reduce the distances and shorten the transportation time. Short routes automatically reduce shipping costs. According to the analysis, there is a positive effect on transportation costs for China's imports and exports. With the CPEC route, China can save a lot of money. Lowering the price of each import or export container lowers the overall price of Chinese goods. Lower transportation costs will lower the price of Chinese raw materials from other countries. As a result, cheaper raw materials are available for more expensive production. In addition to raw materials, electricity (oil) is also available at low cost. Also, Chinese buyers have to pay low shipping costs, which allows them to lower their purchase costs. Chinese products become more competitive in international/global markets by lowering prices and offering faster delivery dates. Research findings also show that China can save 9-10 days in total imports and exports to Europe. Also, China can reduce transit times on routes to Middle East countries. There is no doubt that CPEC will transform the region. This will help Pakistan and China but also other countries.

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Performance Enhancement of 5G Networks: Remodeling Power Domain Scheme Through NOMA- MIMO Technologies Integration

Umer Shafie Bhatti

umer.shafie@ptclgroup.com

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Abstract – In 5G mobile systems, Non-Orthogonal Light Acquisition (NOMA) and Multiple End-to-End (MIMO) technologies must overcome numerous obstacles, including space limitations, connectivity restrictions, and the requirement for increased reliability. It is vital to concentrate on enhancing and reconsidering criteria of BER, SE, average power rate and potential for a link transmission error in order to boost performance in 5G networks using MIMO. Phase modulation was accomplished in a few frequency channels by the suggested model, which took into account input power, bandwidth, transmission power, and signal-to-noise ratio. Following an evaluation of the model's efficacy, the results showed superior performance over earlier research. The transmission findings demonstrate that MIMO-NOMA enhances the critical user's bit error rate and transmission power. The average active rate was used to determine link transmission outcomes. Furthermore, in both uplink and downlink scenarios, with and without MIMO, NOMA's BER, SE, average power rate & failure probability was assessed. Study discovered that MIMO-NOMA installation significantly improved performance for all users.

Keywords – MIMO, NOMA, 5G Networks, BER.

I. INTRODUCTION

- Background

Wireless transmission has undergone a significant technological revolution during the previous several decades. Future wireless communication networks must be cost-effective, able to support a high user density, demand connectivity, and provide extensive coverage. The transition across several generations has altered people's lifestyles. Cellular networks have undergone a revolution in recent years, moving from first generation (1G) to fifth generation (5G) and beyond (5G) networks. Data rates for voice communication on 1G are measured in kilobits per

second (Kbps), whereas data rates for highly interactive multimedia applications on 5G and beyond fifth generation can reach gigabits per second (Gbps).

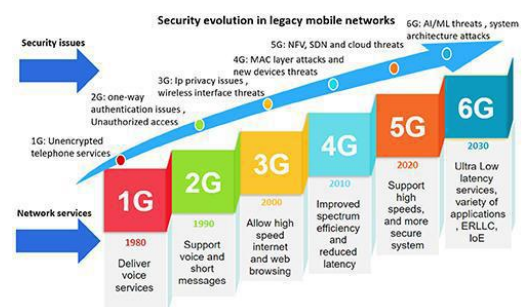


Fig 1: Evolution

In order to surpass the limitations of 5G, we must discover innovative technological approaches that lower costs while increasing spectrum efficiency and energy efficiency. Multiple access systems play a crucial role in addressing these issues in certain ways. When users use network resources, orthogonality assigning frequencies, time slots, or codes to each user to ensure that there is no interference. (Kalra and Chauhan, 2014) [1].

Inherent benefits of NOMA technology include, but are not limited to, high cell-edge throughput, better spectrum utilization, and reduced dependence on accurate channel state information feedback, and low end-to-end latency. This is because it is able to support several users simultaneously within the same frequency resource and with the use of successive interference suppression. The need for large-scale interconnection is provided, this is encountered as it can accommodate a large number of clients at a given time but at the same time, a specific time for information exchange of information transmission is strictly provided to lower the possibility of delays in exchange of information. Due to the reason that NOMA is able to adjust the power level of powerful users over that of powerless users, uniformity of methods and different levels of correctness are achieved and maintained. (Ahmad, 2016) [2].

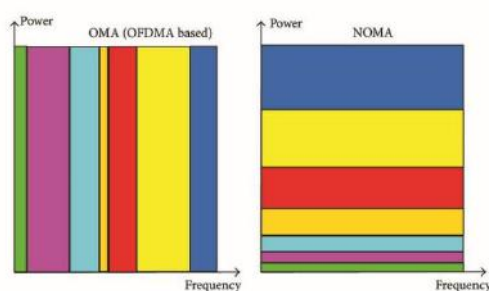


Fig 2: OMA Vs NOMA

NOMA has drawn lot of interest as a multiple access technique for LTE systems. Multiple uses of NOMA are now being investigated by the third-generation collaboration project (3GPP). In order to reduce inter-cell interference (ICI), network-assisted interference

cancellation and suppression (NAICS) was expanded to include NOMA in LTE Release 12 (3GPP, 2014) (Chen et al., 2018) [3]. Another vital but difficult duty in NOMA is interference management. Using effective resource allocation systems, networks can be optimized in terms of user coverage and throughput (Vaezi et al., 2019b) [4].

NOMA was thoroughly examined by Lu et al. (2017) [5 - 8], who covered its foundational ideas, contemporary advancements, and prospective research prospects. They thoroughly evaluated the spectrum efficiency, system performance, and receiver complexity of several NOMA designs and made an information theory comparison between NOMA and OMA. In order to address those difficulties, they also highlighted difficult open problems, put up solutions, and recommended potential future research topics.

Two methods that increase 5G capacity are NOMA and tiny cells [10]. The employment of NOMA in conjunction with a useful resource can increase spectral efficiency.

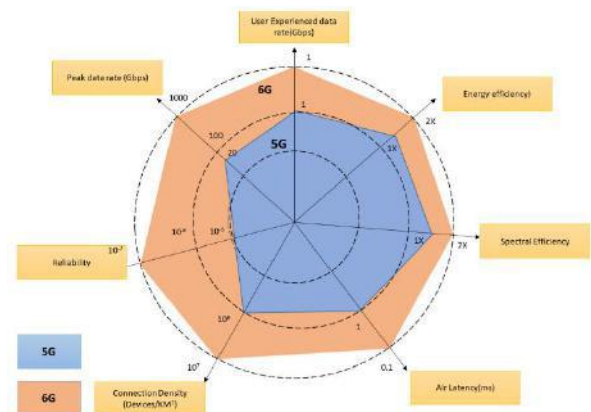


Fig 3: 5G & 6G Performance [24]

New operational frequency bands, MIMO, mmWave (Millimeter Wave), and NOMA are some of the additional improvements included in 5G [11].

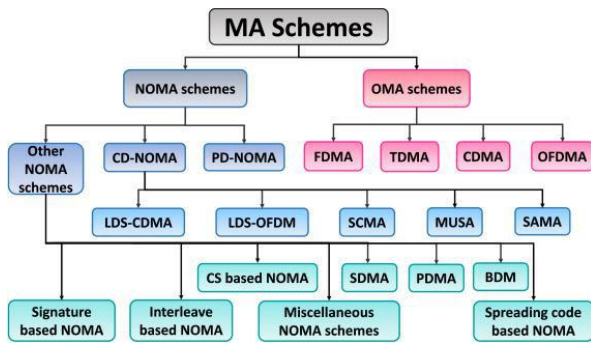


Fig 4: MA Schemes

- NOMA B5G (Beyond 5G) and 6G Systems: Applications

Human lifestyle has altered as a result of technology. People are continuously looking for innovative answers to a wide range of issues and seeking new routes for advancement. Wireless communication has progressed from 1G to 5G as a result of people's aspirations. This evolution hasn't halted yet, though. To build 5G and B5G (Beyond 5G) connectivity, researchers are working very hard.

The rising demand for additional devices and greater data rates are the main drivers of ongoing advancement in wireless technology (Benisha et al., 2019) [12]. However, because there is not enough spectrum to meet these requests, congestion is getting worse every day. The current generation of networks—1G, 2G, 3G, and 4G—cannot guarantee continuous connectivity.

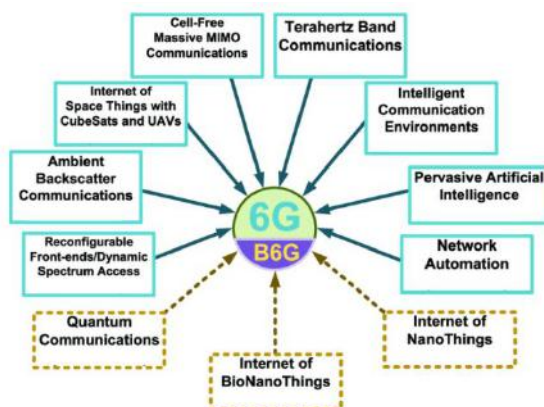


Fig 5: Enabling Technologies [25]

Need for data rates & connection has increased due to the users' exponential growth. Utilizing cutting-

edge technical trends like NOMA-assisted BS, these needs can be satisfied. Numerous obstacles must be overcome for NOMA's resource use to be efficient.

Fifth-generation (5G) mobile communication technology is now used by millions of people and is now extensively available in many countries. Therefore, it is now important for business and academia to focus on the next generation. The upcoming B5G apps will have more demand than the current 5G networks and a larger network capacity. As a result, more network capacity will be needed for new 6G applications. One of the key elements of our future way of life, economic sectors, and social structures will be next-generation wireless networks. In order to achieve a unified goal, the scientific community and industry should enhance these networks (Goyal et al., 2019) [13].

Due to the requirements of modern apps, the future generation of wireless networks should accomplish a number of goals to support these applications' QoS. By 2030, we can assume that the wireless networks will need to accommodate the next evolution's increased needs.

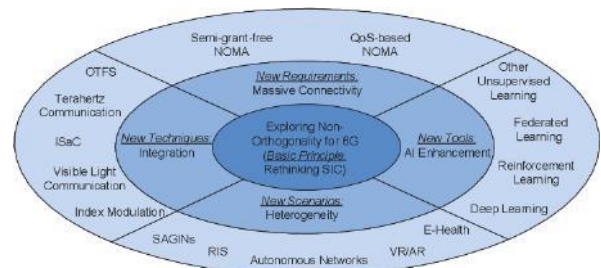


Fig 6: NOMA Applications - B5G [26]z

It is anticipated that there will be many new application opportunities in the future up to 2030 and these can be grouped into three broad areas as follows [14].

- Smart Production

B5G will use information technology to accomplish intelligent manufacturing. Drones, for instance, are used in agriculture. Virtual reality and robotics will increase production effectiveness. Digital twins and other cutting-edge technologies will

significantly increase the impact of intelligent manufacturing in B5G.

- Smart Life

Network of twin bodily areas in 2030, online synesthesia and intelligent interaction are expected to change how we live.

- Smart Society

Due to the ubiquitous availability of the coverage network, public service coverage will noticeably increase by the year 2030. By guaranteeing that all regions have equal access to digital services, this expansion seeks to close the regional digital divide.

Fig. shows the new 6G network scenarios.

Tab 1: Beyond 5G/6G [15]

	5G	Use Cases	6G	Use Cases
Data Rate	1 – 10 Gb/s	Telemedicine	100 Gb/s – 1 Tb/s	3D holographic AR/VR Robotics Arm
Coverage Extension	0.1 km	The limited scale of IoT network	3D coverage scenarios (10000 m (Sky, 200NM (sea)	Terrestrial, aerial, space and sea domain, massive-scale IoT network
Power Consumption	10 years battery life	IoT devices	50 times improvements compared to 5G, nearly (1 ThJ)	Wearable user devices Zero energy devices
End-to-End Latency	1–5 ms	Vehicular Networks Military Services	< 1 ms	Healthcare Networks AR/VR Unmanned Aerial Vehicle (UAV) Robotics Arm
Reliable Communication	99.9%	Vehicular Networks Telemedicine	~ 99.9999%	Healthcare Networks AR/VR Unmanned Aerial Vehicle (UAV) Robotics Arm
Massive Connectivity and Sensing	1 millidevice/km ²	IoT devices	10 millidevice/km ²	Wearable user devices AR/VR IoT
Frequency Extension and Improved Spectrum	3 – 300 GHz	mmWave for fixed access	Up to 1 THz	mmWave Sub-6 GHz Exploration of THz bands (above 300 GHz) high-definition imaging and frequencyNon-RF (e.g., optical, VLC) spectroscopy localization
Mobility and speed supportive	500km/hr	Vehicular Networks	1000 km/hr	Terrestrial, space, sea, aerial, and airline

- NOMA & MIMO

Creating an energy efficient network incorporating non-orthogonal multiple access (NOMA) with massive MIMO, that assists in serving a large population of distant users and Internet of Things (IoT) devices, is necessary for speeding up the evolution of intelligent wireless systems of the future. This network must eliminate the complexity of networking and the transportation of information. However, such an energy related concern emerges in B5G communications with the aim of ensuring constant connection and provision of fast data transport among IoT gadgets.

MIMO, on the other hand, tends to increase the maximum data rates which may be achieved and is thus considered to be a very flexible technique by which capacity can be increased. MIMO and NOMA

where MIMO is interfaced with NOMA can deliver better capacity when compared to combination of MEMO - OMA [27].

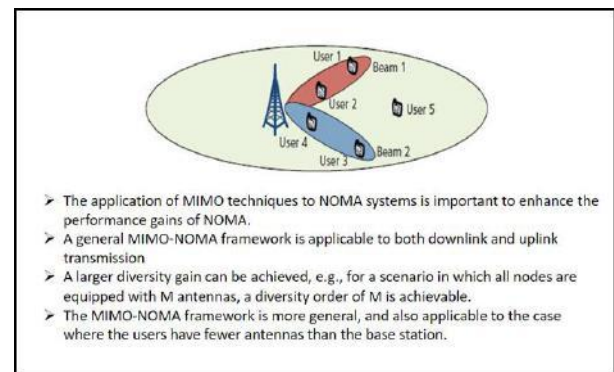


Fig 7: NOMA in Massive MIMO [30]

Researchers compared allocation methods for determining which was best for NOMA (MIMO-NOMA) technology [28]. Utilization of several antennas has been integrated into B5G naturally. Instead of being assigned to orthogonal time-frequency resources, users can be spatially multiplexed when there is an antenna array. Massive MIMO is a non-orthogonal multiple access method that results in interference leaking across beams if a spatial beam is directed at each user. MIMO technologies, such as spatial division multiple access, have been used for many years (SDMA). There is evidence, both theoretically and experimentally, that the broad adoption of Massive MIMO in B5G represents a paradigm change in terms of spectrum efficiency.

Modern communication networks can boost capacity without using excessive power or bandwidth by employing MIMO configuration. A viable solution to address the increasing needs appears to be combination of MIMO structure with non-orthogonal multiple access (NOMA) configuration [29]. Fig. below illustrates how the MIMO approach is used in B5G systems to represent NOMA.

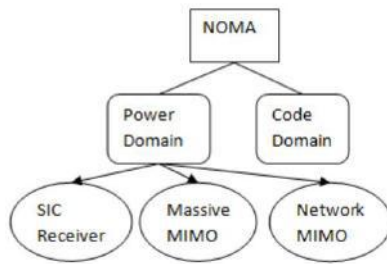


Fig 8: MIMO Techniques: NOMA in B5G - [31]

- AI applications for NOMA implementation

Mobile gadgets and new wireless applications are proliferating quickly in wireless systems. Next-generation wireless networks are heavily researching enhanced multiple access technologies. NOMA, one of these technologies, has come up as a promising technique and is considered as a crucial component of next-generation multiple access (NGMA) [16]. Significant interest in and evidence of considerable promise for attaining extensive connection have been generated by the combination of NOMA with multiple-antenna technology [17] [18].

Beamformer-based NOMA and cluster-based NOMA are two primary types of multiple-antenna NOMA algorithms now in use. The beamforming and successive interference cancellation (SIC) designs of these techniques are what set them apart the most. In BB-NOMA, SIC is used to reduce any remaining spatial interference after each user receives a beamforming vector. When consumers have low channel correlations, SIC usage also becomes troublesome. Contrarily, CB-NOMA groups users into clusters, often with the same number of clusters as radio frequency (RF) chains. Contrary to BB-NOMA, CB-NOMA lowers expenses by performing SIC sequentially within each cluster while providing each cluster with the same beamforming vector. According to CB-NOMA, users can be classified into a number of ideal clusters, each of which include users who are highly correlated with one another while being less correlated with one another. Due to channel unpredictability, this ideal presumption might not always be true.

Despite the potential advantages of next-generation

multiple access (NGMA), interference suppression and system optimization are made difficult by the complexity of multi-domain multiplexing.

- To transform non-convex issues into solvable convex problems, they rely on complex mathematical transformations and specialized knowledge.
- The initialization parameters for these approaches must be carefully configured for various contexts using labor-intensive hand-engineered designs because they have a significant impact on how well they operate.
- They frequently necessitate numerous cycles to reach convergence, leading to unmanageable computing complexity, particularly in circumstances involving overload or multi-cell networks.

These difficulties make it difficult to use conventional convex optimization techniques effectively in next-generation NOMA systems.

Fortunately, recent developments in artificial intelligence (AI) have made it possible for automated communication designs to address the complexity, opening up new avenues for overcoming the problems listed above [19] to [22]. This has inspired encouraging research into using cutting-edge ML techniques to improve NGMA through AI - ML is still in infancy, even if prior research has established a solid foundation for communication designs using multiple-antenna NOMA. The illustration below shows how AI/ML is applied during planning stage:

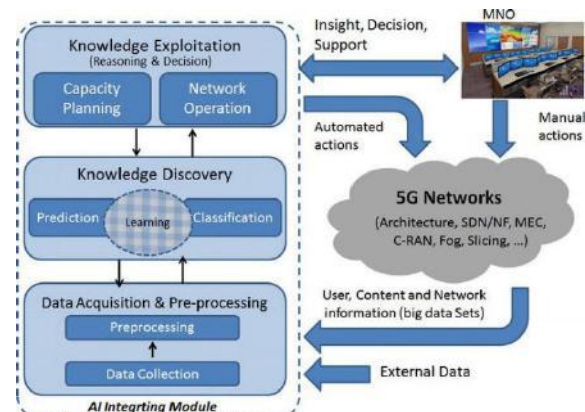


Fig 9: Integration of AI - ML [32]

AI can train deep neural networks (DNNs), which can then use their exceptional function-fitting capabilities to roughly answer complicated problems. AI allows for the automatic learning of high-quality communication designs from data without the need for specialist knowledge or human initialization of parameters, which is occasionally required by traditional optimization techniques.

Automation of the parameters and learning process is essential for next-generation wireless systems, which feature great time-variability and cover a variety of applications. The learning model's neural network design ought to be flexible and capable of self-configuring for different situations. The new AutoML paradigm [23] should be integrated to improve machine learning-based communication design, minimizing the need for human interaction and increasing performance, in order to accomplish automatic construction of learning models [23]. NAS makes it possible for learning models to automatically optimize hyper parameters and neural architectures. In order to support next-generation mobile and wireless communication systems and meet the needs of various application situations, these ML approaches can be added as new modules.

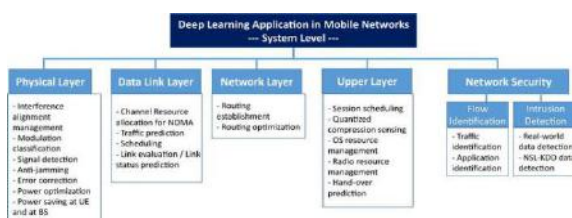


Fig 10: Deep Learning Applications [33]

Research into Next-Generation Mobile and Wireless Communications (NGMA) with AI support is still in its infancy. Here are a few unresolved research questions in this area:

- Machine Learning for NGMA.
- Dynamic Multi Objective Optimization in NGMA Using ML:

It can be difficult to forecast how the Pareto optimal front will vary as wireless surroundings change over time. This is

because the optimal objectives and constraints may also change. It is necessary to look at effective multitask machine learning techniques in order to enable dynamic multi-objective optimization in NGMA.

- NGMA Automated Machine Learning (AutoML) Acceleration:

While back-propagation-based machine learning can effectively predict desirable solutions, the training process frequently necessitates a large number of data samples and places a heavy computing burden on the system. The training procedure becomes significantly more time-consuming and computationally costly when AutoML techniques like meta-learning and neural architecture search (NAS) are used.

In conclusion, major research paths to solve outstanding difficulties and promote AI-enabled NGMA communication design include the development of model-based constrained machine learning, dynamic multi-objective optimization approaches, and effective AutoML techniques.

Problem Statement

MIMO and NOMA integration technologies in a hybrid technology environment should solve many problems in 5G and B5G mobile systems, which have high connectivity problems, limited space and reliability. User performance is degraded due to channel interference and fading, and eventually the connection is broken due to these interferences. MIMO and NOMA technologies can be combined to develop a hybrid solution that can address many of the challenges facing 5G and beyond. By increasing the number of antennas and bandwidth without improving the weak conditions, it is possible to reduce the performance in the 5G network. As a result, it is possible to increase the BER, decrease the spectral efficiency (SE), decrease average power rate, and increase uncertainty (OP) for the upstream and downstream connections.

Research Objectives

- Designing of an integrated hybrid technologies based network architecture.
- Designing a network for large connectivity, having low latency with high dependability by proposing a network model with enhanced performance with MIMO-NOMA implementation solving near/far user's problems.
- Improving BER, SE for DL, average capacity rate & outage probability (UL) in B5G network utilizing MIMO.
- Evaluation of DL NOMA's BER and SE performance.
- Examining uplink NOMA's bandwidths, SNR and distances.

Research Questions

- Can a network architecture be designed based on hybrid technologies with MIMO and non-orthogonal multi-input?
- Can network design with high connectivity, low latency, and high reliability can be provided by providing a network model with better performance using MIMO-NOMA to solve internal/external user problems?
- How to improve BER, SE (DL), Average Capacity and Loss Probability (UL) in B5G networks using MIMO?
- Can we analyze the correlation of BER reduction and SE performance?
- How can the average power rate and possible NOMA function be examined for varying signal-to-noise ratios, platforms, and distances?

Significance of Research

B5G networks, this architecture tries to offer high reliability, low latency, and huge connection. The suggested network model improves performance and tackles concerns with near/far users by utilizing MIMO-NOMA. Overall goal is to integrate MIMO

and NOMA technologies to effectively improve the performance and dependability of B5G networks.

Literature Review

Wireless Communication

Non-orthogonal multiple access (NOMA) [34,35], a promising strategy, has been suggested to fulfill the required aims of retaining spectral efficiency and permitting mass accessibility [36,37]. Signal reception in the presence of noise is made possible by NOMA, which uses receiver-based sequential interference cancellation (SIC) techniques to control the power levels [38-41].

- NOMA

NOMA is able to support extremely large connections while significantly reducing transmission delay [42 - 44]. Need of the current wireless environment can be satisfied by NOMA [45, 46], a wireless technology. The evaluation of various access technologies is still developing [47]. Since all features are constantly being produced, the primary leading research group is attempting to determine the efficiency of the spectrum [48,49].

Channel characteristics of other users statically define the interference [50-52]. The BS uses successive interference cancellation (SIC) algorithms to decode the communications in order to reduce this interference. The receiver BS must receive distinct message signals with adequate intensity variance in order for the SIC method to function well. Utilizing various power levels at the transmitter is normally how downlink (DL) signal separation is managed. Such power level changes are not necessary in UL NOMA, though, as the UL channel gains already adequately separate signals. In actuality, the transmit power is optimized by the UL's power control system based on the channel conditions. It is not advised to employ UL NOMA in broadcast scenarios including power regulation since it could make channels less distinct and lead to uneven received signal levels among users. [53-57].

- MIMO

MIMO can manage many independent channels in

the same bandwidth yet has separate antennas [58–61]. In [62, 63], three power distribution methods are presented to enhance the power allocated to each NOMA. Nevertheless, only a small amount of transmitted symbols is offered to each user, which could produce false results. To guarantee optimum performance, the ergodic rate obtained is monitored and examined for performance of the pre-detection and encoder systems that make it easier to decode the DL and UL signals in the dual receive channels.

- **Bandwidth, Average Capacity Rate, Outage Probability, BER & SE**

The researchers demonstrated the vulnerability of the network to Rayleigh fading. This study used modeling techniques to examine different system designs. Specifically, the researchers proposed and investigated multiple bandwidths (BW) in the context of a non-orthogonal multiple access (NOMA) system based on an alternating channel. When supporting system users, combination of NOMA and MIMO shows significant improvements [93].

II. RESEARCH LITERATURE

- **MIMO-NOMA Performance**

The successful precoding and detecting techniques developed by the author in [65-66] allow for the realization of NOMA's potential despite similar beginning channel conditions among users. As a result, there are noticeable variances in effective channel gains amongst users. Investigating how MIMO-NOMA performed with several users clustered together. According to the results in [67], MIMO-NOMA performs better than MIMO-OMA. Additionally, [63] used statistical channel state data from transmitter to investigate the maximization problem of ergodic capacity in selective Rayleigh fading MIMO-NOMA systems. According to the research, MIMO-NOMA approaches perform noticeably better than the conventional OMA scheme. In order to evaluate the effectiveness of NOMA downlink integrated with MIMO in practical settings, an experimental investigation was carried out in [68]. Initially, the combination of NOMA downlink and

MIMO was thought of as an idea for user connectivity in the uplink (UL). The study looked at and took into account a number of power allocation strategies as described in [69]. In addition, the author studied a variety of NOMA uplink (UL) and downlink (DL) communication systems [70-72]. For NOMA DL and UL systems, analytical formulations for the outage probability (OP) were created, especially in conditions with high signal-to-noise ratios (SNRs) [95].

- **Correlation Similarity for NOMA Effectiveness**

Experts from across world have begun examining how to apply the NOMA principle to different generation. Majority of initial studies on NOMA relied on single integrated version (SISO), with primary concerns being power distribution and user accuracy [73, 76, 77, 78].

- **Combining MIMO and NOMA**

Since a thorough search is required, finding the ideal user pairing is not easy. Random pairing is used in [79] to reduce the computational cost. Additionally, a greedy user pairing method is suggested in [80 - 83] to provide performance that is close to ideal, based on the channel correlation and gain difference.

The research was restricted to a single-cell system. Inter-cell interference (ICI) is a significant barrier in multi-cell networks, where researchers have just begun to look into the performance of NOMA in these networks. In a two-cell MIMO-NOMA network, there are two ways to deal with the ICI. In [84], synchronized beamforming strategies are suggested [85-86].

III. RESEARCH METHODOLOGY

The goal of this project is to develop an integrated network architecture using MIMO and NOMA. This design will leverage MIMO-NOMA to address distant and exterior issues, as well as a network model that prioritizes high connection, minimal area, and high dependability. user. MIMO enhances the B5G network's BER, downlink SE, average rate capabilities, and UL operation. The performance of 64

x 64 MIMO, DL and uplink UL, NOMA PD technologies in a 5G network was evaluated. They evaluated the performance of BER and SE in DL NOMA with various factors, including distance, local power coefficient, transmission power, and bandwidth. Average power and OP performance in UL NOMA were investigated at various distances, SNRs, and bandwidths. The results revealed that using 64x64 MIMO technology improves BER and SE performance in DL NOMA, hence decreasing the near-user problem. Furthermore, as compared to DL NOMA without MIMO, all users perform similarly at various transmission locations, distances, and power coefficients.

- Methodology

NOMA systems serve a large number of users by generating many beams from a single carrier. This approach incorporates a two-stage beam forming solution that makes use of modular beam forming vectors. In addition, a simpler transmission packet shaping problem is constructed to determine the power and packet-shaping vectors of each user. Certain authors have developed successful precoding and detection approaches that result in a large difference between users' effective channel gains.

Researchers tested the effectiveness of combining NOMA in the downlink (DL) with multiple-input multiple-output (MIMO) in conditions that were realistic, offering helpful insights into the theory. Additionally, NOMA in the uplink (UL) was examined while taking into account different power allocation strategies.

A NOMA network with UL and DL broadcasts that was aided by an unmanned aerial vehicle (UAV) was also the subject of research. In order to increase fairness and application, analytical formulations for the OP were generated, and a novel UL/DL NOMA system that combines statistical channel state information was proposed.

Another approach examined effectiveness of several NOMA techniques over delay line channel, taking into account both slow and fast UE speeds as well as

correlation-level modeling, with the goal of detecting correlation similarities. The results showed that NOMA approaches behaved differently when UE was operating at regular and rapid speeds.

- Methods

• DL Scenario

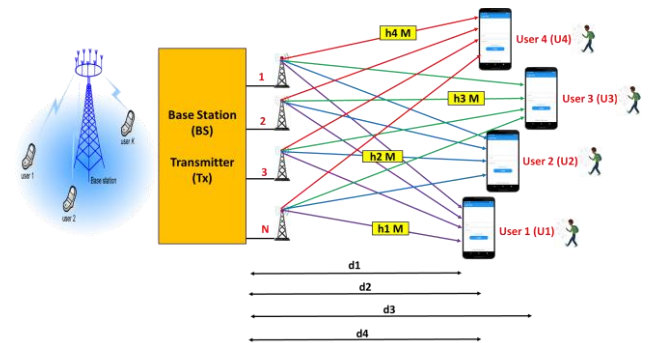


Fig 11: Users 64 x 64 MIMO-DL-NOMA PD

Table 2: Design Parameters

S/No	Design Parameters	Notation
1	Bandwidth	80 MHz, 200 MHz
2	Users (4 Users)	U1, U2, U3, U4
3	Distance of Users from the Base Station (BS)	d1, d2, d3, d4
4	Rayleigh Fading Coefficients	hT1, hT2, hT3, hT4

Users' distances, from base station are different, depending on how close or how far they are from it.

Table 3: Design Formulas (DL)

S/No	Description	Formula	Reference
1	* Total Rayleigh fading channel (each user)	$h_{Tj} = \sum_{i=1}^M h_{Ti}$	[87]
2	* Base Stations Encoded Overlay Signal	$x = \sqrt{P}(\sqrt{a_1}x_1 + \sqrt{a_2}x_2 + \sqrt{a_3}x_3 + \sqrt{a_4}x_4)$	[88 - 89]
3	* U Rate R1	$R_1 = \log_2 \left(1 + \frac{a_1 P h_{T1} ^2}{a_2 P h_{T1} ^2 + a_3 P h_{T1} ^2 + a_4 P h_{T1} ^2 + \sigma^2} \right)$	[88]
4	* U Rate R2	$R_2 = \log_2 \left(1 + \frac{a_2 P h_{T2} ^2}{a_3 P h_{T2} ^2 + a_4 P h_{T2} ^2 + \sigma^2} \right)$	[88]
5	* U Rate R3	$R_3 = \log_2 \left(1 + \frac{a_3 P h_{T3} ^2}{a_4 P h_{T3} ^2 + \sigma^2} \right)$	[88]
6	* U Rate R4	$R_4 = \log_2 \left(1 + \frac{a_4 P h_{T4} ^2}{\sigma^2} \right)$	[88]
7	* Spectrum Efficiency	$SE = \frac{T_b}{BW}$	[88]

BW = Bandwidth

OP = Outage Probability

r = User with different target rates ($r_1=1, r_2=2, r_3=3, r_4=4$)

C = Capacity of users with different target rates.

C_1 = Capacity of user 1 with specific target rate.

C_2 = Capacity of user 2 with specific target rate.

C_3 = Capacity of user 3 with specific target rate.

C_4 = Capacity of user 4 with specific target rate.

P_i = Outage Probability

N = Number of Transferred Samples

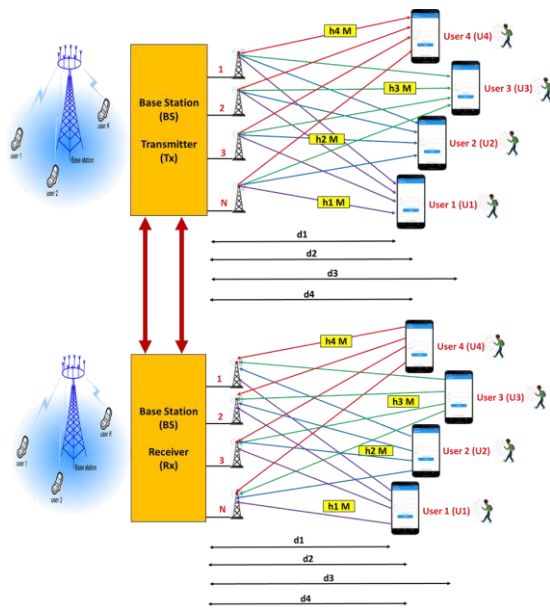


Fig 13: 4 Users 64 x 64 MIMO-DL-UL-NOMA PD

Simulation Parameters

Simulation variables were integrated using MATLAB.

Table 5: Parameters DL

S/No	Parameters	Values
Downlink Scenario		
1	No of Users	4
2	Transmit Power	0 to 40 dBm
3	B/W	BW1 80 MHz BW2 200 MHz
4	Distances	User 1 900 m User 2 700 m User 3 400 m User 4 200 m
5	Power Coefficients	User 1 0.843 User 2 0.219 User 3 0.062 User 4 0.022
6	Path Loss Exponent	4
7	MIMO	64 X 64
8	Modulation	QPSK

Table 6: Parameters for Uplink (UL)

S/No	Parameters	Values
Uplink Scenario		
1	No of Users	4
2	Transmit Power	-30 to 30 dBm
3	B/W	BW1 80 MHz BW2 200 MHz
4	Distances	User 1 900 m User 2 700 m User 3 400 m User 4 200 m
5	Path Loss Exponent	4
6	MIMO	64 X 64

IV. RESULTS ANALYSIS

- Downlink

- Improved bit error performance (BER).
- Better performance based on spectral efficiency (SE).
- Fixed close user issue

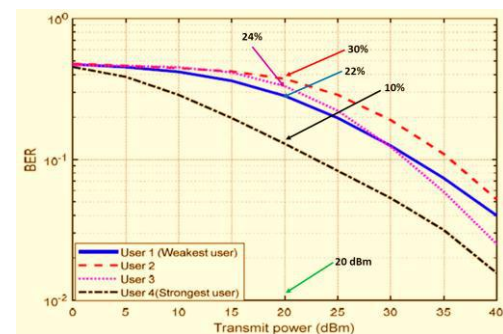


Fig 14: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth

As seen;

- The performance of BER decreases with increased transmission power.
- U4 offers the finest BER performance for all customers because it is the closest.
- At 20 dBm transmitter power, BER rates (U1, U2, U3, & U4) are 22.0%, 30.0%, 24.0%, & 10.0%.

Fig below compares performance against transmitted power.

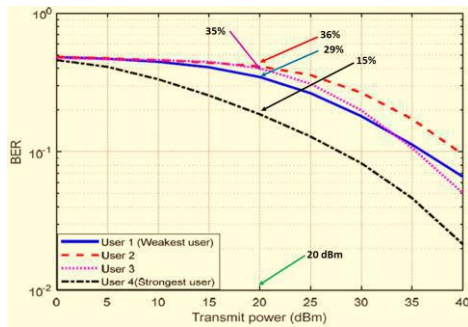


Fig 15: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth

The results found that;

- Because of its close proximity to the base station, U4 performs best among all users in terms BER.
- BER rates for U1, U2, U3, and U4 are 29%, 38%, 35%, and 15%, respectively, for a transmission power of 20 dBm.
- With a transmission power of 40 dBm, U4, the top-performing user in the 64x64 MIMO downlink (DL) NOMA system, enhanced its BER performance from $10^{-1.48}$ to $10^{-4.93}$ at a 200 MHz BW and from $10^{-1.68}$ to $10^{-5.1}$ at an 80 MHz BW.
- Furthermore, U4's SE rose by $8 \times 10^{-2.9}$ bps/Hz for 80 MHz BW and by $10^{-1.9}$ bps/Hz for 200 MHz BW at a transmission power of 40 dBm.
- The OP for 80 MHz BW at SNR of 1 dB dropped by $14 \times 10^{-2.9}$ in UL NOMA systems employing 64x64 MIMO, while the average capacity rate increased to 11 bps/Hz.

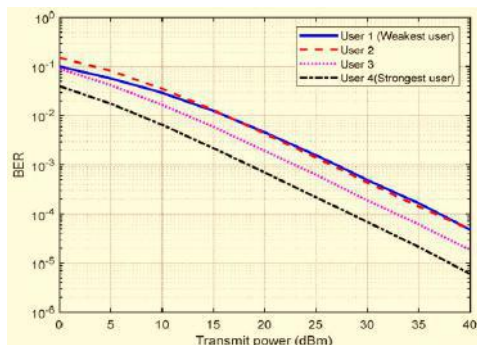


Fig 16: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

As can be seen, MIMO system improves BER efficiency.

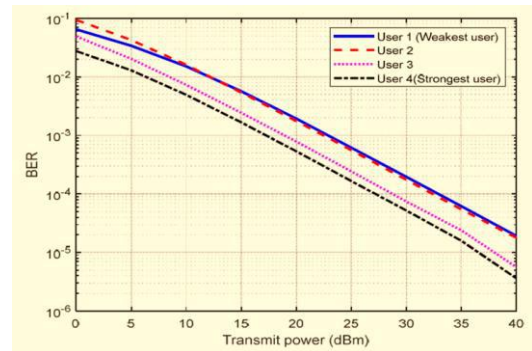


Fig 17: BER vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth with 64 x 64 for DL NOMA

Ideal performance (SE) of transmission power and NOMA with an 80 MHz bandwidth is displayed in Figure. The outcomes demonstrate enhanced transmission power and SE performance. User U4 attains the best bit error rate (BER) in comparison to other users because they are the closest user. There is a 5 dBm transmission power difference in each user's SE performance.

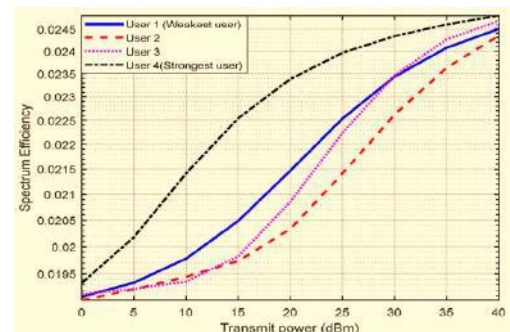


Fig 18: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 80 MHz Bandwidth with 64 x 64 for DL NOMA

The SE will perform better and increase the transmission power. Notably, given its close proximity to other users, user U4's SE performance is the most amazing. Additionally, the outcomes show a BER improvement rate of $10^{-2.2}$, outperforming the top user U2.

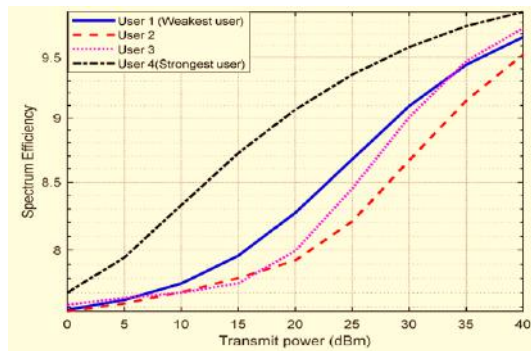


Fig 19: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) DL NOMA at 200 MHz Bandwidth for DL NOMA

In Fig, SE is close for all users @ 5 dBm.

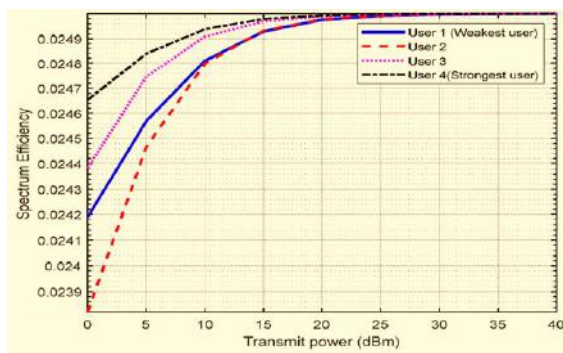


Fig 20: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for DL NOMA

SE has improved as a result of MIMO.

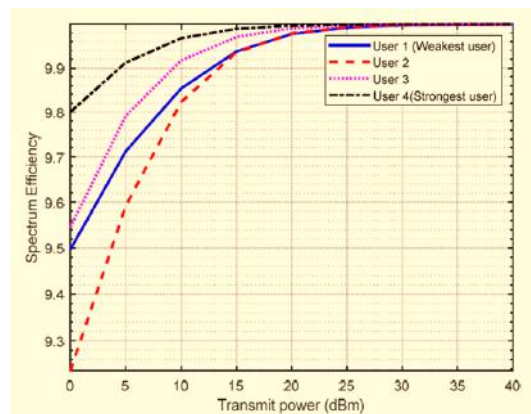


Fig 21: Spectral efficiency (SE) vs Transmitted Power (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for DL NOMA

UL Results & Discussion

Average capacity rate vs signal-to-noise ratio (SNR)

for an 80 MHz bandwidth is shown in Fig 4.9. As a result of being the nearest user, U4 achieves the highest average capacity rate of all users. Specifically, 1.6873, 2.8718, 6.4960, and 12.7814.

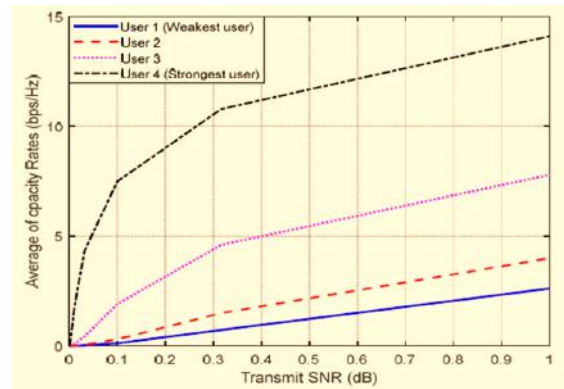


Fig 22: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Figure show improvement in the average power rating occurs with increasing SNR values. Improvement in average performance rate of 11 bps/Hz when 64x64 MIMO setup is used. As a result of this enhancement, user U4's outage probability (OP) at 200 MHz bandwidth and 0.18 dB SNR was reduced by a factor of $11 \times 10^{-2.9}$. In a similar vein, the OP was reduced by a factor of $14 \times 10^{-2.8}$ at an 80 MHz bandwidth and 1 dB SNR. Both average capacity rate and BER increase at the same time. Using MIMO significantly increases throughput for each user.

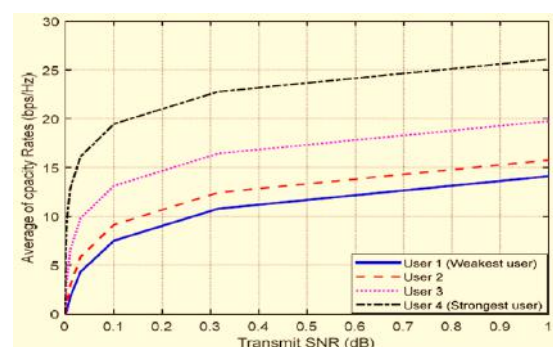


Fig 23: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

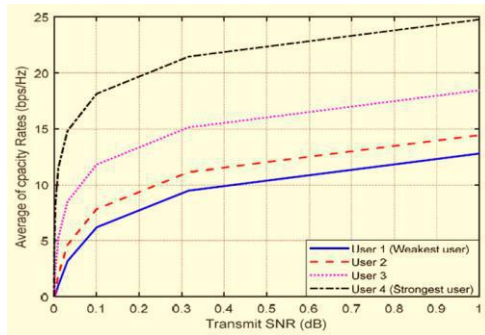


Fig 24: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Average capacity rate performance improves with increasing SNR. Data collected at 1 dB SNR for four users revealed the following values: 14.0921, 15.7563, 19.7586, and 26.1820, in that order. U4 performs best at average capacity rate.

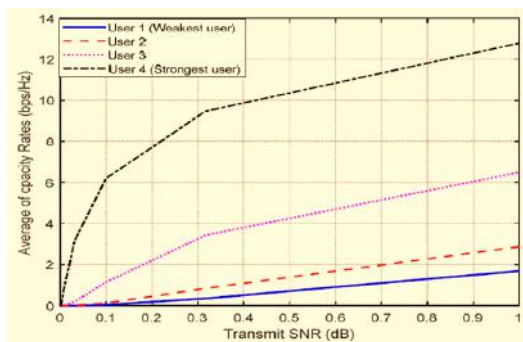


Fig 25: Average Capacity Rate vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

The relationship between OP and SNR for uplink UL NOMA is depicted in Figure, which shows the 80 MHz bandwidth plot. The OP values at SNR of 0.169 dB are shown for U1, U2, U3, and U4.

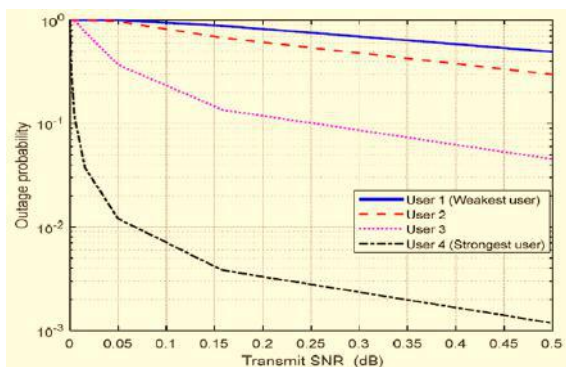


Fig 26: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 80 MHz Bandwidth for UL NOMA

Results show that the OP performance decreases with increasing SNR.

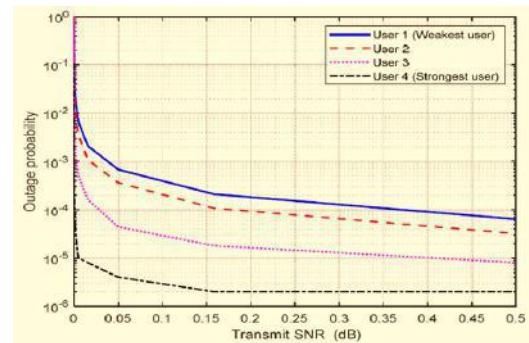


Fig 27: OP vs SNR (4 Users, Varied Distances & Power Coefficients) and 200 MHz Bandwidth for UL NOMA

With 64 x 64 MIMO, UL NOMA of OP vs. SNR is 80 MHz BW. At SNR of 0.169 dB, the findings for U1, U2, U3, and U4 are 0.0061, 0.0026, 0.0002 & 0.0001.

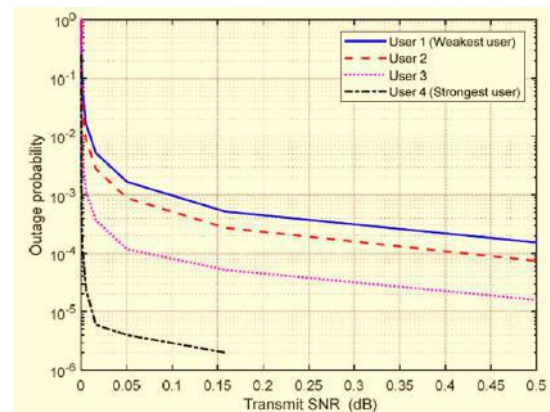


Fig 28: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 80 MHz Bandwidth for UL NOMA

Findings demonstrate negative relationship between two variables, with OP performance declining as SNR rises. OP lowers with increasing bandwidth, and system optimized with MIMO approach, OP drops. OP performed better.

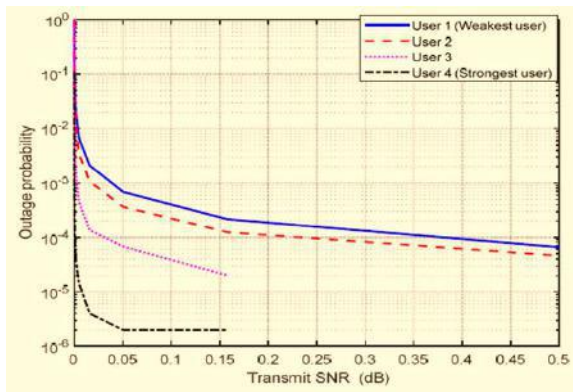


Fig 29: OP vs SNR (4 Users, Varied Distances & Power Coefficients) with 64 x 64 MIMO and 200 MHz Bandwidth for UL NOMA

V. CONCLUSIONS

- Checking and analyzing BER and SE for different distances of DL NOMA, power input coefficients.
- Power rate and performance of OP UL NOMA were investigated for various distances, SNR & BW.
- Results of the DL NOMA system showed that the use of 64x64 MIMO improves the BER and SE performance and solves the near-user problem, where each user's performance approaching the work of other users.
- Power transmission, distance, and power distribution are only a few of the metrics that differed between MIMO DL NOMA and non-MIMO. For best-performing user, U4, MIMO DL NOMA 64x64 system showed the best bit error rate (BER), improving from $10^{-1.7}$ to $10^{-5.2}$.
- User U4's performance increased by 0.8% bps/Hz for an 80 MHz bandwidth and by 1.01% bps/Hz for a 200 MHz bandwidth at 40 dBm transmission power in terms of spectral efficiency (SE).
- The results indicated an increase in average power rate for uplink (UL) NOMA systems using 64x64 MIMO, with the best user U4 reaching an increase of 12 bps/Hz. In

addition, for 200 MHz bandwidth at 0.17 dB SNR and 80 MHz bandwidth at 1 dB SNR, the outage probability (OP) was decreased by 0.0120 and 0.0150, respectively.

- While BER and average power rate increased, SE and OP decreased as the bandwidth was raised.
- MIMO improves SE performance per-user considerably.

The suggested model includes two bandwidths (80 and 200 MHz), 4 users with various power location coefficients, QPSK modulation, selected frequency Rayleigh fading channels, SNR, and transmit power. The performance of proposed model is assessed using MATLAB software. Results demonstrate MIMO-NOMA enhances the best user's BER performance in comparison to transmitted power in the DL domain.

The strength of the UL was assessed at 80 and 200 MHz BW, average power rating, and OP vs. SNR. For the ideal user (U4) at SNR 1 dB 11 bps / Hz, the MIMO-NOMA model findings indicated a decrease in OP and an increase in average energy rate.

It was found that the suggested network model – which makes use of MIMO-NOMA – was more effective at resolving problems that both indoor and outdoor users encountered. According to the study, MIMO enhanced B5G networks' bit error rate, average power rate, sub-spectrum efficiency, and redundancy. It also assessed the spectral efficiency and bit error rate in the NOMA downlink at various bandwidths, transmission powers, and transfer coefficients. The average power performance and failure risk at various distances, signal-to-noise ratios, and bandwidths were also examined in the study.

MIMO and NOMA technologies are combined to overcome many obstacles in 5G and B5G mobile networks, such as large connectivity issues, less long and more reliable. Channel fading and interference can affect users' performance and may cause their connections to drop. Current

literature focuses on how the use of MIMO in B5G can improve and re-evaluate key parameters to increase network performance, such as BER, SE) in DL, average energy density and probability of death (OP) in UL.

VI. FUTURE RESEARCH

The potential synergies between MIMO cooperative NOMA and cognitive radio were not explored in this work. To improve network performance, this topic can be researched upon in future.

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Maintenance Plan for a Heidelberg Vane Foiling Machine

Flores Sánchez Verónica¹, Espinosa Hernandez María Guadalupe², Juárez Vargas
Jesús Antonio ³, Vallejo Hernández Arely⁴

¹Department of IMI, Universidad Tecnológica del Centro de Veracruz, Veracruz, México

Email: calidad.utcv@gmail.com

²Department of CETis 164, Centro de Estudios Tecnológicos Industrial y de Servicios No. 164, Veracruz, México

Email: lesh1970@hotmail.com

³Department of CBTis 102, Centro De Bachillerato Tecnológico Industrial Y De Servicios No. 102, Veracruz, México

Email: antonio.juarez.vargas@hotmail.com

⁴Department of IMI, Universidad Tecnológica del Centro de Veracruz, Veracruz, México

Email: arely.vallejo@utcv.edu.mx

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Abstract— Preventive Maintenance Plan for a Heidelberg vane foiling machine. The machine's performance had decreased from 130,000 folios to 100,000 folios per 24 hours. This drop in efficiency impacted productivity, delivery times, and generated additional costs and client dissatisfaction. The primary goal was to restore and optimize the machine's performance by identifying the causes of the efficiency reduction and implementing necessary preventive maintenance. The object of this study is the Heidelberg vane foiling machine, a key asset in the foiling process that ensures high quality and production efficiency. The methodology follows a preventive maintenance approach, which includes visual and functional inspections, general and deep cleaning, component lubrication, and the replacement of worn or damaged parts. All activities were documented and performed according to manufacturer standards and industrial maintenance best practices. It is estimated that regular, comprehensive maintenance will increase the machine's performance and prevent future breakdowns

Keywords— Heidelberg, foiling machine, preventive maintenance, performance, productivity

I. INTRODUCTION

The company study case is a medium-sized printing company that holds the top position in sales and quality within its region. It was founded in 1984 by Mr. Martin Fernández Salgado and Mrs. María Eugenia Vázquez Ahumada. The company's mission is to provide high-quality, innovative, and sustainable printing solutions. Its vision is to be a leader in the printing industry, known for its innovation, quality, and commitment to sustainability.

The company's product offerings serve various sectors, including editorial, marketing, corporate, events, and government. The department responsible for foiling production has eight machines, including the Heidelberg foiling machine. The staff in this department includes machine operators, maintenance technicians, production supervisors, and quality control personnel. The primary product of this area is foiled material used in special finishes for packaging, cards, and labels. The company's main production process is centered on the processing of foiled material, and the Heidelberg foiling machine is

a crucial part of these operations. However, due to operating 15 hours per day, the machine tends to experience a breakdown approximately once every two months. This results in prolonged downtime of a week or more while waiting for an external technician to arrive for repairs. This challenge directly impacts the operational efficiency, which is currently at 83.33%, and the productivity of the foiling department, which produces 100,000 folios in 24 hours

Objective

Preventive Maintenance Plan for the Heidelberg foiling machine to improve operational efficiency to 90% and reduce the prolonged downtime to a maximum of two days, thereby ensuring the continuity of the production process.

Hypothesis

Conduct a preliminary inspection of the machine to identify critical areas that require maintenance.

Disassemble the machine to access its internal parts for a thorough review.

Analyze the key parts identified during disassembly to assess their condition and determine necessary maintenance actions.

Replace worn or damaged parts and perform the necessary adjustments to ensure the machine's correct operation.

Develop a preventive maintenance plan based on the findings from the machine's inspection and analysis.

II. JUSTIFICATION

Implementing a preventive maintenance plan is a crucial strategy to enhance operational efficiency and ensure production continuity. Preventing failures is more cost-effective than making repairs, which leads to savings on operating costs. Maintaining the machine in good condition also ensures product quality, which strengthens customer satisfaction and the company's reputation. Furthermore, it improves worker safety by reducing unexpected failures. The project aims to position the company as a model of efficiency in the foiling industry, which will improve its profitability and competitiveness. An efficient and productive company contributes significantly to regional economic development, creating stable jobs

and promoting environmental sustainability through the optimization of resources

THE PROJECT'S SCOPE INCLUDES THE FOLLOWING:

Operational Efficiency Optimization: The plan will ensure the machine's efficiency, reducing downtime and increasing productive capacity.

Personnel Training: Production staff will receive training in preventive maintenance, which will improve their technical skills and internal human resource management.

Operating Cost Reduction: Preventing failures will reduce the need for expensive repairs and dependence on external technicians, thus lowering operating costs.

Product Quality Improvement: Keeping the machinery in good condition will ensure that the foiled material meets quality standards, boosting customer satisfaction.

The project is grounded in various maintenance concepts and methodologies.

Condition-Based Maintenance (CBM) uses real-time data to evaluate equipment condition and predict failures. The

Failure Mode and Effect Analysis (FMEA) is a systematic methodology for identifying potential failure modes, their causes, and effects.

Predictive Maintenance (PdM) uses monitoring techniques and data analysis to predict when a failure will occur, employing tools like vibration analysis, thermography, and oil analysis.

Visual and Sensorial Inspection is a basic but crucial technique for identifying critical areas, involving direct observation for signs of wear, damage, or other anomalies.

Infrared Thermography detects temperature differences to reveal excessive friction or electrical problems. The

Manufacturer's Service Manual is an essential guide for specific disassembly and assembly instructions, diagrams, and safety precautions.

Other methodologies include

Procedure-Based Maintenance (PM), which focuses on standardized procedures for maintenance tasks , and

Disassembly and Assembly Analysis (D&A), which involves meticulously planning and documenting each step of the process. The

Tagging and Tracking Method labels each component during disassembly to ensure correct reassembly.

Reliability-Centered Maintenance (RCM) evaluates component functions and failure modes to prioritize critical parts for inspection. The

Analysis of Tasks and Procedures (TAP) breaks down disassembly tasks into detailed steps, including the necessary tools and safety precautions.

Further techniques and concepts include:

Reliability, Availability, and Maintainability (RAM) Analysis, Vibration Analysis for detecting issues in rotating components, Oil Analysis for evaluating lubricants and detecting internal wear, and Non-Destructive Testing (NDT) for assessing component integrity. The project also uses Life Cycle Analysis (LCA) to predict the remaining life of key components, and relies on.

Corrective and Preventive Maintenance strategies. The Total Productive Maintenance (TPM) methodology aims to maximize equipment efficiency by involving all employees in maintenance. Finally, the Six Sigma methodology is mentioned as a data-driven approach to improve process quality and reduce defects in maintenance.

Legal Framework

The project is guided by several applicable ISO standards:

ISO 9001: This standard ensures that preventive maintenance activities are planned, documented, and controlled to guarantee consistency and effectiveness.

ISO 14001: This standard helps integrate environmentally responsible practices, such as proper waste management and efficient resource use during maintenance activities.

ISO 12647 and ISO 16762: These are specific to the graphic arts industry. Preventive maintenance should include the regular calibration of color management systems as specified by ISO 12647 to ensure product quality and consistency. The plan

also follows the manufacturer's specifications as recommended by ISO 16762.

ISO 12100 and ISO 13849: These safety standards are fundamental. Adhering to ISO 12100 protects operators by ensuring safety design principles are followed, while ISO 13849 requires verification and maintenance of safety-related control systems to prevent accidents.

Manufacturer's Standards: The project emphasizes the importance of following the specific recommendations from the Heidelberg manufacturer, including recommended maintenance intervals, lubrication procedures, and adjustments.

III. METHODOLOGY

The research is applied and quantitative, with a focus on improving operational efficiency through a preventive maintenance plan. The methodology is inductive, deriving general conclusions from the analysis of specific data from the machine and its production environment.

Data was collected using the following operational techniques:

Direct Observation: Monitoring the machine's operation to identify failure patterns and critical areas.

Historical Data Analysis: Analyzing past maintenance and failure records to identify trends and common causes of breakdowns.

Surveys: Polling technical and production staff to gather information on machine use, failure frequency, and current maintenance practices.

Analytical tools included:

SWOT Analysis: To evaluate the current state of the machine and the production department.

Pareto Chart: To identify and prioritize the most frequent failures.

Root Cause Analysis (RCA): To pinpoint the fundamental causes of the machine's failures.

The project was executed in four phases:

Phase 1: Preliminary Inspection: To identify critical maintenance areas through visual inspection, operator interviews, and historical data analysis.

Phase 2: Disassembly and Component Analysis: To evaluate the condition of internal parts by disassembling the machine, inspecting key pieces, and documenting worn or damaged components.

Phase 3: Preventive Maintenance Plan Development: To create a plan based on the findings, including replacing parts, developing a maintenance schedule, and establishing maintenance protocols.

Phase 4: Implementation and Training: To put the plan into action, train technical staff on the new procedures, and monitor the plan's effectiveness.

IV. RESULTS AND DISCUSSION

After implementing the preventive maintenance plan, the machine's performance showed significant improvements.

The preliminary inspection identified several critical issues, including significant wear on rollers, damage to vanes, loose electrical connections, minor alignment deviations, and substantial residue buildup.

The maintenance actions taken included replacing worn rollers and damaged vanes, adjusting electrical connections, replacing worn cables, and performing a deep cleaning. As a result, the machine's operation became optimal, smooth, and free of vibrations.

The project's outcomes were quantified in the test results. The annual frequency of failures was reduced from 6 failures per month (before) to 1.5 failures per month (after). This represents a 75% reduction in the frequency of failures. Operational efficiency increased by 20%, allowing the machine to produce 120,000 folios in 24 hours, up from 100,000. Unscheduled downtime was also significantly reduced, dropping from seven days bimonthly to four days.

The implementation of the preventive maintenance plan proved crucial for enhancing both operational efficiency and the machine's lifespan. The process, from a thorough preliminary inspection to detailed disassembly and component analysis, precisely identified worn components and those needing immediate replacement. A key result was the 75% reduction in failure frequency, which significantly boosted the machine's reliability and availability for scheduled production cycles. The 20% increase in

operational efficiency, reflected in the jump from 100,000 to 120,000 folios per day, not only improved productivity but also optimized resource use and enhanced the company's competitiveness. The reduction in unplanned downtime, from seven to four days, was a result of a proactive maintenance approach that anticipated failures and prevented major breakdowns. This creates a more constant and predictable production schedule. The plan also establishes a maintenance standard that can be applied to other machines within the company, ensuring continued improvements and minimizing unexpected failures. The project provided tangible, quantifiable results, validating the effectiveness of a preventive maintenance approach for critical equipment

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Mitigating Risks through Effective Management for Enhancing Organizational Performance

Syed Muhammad Fayaz

engrfayaz.696@gmail.com

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Abstract – In the modern era of globalization and rapid technical breakthroughs, the significance of risk management has dramatically increased. The strategic protection, effective use, and skilled administration of vital resources and information are all included in risk management. Understanding how important it is for a company to incorporate risk management procedures is crucial. It is troubling, though, that so few businesses and organizations in Pakistan have actively carried out effective risk management strategies. Furthermore, it's also unknown how using risk management approaches would affect these firms' overall effectiveness and reputation. Therefore, the main goal of this research is to carefully examine and investigate how risk management impacts an organization's performance. It aims to understand how efficiently risk management procedures support the expansion and financial stability of a firm. The goal of this study's analysis is to demonstrate how risk management has the ability to greatly increase the general effectiveness and successes of enterprises and organizations functioning in Pakistan.

Keywords – Risk Management, Effective Management, Organizational Performance.

I. BACKGROUND

The success of the organization performance is dependent upon number of key parameters such as employee's performance, system deployment and many others. However, it is analyzed that parameters under the context of the organizational Performance are continuously increasing. This research work has been conducted to analyze the effect of risk management on organizational Performance. To gather participant opinions on how Risk Management and Organizational Performance intersect, this study will use a survey-based methodology. This method will make it possible to gauge how respondents feel about these factors. A clear strategy or approach is always required to ensure the efficient execution and total integration of risk management inside the company.

- Risk Management

In order to minimize or eliminate risks' potential negative effects on an organization's goals, risk management is a systematic method of recognizing,

evaluating, and prioritizing risks. Analyzing and comprehending the risks and potential threats that an organization faces, as well as taking the necessary steps to manage and control those risks, are all part of this process.



Figure 1: Basic RM

- Risk Identification

Identifying & recognizing potential risks could affect achievement of organizational goals. This involves examining internal and external factors, such as operational processes, financial risks, regulatory

changes, market volatility, natural disasters, technological advancements, and human factors.



Fig.2: Risk Identification in Risk Management System

(Source: <https://grm.institute/blog/what-is-risk-identification-in-a-risk-management-system/>)

- Risk Assessment

Evaluating the significance and likelihood of identified risks to determine their potential impact on the organization. This assessment helps in prioritizing risks based on their severity and the level of exposure or vulnerability to the organization.

		Severity				
		Negligible	Minor	Moderate	Significant	Severe
Likelihood	Very Likely	Low Med	Medium	Med Hi	High	High
	Likely	Low	Low Med	Medium	Med Hi	High
	Possible	Low	Low Med	Medium	Med Hi	Med Hi
	Unlikely	Low	Low Med	Low Med	Medium	Med Hi
	Very Unlikely	Low	Low	Low Med	Medium	Medium

Risk Matrix Example Likelihood X Severity = Risk Level

Fig.3: Risk Assessment

(Source: <https://riskpal.com/risk-assessment-matrices/>)

- Risk Analysis

Analyzing the causes, consequences, and interdependencies of identified risks. This step involves examining the potential scenarios and their potential impacts on various aspects of the organization, such as finances, reputation, operations, and stakeholders.



Fig.4: Risk Analysis Process

- Risk Evaluation

Assessing the tolerability of risks by comparing the potential benefits and costs associated with managing them. This helps in determining whether to accept, mitigate, transfer, or avoid the identified risks based on the organization's risk appetite and strategic objectives.

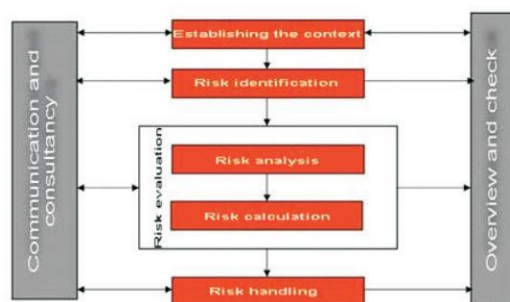


Fig.5: Risk Evaluation Process

(Source: Hlača, Bojan & Aksentijevic, Sasa & Tijan, Edvard. 2008. Influence of ISO 27001:2005 on the port of Rijeka security. 22. 245-258)

- Risk Treatment

It relates to putting in place controls and risk mitigation methods to lessen the likelihood or impact of risks. This could entail carrying out preventive actions, creating backup plans, transferring risks via contracts or insurance, or completely avoiding particular investments or activities.

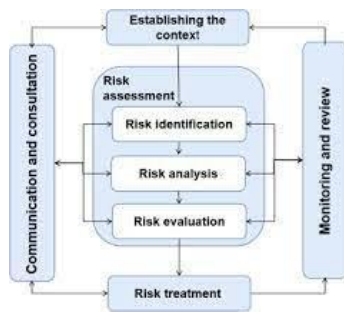


Fig.6: Risk Treatment

(Source: <https://www.sciencedirect.com/topics/engineering/risk-treatment>)

- Risk Monitoring and Review

The effectiveness of risk management techniques and tactics must be continuously evaluated, which necessitates a continuous assessment of risk exposure. This entails keeping an eye out for changes in the internal and external environment and modifying risk management strategies accordingly.

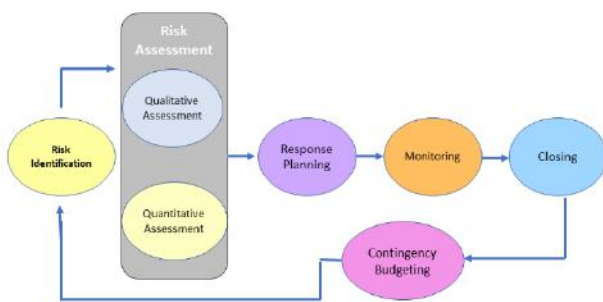


Figure 7: Risk Management Steps

(Source: <https://www.techno-pm.com/2019/10/risk-management-process-steps.html>)

Effective RM enables organizations to anticipate and respond to potential threats, protect their assets, optimize opportunities, enhance decision-making processes, and improve overall performance and resilience. It is an ongoing process that requires collaboration, communication, and a proactive approach to address risks throughout the organization at all levels. In short, risk management process can be summarized below.

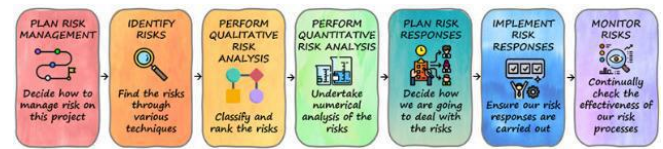


Fig.8: RM Steps

The situation becomes much more complex when the risk management in any specific industry is looked into. In the telecom sector, the risk management has to be extremely effective and ensure its implementation in the complex environments.

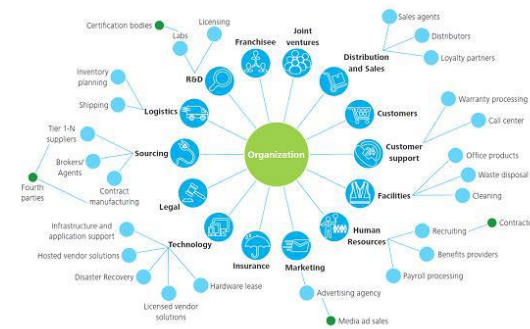


Fig.9: Risk Management in Telecom Sector Companies

(Source: https://img.etb2bimg.com/files/retail_files/fig_vishal.png)

- Effective Management

Effective management is the skillful coordination and application of resources, both material and human, within an organization or a team to successfully accomplish predefined goals and objectives. This multidimensional idea entails a variety of abilities, plans, and methods that provide leaders the power to encourage, inspire, and lead their teams to victory. Among the essential elements of efficient management are:

- A well-articulated vision and goals that give the business a clear sense of direction are essential for effective management. A manager needs to be able to convey this vision to their team and coordinate their efforts with the broad goals.
- Strategic planning entails the creation of thorough, organized plans that specify the procedures required to meet the set objectives. It also entails the capacity to

anticipate probable difficulties and proactively develop backup plans to reduce risks.

- **Strong Leadership:** Strong leadership is necessary for effective management. This includes the capacity to support and motivate team members, create a great work atmosphere, and promote both individual and group development.
- **Effective Communication:** A manager must be skilled at promoting honest and open dialogue among the team members and facilitating the sharing of information, ideas, and feedback. Unambiguous communication helps avoid misunderstandings and fosters a positive workplace culture.
- **Resource management:** Effective management depends on the effective allocation and utilization of resources, such as money, human capital, and time. To increase productivity and reduce waste, this entails prioritizing tasks, assigning roles, and optimizing resource allocation.
- **Resolution of disagreements:** A key component of efficient management is handling disagreements and difficulties within the team in a positive and diplomatic way. To maintain a happy and effective work environment, managers need to have good dispute resolution abilities.
- **Performance Assessment and Feedback:** It's crucial to regularly evaluate team and individual performance and offer helpful criticism in order to pinpoint strengths and flaws and promote professional development.
- **Flexibility & Adaptability:** In the fast-paced corporate climate of today, managers who are successful must be flexible and open to change. They must have the flexibility to swiftly modify strategy and plans in reaction to shifting market conditions, technology developments, or organizational changes on the inside.
- **Making decisions:** Making timely and informed decisions is a key component of

effective management. Managers must assess a variety of variables, consider possible outcomes, and make decisions that are best for the firm and its stakeholders.

- **Ethical Responsibility:** Good management entails preserving moral principles and building an environment where honesty and accountability are valued. Managers should set a good example for their team members and encourage moral conduct and sound judgment.

Strategic planning, effective leadership, efficient resource allocation, effective communication, and the capacity to adjust to changing conditions while upholding moral standards and fostering a cohesive and effective workplace environment are all components of effective management.

- **Risk Management Strategy, Skills and Tools**

A risk management strategy is a detailed plan created to recognize, evaluate, and reduce any risks that can compromise the stability or success of a project, organization, or business. The main objective is to foresee possible dangers and create preventative actions to lessen their impact or possibility of happening. The following essential components are often present in a strong risk management strategy:

- **Risk identification** entails a methodical approach to locating and documenting any hazards that might have an impact on the project or organization. To find possible hazards, a variety of strategies are employed, including checklists, historical data analysis, and brainstorming.
- **Risk assessment:** Once a risk has been discovered, it is evaluated in terms of its likelihood of happening and its effects on the project's or the company's goals. To determine how serious, the dangers are, both qualitative and quantitative methods are frequently used.
- **Risk Mitigation:** After evaluating the risks, a strategy is created to lessen or minimize their possible effects. Implementing preventive steps, coming up with backup plans, or

shifting the risk via contracts or other legal ways are all examples of how to do this.

- Risk Monitoring: To make sure the risk management plan is still successful; it is essential to continuously monitor the risks that have been identified. This entails monitoring shifts in the risk environment, evaluating the success of mitigation strategies, and revising risk management plans as necessary.
- A shared awareness of potential hazards and the steps being taken to reduce them depends on effective communication of risks and the risk management strategy to stakeholders, team members, and other relevant parties.

- Skills for Effective Risk Management

- Analytical Skills: For effective risk management, it is essential to be able to analyze complicated data and spot patterns or trends that could point to potential threats.
- Decision-Making Capabilities to analyze different risk mitigation solutions and select the best course of action for the organization, sound decision-making abilities are required.
- Communication Skills: Clear and concise communication of complex risk-related information to team members and stakeholders requires effective communication skills.
- Problem-Solving Skills: Effective risk management depends on the ability to come up with innovative answers to difficult risk-related problems.
- Leadership Skills: Effective management of teams and helping them through difficult situations that may develop due to identified risks require strong leadership skills.

- Tools for Risk Management

- Risk registers: These are thorough records that identify all recognized risks, their possible effects, and the actions intended to mitigate them.
- Risk Assessment Matrices: By allowing a more methodical approach to risk evaluation,

these matrices assist in assessing hazards based on their likelihood and potential impact.

- SWOT analysis: A SWOT analysis, which stands for "Strengths, Weaknesses, Opportunities, and Threats," is a helpful technique for figuring out potential dangers and possibilities for the business from both the inside and the outside.
- Decision trees: option trees assist in risk analysis and decision-making by examining many option choices and their potential implications.
- By performing numerous simulations based on probability distributions, the Monte Carlo simulation technique aids in assessing the impact of various risk variables on project outcomes.
- Contingency planning is creating a strategy to deal with anticipated risks and lessen their influence on the goals of the project or organization. Choosing other options for action and allocating resources is a common component of contingency planning.
- Software tools for risk management are available to make the process of identifying, evaluating, and monitoring risks more efficient. These technologies frequently include functions for risk monitoring, reporting, and group risk management.

Organizations can manage risks and lessen their influence on project success and organizational stability by incorporating these skills and using the relevant tools.

- Organizational Capabilities

The concept of organizational capability, as highlighted by Spanos and Prastacos (2004), encompasses a company's aptitude in efficiently managing its range of resources, including its employees, to achieve a significant competitive edge within the dynamic marketplace. It is the responsibility of the company to direct its attention toward developing these talents and making sure they are in line with the needs and preferences of its clientele. The development of a distinctive organizational perspective, which enables the

business to traverse the competitive landscape with resiliency and creativity, is an essential component of this strategy. An corporation can orchestrate major business changes by strategically utilizing its resources, creating a strategic environment that opens the door for long-term competitive advantage.

According to Bititci and GurkanInan (2015), a strong portfolio of skills enables an organization to operate efficiently within the market, permitting the continuous development and upgrading of current competencies to successfully resist competitive forces. These capabilities cover a wide range, including product licenses, knowledge assets, and innovative designs. As a result, an adaptive strategy is required that prioritizes the ongoing development of a workforce with knowledge-based skills in a flexible work environment, leading to successful business domain transformations.

Furthermore, Martelo (2013) explains how organizational qualities are closely related to developing strong customer relationships, underlining the necessity of ongoing competition and market expansion. The development of employee capabilities, which have a substantial impact on the organization's reputation, sales success, and customer loyalty, is essential for building good customer relationships. A harmonious workplace that is geared to addressing the changing requirements and expectations of customers in a timely and effective manner is crucial. Within the organizational framework, both existing and new customer interactions serve as important drivers of overall growth.

- Organizational Performance

According to Tzabbar and Baruch (2017), the idea of organizational performance encompasses the thorough assessment of a company's effectiveness in achieving its set goals in the competitive marketplace. As a result, it is essential to continuously evaluate and review the organizational performance, which forms a crucial part of the larger strategic management viewpoint. A clear understanding of performance within the operational framework of any business is extremely valuable to stakeholders, empowering them to take well-informed decisions and put those decisions into action whenever necessary to support continuing improvements. It is

critical to understand that organizational performance is a complex and nuanced idea that requires constant observation and assessment throughout time in order to pinpoint areas that could be improved.



Fig.10: Sustainable High Performance Organizational

(Source: <https://www.insidehr.com.au/how-to-build-a-sustainable-high-Performance-organisation/>)

The efficacy of organizational performance is closely related to the common vision that is articulated to and accepted by all levels of the workforce and serves as a compass for group strategic initiatives. Employee performance directly affects how smoothly tasks are carried out at each organizational level, underlining how crucial it is for each team member to strategically contribute to the overall goal. A culture of active involvement and reciprocal cooperation is established when the company, its administrative staff, employees, and other stakeholders work together in a structured and coordinated manner. A systematic strategy is necessary for the development of a successful organizational performance landscape, ensuring that work activities are streamlined and coordinated in an orderly manner. The preservation and enhancement of organizational performance remain dependent on the seamless integration of organizational learning efforts and the availability of a skilled workforce, despite the fact that the dynamic character of business settings frequently necessitates quick recalibrations and adaptations. According to Devece, Palacios, and Simarro (2017), this proactive approach enables the timely implementation of critical adjustments, enabling the company to maintain and improve performance standards over

time.



Fig.11: Measuring OP

(Source: DOI:10.5897/AJBM11.1768)

According to observations made by Loosemore (2017), organizational performance emerges as a continuous and dynamic process that forms the basis for protecting and distributing resources in accordance with an organization's broad goals. The nurturing of staff development initiatives, a crucial path that thrives via the facilitation of effective learning mechanisms, is integral to this process. The active participation of managerial and executive personnel, who supervise the creation of customized developmental strategies and keep an eye on workforce activities to support overall development and productivity levels inside the firm, is closely linked to this learning imperative. As a greater emphasis on comprehensive learning efforts invariably converts into a similarly increased performance standard within the cutthroat marketplace, the symbiotic relationship between organizational learning and performance becomes clear. The combination of learning-driven processes and a proactive dedication to supporting employee development strengthens the basis for long-term organizational success.



Fig.12: Key Organizational Performance Indicators

(Source:

<https://www.beringer.net/beringerblog/why->

does-my-organization-need-key-Performance-indicators-kpis/)



Figure 13: Principles of Organizational Performance

(Source: <https://motivate2b.com/principles-for-org-Performance/>)

Problem Statement

The job of risk management has grown more crucial in today's age of globalization and quick technological advancement. The strategic protection, effective use, and skillful administration of important resources and information are all included in risk management. Understanding how crucial it is for a firm to incorporate risk management procedures is essential.

It is troubling, though, how few firms and organizations in Pakistan have really put good risk management plans into practice. Furthermore, it is yet unclear exactly how the application of risk management approaches affects the overall effectiveness and legitimacy of these organizations.

Therefore, the goal of this study project is to carefully examine and investigate how risk management affects an organization's performance. It aims to comprehend how successfully risk management procedures support an organization's expansion and profitability. The study's investigation of this topic aims to highlight how risk management has the ability to significantly improve the overall effectiveness and performance of enterprises and organizations in Pakistan.

Research Questions

RQ1: Is it possible to examine and investigate influence of RM & acquisition on the overall

organization's performance?

RQ-2: How to identify and examine role of and to implement RM strategies linking them to the organization's performance?

RQ-3: Is it possible to design validated and innovative conceptualized models incorporating risk management with organizational performance through the identification of key variables and factors?

Research Objectives

- Examining and investigating the influence of risk management and acquisition on the overall organization's performance.
- To identify and examine the role of risk management and to implement risk management strategies linking them to the organization's performance.
- Designing a validated and innovative conceptualized models incorporating risk management with organizational performance through the identification of key variables and factors.

Significance of Research

"Risk management & Organizational performance" reflects influence of RM to well perform business operations. Importance of risk management cannot be overlooked at any cost. Research needs to be conducted on various other sectors such as governmental and NGO's as well so that the designed validated model can be applied everywhere by fine tweaking and adjustments based on any particular organizations requirements. In order to evaluate the true value of organizational performance in the market, a contribution to knowledge will focus on the major components of risk management and how to execute them. RM is a broad topic. Key steps in RM are focused on developing, disseminating, and managing relevant knowledge and information inside an organization. Management can achieve successful organizational performance by using risk management as a tool.

II. LITERATURE REVIEW

The fundamental tenets, underlying presumptions, and intricate behavioral patterns that distinguish one organization from another are highlighted in this study project's examination of organizational behavior by using organizational culture theory as its foundational pillar (Ortega, 2013). According to Yirdaw (2014), who emphasizes this theory, organizational culture serves as a crucial unifying force that is intricately woven into the structure of an organization, smoothly integrating both nonhuman and human resources to promote collaboration and improve overall performance. It acts as the physical manifestation of deeply established habits and behaviors that a company not only values but actively supports in its everyday operations, shaping its unique identity and character both inside and outside of its industry.

A better knowledge of organizational culture indicates that it is the collective attitude and shared values that create the basic operating principles of the organization as well as how decision-making processes are shaped. It is a dynamic fusion of attitudes, conventions, beliefs, and rituals that permeate every aspect of the organizational structure and have a big impact on how workers interact, communicate, and approach their jobs. A strong and clearly defined organizational culture frequently promotes a strong sense of belonging, a common goal, and a cohesive mission among its members, creating a positive work environment and a sense of common purpose.

Organizational culture is manifested via concrete, actionable practices and policies that demonstrate the organization's steadfast dedication to its basic principles and overarching goal. This goes beyond simple verbal declarations. It plays a crucial role in determining employee behavior, attitudes, and work ethics, ultimately having a significant impact on the performance, productivity, and long-term success trajectory of the firm. Additionally, it establishes the foundation for developing a culture of innovation, adaptation, and resilience, enabling the firm to skillfully overcome obstacles and seize untapped economic opportunities.

Recognizing the immense potential for smoothly

integrating risk-awareness and proactive risk management practices into the current business processes is crucial when thinking about how risk management may be integrated into organizational culture. The leadership sets an exemplary tone by prioritizing risk management as a core organizational objective. This revolutionary integration emerges through many channels inside the business. Additionally, the hierarchy of duty that has already been established encourages a culture of accountability and ownership among workers, ensuring that risk management procedures are thoroughly embedded at every level of the organization.

The development of a culture marked by difficult but attainable goals also promotes a pervasive awareness of risk and encourages deliberate, considered decision-making, highlighting the crucial importance of striking a balance between risk and reward in the pursuit of organizational goals. As a further catalyst for the seamless integration of risk management into the very fabric of the organization's culture, the current compensation and incentive system, which duly acknowledges and rewards prudent risk management practices, incentivizes employees to actively participate in risk assessment, mitigation, and control measures.

The successful integration of risk management into organizational culture depends on a shared commitment to cultivating a mindset that permeates every element of the company and is not only aware of possible risks but also robust in its response to them. This interdependence between organizational culture and risk management highlights the significance of implementing a thorough risk mitigation strategy, encouraging sustainable growth, and developing a culture of ongoing improvement and flexibility within the organizational structure.

Mohammad (2020) conducted a thorough investigation into the complex interrelationships between risk management strategies and organizational performance within the Hashemite Kingdom of Jordan's insurance industry. The study took a thorough approach in order to clarify the crucial role that risk management methods play in the overall effectiveness and performance of Jordanian insurance companies.

120 seasoned managers working for various Jordanian insurance companies provided their ideas and input as data was painstakingly gathered from a wide range of perspectives to start this extensive inquiry. The study tapped into the invaluable expertise of these important industry actors using a carefully crafted questionnaire, ensuring a thorough and nuanced understanding of the prevalent risk management approaches in the sector.

A number of rigorous analytical tools were methodically used to uncover the complicated linkages between the numerous main variables at play, thereby deepening and broadening the scope of the study. The first stage involved a thorough descriptive analysis that allowed for a detailed comprehension of the various elements and dimensions of the collected data. This first stage established the foundation for a more in-depth analysis of the correlations between the many characteristics being studied.

A detailed correlation analysis was carried out, carefully probing the intricate web of links and associations between various risk management techniques and the corresponding organizational performance measures, building on the insights gained from the descriptive study. The comprehensive understanding of how different risk management strategies affected the overarching operational and performance dynamics within the insurance businesses of the Hashemite Kingdom of Jordan was made possible by this in-depth analysis, which enabled the identification of nuanced patterns and trends.

The implementation of strong regression analysis methods, leveraging the capabilities of cutting-edge SPSS 19 software to unlock deeper insights from the data, was the study's analytical high point. The study not only discovered nuanced statistical relationships by subjecting the large dataset to meticulous regression analysis, but it also pinpointed the nuanced causal effects of various risk management practices on the overall organizational performance in the context of Jordanian insurance companies.

The study's persuasive results confirmed the irrefutable importance of risk management practices by showing how they have a significant and noticeable impact on overall organizational

performance in the insurance industry. The study also emphasized the widespread use of risk management techniques, emphasizing how these methods have permeated the operational framework of most businesses and attested to their ongoing relevance and crucial role in guiding the success and longevity of Jordanian insurance enterprises.

In order to examine the complex dynamics surrounding the effect of internal, external, and enterprise risk management on the operational performance of Micro, Small, and Medium Enterprises (MSMEs) operating in Indonesia's underdeveloped regions, Hanggraeni undertook a thorough investigation in 2019. A holistic and thorough understanding of the current conditions in these economically important regions was achieved through the study's exploration of the operating landscape of these firms throughout five provinces, which together comprise 14 cities.

The study thoroughly collected and evaluated data from a sizeable sample size of 1,401 MSMEs to guarantee a robust and thorough understanding of the prevalent risk management techniques and their associated consequences on the performance of MSMEs. The study employed a well-rounded approach to capture the multifaceted dimensions of risk management practices and their implications for operational performance within the Indonesian MSME sector by leveraging the insights derived from both the resource-based view and the market-based view methodologies.

The study used a carefully planned strategy centered on the distribution of extensive and insightful questionnaires to collect primary data that may give an accurate portrayal of the ground reality. The core of the primary data gathering approach was these questionnaires, which were painstakingly created to elicit subtle and granular insights. This ensured a thorough understanding of the various risk management techniques and their impact on the operational dynamics of the MSMEs under investigation.

The study made use of sophisticated statistical techniques and painstakingly examined the extensive dataset using the renowned statistical program SPSS. This analytical phase involved a methodical and thorough examination of the gathered data, enabling

the extraction of insightful findings and patterns that highlighted the complex relationship between risk management practices and the operational business performance of the MSMEs operating in the targeted Indonesian regions.

The study's compelling results highlight the crucial role that risk identification and management play in influencing and forming the operational business performance of MSMEs. These results not only highlighted the need of good risk management techniques on an internal level, but also highlighted their potential as a key factor in improving the overall operational resilience and sustainability of the MSMEs in Indonesia's underdeveloped regions. Thus, the study provided insightful information about the strategic needs for the implementation of strong risk management frameworks within the operational environment of MSMEs, providing a road map for promoting resilient and sustainable growth within these crucial economic ecosystems.

In a thorough investigation carried out by Erlane and their team in the context of Bursa Malaysia, 106 publicly traded firms were examined in relation to the intricate relationships between risk management practices, operational information disclosure, and financial performance. The study was painstakingly designed to delve into the underlying forces that mold the financial landscape of these businesses, illuminating the critical role that strong risk management procedures and open disclosure of operational information play in fostering long-term financial success.

The study approach used by Erlane et al. (2016) focused on a detailed content analysis of a sizable dataset made up of 318 annual reports, painstakingly covering a thorough three-year timeframe. The researchers were able to develop a thorough grasp of the risk management frameworks and the level of operational information disclosure inside the sampled organizations thanks to the comprehensive inspection of annual reports, which served as an effective research instrument.

The study's findings revealed intriguing insights into the complex relationship between the extent of risk management processes' execution and the disclosure of operational data, as well as their immediate effects on the financial performance of the firms under

investigation. The results underlined the critical function that strong risk management frameworks serve in reducing possible risks and vulnerabilities and promoting a more resilient and long-term financial performance for the firms.

The report also emphasized the necessity of open and thorough disclosure of operational information as a key factor in boosting investor trust and the organizations' overall market standing. Companies might develop a climate of trust and transparency by giving stakeholders a thorough and transparent perspective of the operational landscape. This would improve their financial performance and position them favorably in the competitive market environment.

These profound realizations not only highlighted the crucial necessity of putting in place strong risk management frameworks within the corporate structure, but they also underlined the strategic importance of openly disclosing operational information as a key factor in promoting long-term financial growth and market competitiveness. The study's conclusions are thus a useful road map for businesses engaged in Bursa Malaysia, providing a model for developing a strong risk management culture and encouraging an atmosphere of openness and trust that, in turn, supports long-term monetary stability and market resilience.

Kpodo's (2015) study provided a comprehensive exploration into the intricate dynamics underlying the relationship between risk culture and organizational performance within the context of financial institutions in Ghana. This meticulous investigation focused on unraveling the complex interplay between the underlying risk culture dimensions and their impact on the overall operational efficacy and performance of the financial institutions under scrutiny.

The Financial Stability Board (FSB) risk culture model, which served as a solid framework for thoroughly analyzing the multiple characteristics of risk culture within the Ghanaian banking industry, was adopted as the study's central theoretical framework. Utilizing this complex model, the study aimed to develop a comprehensive understanding of the operational dynamics of major financial institutions' risk cultures and how they affect organizational performance.

Kpodo extensively analyzed all features and dimensions of risk culture within the Ghanaian banking industry using a wide range of descriptive statistical techniques. A thorough analysis of the various risk culture dimensions was made possible by the systematic approach, which also gave valuable insights into how these dimensions affect and shape the overall operational ethos and performance metrics of the financial institutions included in the study.

The dataset for the study was compiled from a sample of 19 banks that are members of Ghana's elite Club 100, which together account for a sizable 70% of the nation's entire banking industry. This open-minded strategy made sure the study covered a wide cross-section of domestic and international financial institutions, enabling a thorough and all-encompassing assessment of the current risk culture dynamics within the Ghanaian banking industry.

The study used surveys as its main method for gathering data and tapped into the firsthand perceptions and insights of the respondents, enabling a nuanced and thorough examination of the complex aspects of risk culture and their implications for organizational performance within the Ghanaian financial system.

The study's compelling findings highlight the fundamental connections between risk culture and organizational performance within the Ghanaian banking industry, highlighting the crucial role played by a strong risk culture framework in influencing the overall operational efficacy and performance of the financial institutions under study. The strategic importance of fostering a strong risk culture framework as a key factor in enhancing organizational resilience, sustainability, and long-term performance within the dynamic and changing financial landscape of the region is stressed by these findings, which act as a crucial compass for financial institutions in Ghana.

Pagach's groundbreaking study from 2010 explored the complex connection between the application of Enterprise Risk Management (ERM) concepts and the long-term performance of businesses, providing insightful information into the many-faceted dynamics that support the convergence of financial assets and market behaviors. The study's core

component was a detailed examination of how the deployment of ERM affected numerous KPIs, illuminating the complex consequences for organizations adopting all-encompassing risk management frameworks.

Pagach carefully chose a sample of 106 companies in order to demonstrate the transformative effects of adopting ERM. These companies publicly announced the appointment of Chief Risk Officers (CROs), demonstrating their dedication to fostering a culture of proactive risk management within their organizational frameworks. This purposeful choice of businesses acted as a cross-sectional representation, enabling a thorough investigation of the significant effects of ERM implementation on the long-term performance dynamics across a variety of industries.

Pagach's study uncovered compelling insights into the complex impact of ERM implementation on various crucial performance metrics by conducting a comparative analysis between the chosen companies that embraced the services of a CRO and their counterparts that did not advocate for such a role. Notably, the study showed that businesses that actively incorporated ERM frameworks into their operational framework experienced a significant decrease in stock price volatility, highlighting the crucial role that thorough risk management practices play in promoting market stability and investor confidence.

The study also found that companies using CROs' expertise had a considerable increase in asset capacity, highlighting the transformative potential of adopting ERM in boosting these organizations' overall operational resilience and strategic capability. The complex trade-offs and dynamics that support the adoption of thorough risk management frameworks within particular sector groupings are highlighted by the fact that this rise in asset capacity was contrasted with a proportionate decline in market value and profit.

The study's main finding also revealed a negative correlation between changes in a company's market value and corresponding changes in profit, highlighting the inherent difficulties and difficulties in navigating the dynamic market environment while simultaneously minimizing potential risks through the implementation of ERM.

In addition to highlighting the strategic importance of fostering an extensive ERM framework, Pagach's study provided a nuanced understanding of the inherent trade-offs and implications associated with the adoption of proactive risk management practices in the context of modern business environments.

In-depth research by Altanashat (2019) explored the significant effects of implementing Enterprise Risk Management (ERM) within the Jordanian public sector, illuminating the complex dynamics underlying the link between comprehensive risk management frameworks and institutional performance. The use of the ERM COSO Integration Practices (2004) framework, which served as a powerful analytical tool to thoroughly dissect the various features of risk management practices within the context of the Jordanian public sector, was a key component of the study.

Altanashat's study utilized a rigorous survey methodology, which facilitated the collection of a substantial dataset made up of 313 carefully crafted questions, to painstakingly unravel the complex interplay between corporate risk management and organizational performance within listed firms in Jordan. By utilizing this carefully designed survey instrument, the study was able to capture the subtle aspects of risk management practices and their inherent effects on the operational effectiveness and performance of the listed companies operating in the dynamic Jordanian public sector.

Altanashat used the sophisticated Smart-PLS (Partial Least Squares) approach, utilizing the capabilities of structural equation modeling to carefully deconstruct the intricate web of interactions hidden within the dataset, to further increase the depth and granularity of the study. This analytical phase permitted a thorough and detailed investigation of the relationships among many critical factors, illuminating the significant influence of putting in place effective risk management practices on the overall institutional performance within the Jordanian public sector.

The study's illuminating conclusions highlighted the significant and palpable effect that integrating thorough risk management practices has on improving the overall institutional performance within the Jordanian public sector. The findings were

a call to action for Jordanian mining companies to actively adopt and embrace international best practices in risk management, highlighting the transformative potential of developing a strong risk management culture in order to foster long-term institutional performance.

The study also showed that every independent variable, which included crucial aspects like the internal environment, event detection, risk assessment, risk response, control activities, information and communication, and monitoring, played a crucial and reliable role in defining the performance metrics of Jordanian mining businesses. In addition to highlighting the strategic importance of developing a holistic risk management ethos as a key driver for fostering sustainable growth, resilience, and long-term performance within the complex and dynamic environment of the Jordanian public sector, these nuanced insights also highlighted the critical imperative of implementing a comprehensive ERM framework.

The research done in 2022 by Modesta Amaka Egiyi and Regina Chekwubechi Eze was crucial in revealing the intrinsic usefulness of risk management techniques in enhancing organizational effectiveness within the complex framework of Nigerian firms. In order to capture a holistic and comprehensive understanding of the current risk management dynamics and their implications for organizational efficacy and performance, the study's empirical investigation, which aimed to draw comprehensive insights from the perspectives of personnel operating within diverse Nigerian organizations, played a central role.

With 510 participants actively offering their views and viewpoints, the study included a sizable sample size, ensuring a strong and complete representation of the varied organizational environment inside Nigeria. These participants served as the main source of information for the study's primary data collection procedure, actively responding to painstakingly created questionnaires that were consciously oriented toward the organizational culture hypothesis. This all-encompassing strategy made it possible to explore in depth and with nuance the many facets of risk management and how they affect overall organizational success in the context of Nigerian firms.

The study made use of the power of sophisticated statistical analysis, relying on the sophisticated Statistical Package for the Social Sciences (SPSS) software to conduct a thorough analysis in order to uncover the significant insights concealed within the gathered information. To systematically analyze the intricate interactions between the various risk management strategies and their effects on organizational effectiveness, the study drew on a wide range of analytical methodologies, such as correlation analysis and regression analysis.

The study successfully revealed the complex relationships and dependencies between various risk management variables and the corresponding organizational effectiveness metrics through the lens of correlation analysis, shedding light on the underpinning forces that influence the organizational landscape within Nigerian organizations. This was enhanced by the regression analysis, which gave a thorough grasp of the causative relationships and prognosticative capacities of different risk management strategies on the total organizational effectiveness in the context of the Nigerian business environment.

The study carefully examined the collected data using these powerful analytical tools, underscoring the transformative potential of effective risk management practices in fostering organizational resilience, adaptability, and sustainable growth within the dynamic and changing environment of Nigerian organizations. The strategic imperatives of integrating strong risk management practices as a fundamental driver for improving overall organizational effectiveness and long-term sustainability within the demanding and competitive business environment are highlighted by these profound insights, which serve as an essential compass for organizations in Nigeria.

Each participating institution used Google Forms as a dependable and user-friendly medium for delivering the painstakingly crafted questionnaires in the study carried out by Egiyi in 2022. These surveys were carefully designed with a well-structured 5-point Likert scale, a tool that is frequently used to assess the attitudes, views, and perceptions of respondents, assuring a systematic and thorough approach to data collection within the study. Through careful technique, the researchers

were able to gather participants' nuanced thoughts and viewpoints, providing a thorough and comprehensive picture of the current dynamics of risk management and their consequences for organizational effectiveness.

The study's insightful results provided new insight into the complex effects of many important risk management factors on the overall organizational effectiveness in the context of the participating firms. Notably, the research found that a number of critical components of the risk management process, such as risk analysis, risk evaluation, the threat of risk, and monitoring and review of risk, had a statistically significant beneficial influence on organizational efficiency indicators. The important contributions made by these particular risk management techniques in building a culture of proactive risk mitigation and strategic planning were highlighted by these convincing results, which also increased the overall operational efficacy and efficiency of the participating firms.

The study did, however, offer an unusual perspective on how risk identification influences organizational effectiveness. The statistical study revealed that the risk identification procedure did not show a statistically significant influence on the overall organizational effectiveness indicators at a level of significance of 5%. This discovery raises the need for a more thorough and integrated approach to risk management that includes a holistic understanding of different risk dimensions. Risk identification is a crucial first step in the risk management process, but it may not alone contribute to concrete improvements in the overall efficiency and effectiveness of the organizations.

These profound realizations serve as an essential road map for businesses looking to optimize their risk management strategies, highlighting the necessity of fostering a framework that goes beyond simple risk identification to include thorough risk analysis, evaluation, threat assessment, and ongoing monitoring. Organizations can strengthen their operational efficiency and take a competitive advantage in the market by adopting a holistic approach to risk management and fostering a culture of resilience and adaptation.

III. RESEARCH METHODOLOGY

Research methodology relates to designing & developing a model for risk management and its effect on the organization's performance. The research will be quantitative in nature. Information source considered from the primary data will be utilized for the process of data collection and SPSS software will be used to process data. Research methodology comprises of the several phases. Every phase of the research methodology would be overall interlinked with the prior phase. The first phase of methodology is the defining of research problem. The focus has been laid on the clear defining of the problem in the existing research environment as is considered as foundation of study.

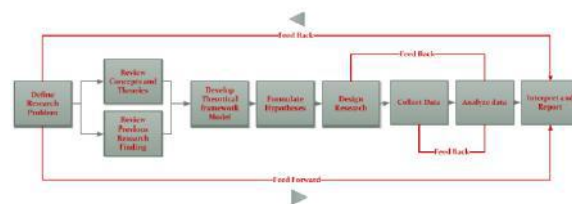


Fig.14: Research Methodology

Next phase is the reviewing concept, theories as well as prior research findings. This component will be known as literature review. The third phase will be identified as the creation of the theoretical model framework. The fourth phase will be very beneficial for designing and formulating hypotheses. The design of hypotheses will be guided by the study's theoretical framework. Fifth phase will be research design. It is considered that in the research design focus will be laid on the transformation of the knowledge, idea as well as information about the risk management for improving overall organizational performance into the meaningful aspect. Sixth phase is collecting data through Information source considered from the primary data. Information source considered from the primary data includes questionnaire techniques. Seventh phase will be conducting analysis of the data with the assistance of the SPSS business software.

- Research Design

Research design has been based on risk management for improving organizational performance. The focus will lay on the considering of observed ideas about RM practically implemented within selected

organization i.e. Pakistan Telecommunication Company Limited, PTCL).

- Data Collection Tools

Information source considered from the primary data will be utilized for the process of data collection (Questionnaires distributed among PTCL management employees working in the operations department on various projects) acting as a tool for investigation.

- Sampling Size Technique

Random sampling techniques would be utilized. The limit of sample size will be no more than 200 respondents that are directly and indirectly connected with risk management of the organization. Sample size will be obtained from PTCL, spread all across the country.

- Statistical Instrument Development

In this investigation, statistical instrument development will be based on SPSS software. This business software's is selected based on its effective data analysis, data processing and data required outcomes. These outcome or results will be in analyzed for reliability statistics, information of demographics, conducting of correlational analyses and regression analyses.

Conceptualized Research Model

Based on the literature review and already designed risk management and organizational performance models (as shown below), the researcher designed his own conceptualized model for analysis.

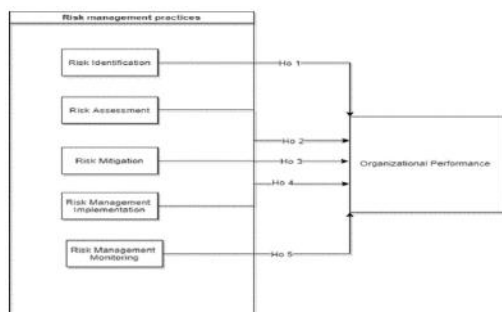


Fig.15: The Impact of Risk Management Practices on the Organizational Performance: Field Study of Jordanian Companies

(Source:

<https://meu.edu.jo/libraryTheses/The%20Impact>

%20of%20Risk%20Management%20Practices%20on
%20the%20Organizational%20Performance.pdf)

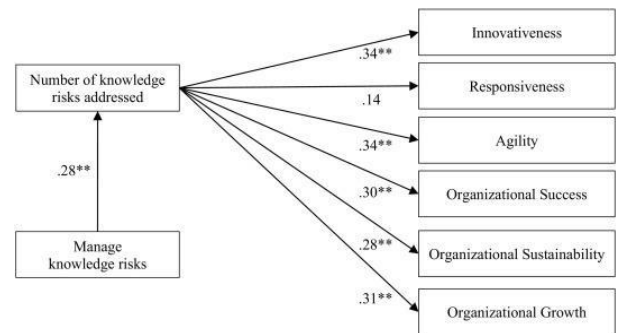


Fig.16: The linkage between knowledge Risk management and Organizational Performance

(Source: Susanne Durst, Christoph Hinteregger, Malgorzata Zieba. The linkage between knowledge risk management and organizational performance, Journal of Business Research, Volume 105, 2019, Pages 1-10, ISSN 0148-2963, <https://doi.org/10.1016/j.jbusres.2019.08.002>.)

Based on the above and the literature review, the researcher conceptualized the below model for the analysis.

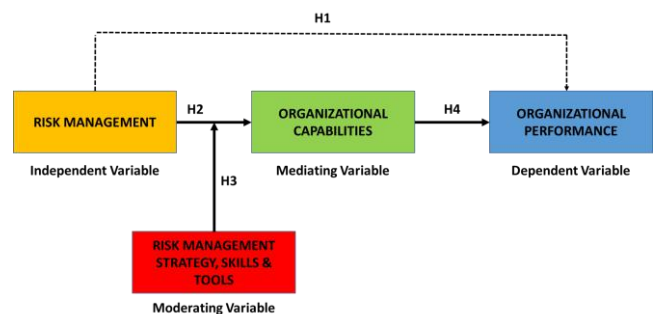


Fig.17: Conceptualized Model

Independent Variable

- Risk Management

Moderating Variable

- Risk Management Strategy, Skills and Tools

Mediating Variable

- Organizational Capabilities

Dependent Variable

- Organizational Performance

Research Hypothesis

- H1:** Risk Management is positively associated with respect to organizational performance.
- H2:** Implementing Risk Management Strategies has a positive effect on improving Organizational Capabilities.
- H3:** Risk Management Strategy, Skills and Tools moderates the relationship between Risk Management and Organizational Capabilities.
- H4:** Organizational Capabilities mediating between risk management and organizational performance leads to having an organization having better and improved performance.

SPSS Tools

Statistical Package for the Social Sciences, or SPSS, is a piece of software that is frequently used in social science research, including psychology, sociology, and other related disciplines. It was created by IBM and offers a full and integrated collection of tools for data management, data analysis, and data documentation.

Here are some of SPSS's main attributes and capabilities:

- **Data Management:** By cleaning, sorting, and organizing datasets, SPSS enables users to get ready data for analysis. Data entry, data transformation, data validation, and case selection are all included in this.
- **Descriptive statistics, bivariate statistics, multivariate analysis, and sophisticated statistical techniques** are only a few of the statistical tools it offers for examining data. Tests including t-tests, ANOVA, regression analysis, factor analysis, cluster analysis, and more are available to users.
- **Data visualization:** In order to successfully evaluate and present data, SPSS enables users to build a variety of graphs and charts, including histograms, scatterplots, bar charts, and pie charts.
- **Customization and Automation:** To speed up the analysis process, users can automate

operations and modify analyses and reports to meet unique needs.

- **Integration:** SPSS is compatible with other data analysis programs and technologies, making it easier to combine data from many sources for thorough analysis.
- **Reporting & Output:** It creates thorough reports and visualizations that can be exported to a number of formats, making it simpler to share study conclusions.

The user-friendly interface of SPSS is well regarded for making it accessible to both inexperienced and seasoned researchers. It is one of the most widely used tools for data analysis in the social sciences due to its adaptability, vast analytical skills, and capacity for handling enormous datasets.

IV. DATA ANALYSIS, RESULTS & INTERPRETATION

The successful conclusion of this inquiry depends heavily on the chapter devoted to data processing, outcomes, and interpretation. This section was created with the explicit goal of examining the connection between Risk Management and organizational performance. It has been observed that Risk Management plays an active role in context of any organization. Without practical implementation of Risk Management, it's very difficult for organization to accomplish their goals and objectives according to management requirements (Bhatt, 2001). The domain for measuring Risk Management is wide and complex in situations. This is the key reasons that well-known companies are using RM for overall increase their organizational performances in market and also increase high competition in market.

A variety of statistical tests are included in the chapter on data analysis, outcomes, and interpretation. These tests entail analyzing user demographic data, using correlational analysis, presenting a summary evaluating hypotheses, as well as actually using multiple regression analysis models and mediation analysis. In the context of this investigation, these approaches help to demonstrate the genuine influence of research factors on performance as a whole.

The key operative functional activities of demographic information are associated with respect to marital status of respondents, gender differentiation, employee age, employee work experience and private companies that are directly and indirectly connected with Risk Management in order to measure their performance in market. In this investigation, researchers apply correlational analysis for testing of suggested hypotheses derived from research framework model. Hypotheses assessment summary is typically design and develop by using correlational values to know the importance of research model in this study. The multiple regression analysis model's main job is to show the variations present in the current research model and to evaluate the impact of all independent variables on the dependent variable. Mediation analysis is also applied in this investigation. The key main functionality of mediation analysis is to check the moderating effect on independent variables and dependent variable. In this investigation, main variables are in the form of Risk Management (Bhatt, 2001) and Risk Management Strategy, Skills & Tools (Asongu & Simplice, 2017) having mediation impact on organization capabilities (Keskin, 2006) that lead towards organizational performance (Malhotra & Segars, 2001). Some of the imperative outcomes of statistical tests are assumed below:

- Demographic Information

Out of 200 questionnaires sent, 160 were valid bringing the response rate to 80% which is sufficient. Some of the imperative demographic information with respect to RM on organizational performances is assumed below:

		F "Frequency"	%	Valid	Cumulative
Valid	Male	117	73.125	73.125	73.125
	Female	43	26.875	26.875	100.0
	Total	160	100.0	100.0	

Fig.18: Gender Distribution

A key demographic data point for comprehending the users engaged is the gender information that is included. The binary classification of people into male and female groups is represented by two main components in this particular dataset. Male participants made up 73.125% of the sample, according to an examination of this data by gender, while female participants made up 26.875% of the entire population involved.

		F	%	Valid	Cumulative
				%	%
Valid	18 - 25 years	11	7.0	7.0	7.0
	26 - 30 years	53	33.1	33.1	39.2
	31 - 35 years	52	32.9	32.9	72.2
	36 - 40 years	28	17.7	17.7	89.9
	40 & above	16	10.1	10.1	100.0
	Total	160	100.0	100.0	

Fig.19: Employees Age Brackets

In this investigation, employee age plays an active role in context of any organization. This employee age shows employees skills, abilities, knowledge and decision making powers to effectively run business operations in market. Employee age encompasses a wide range of age groups that can be divided into various unique categories. These age ranges include 18 to 25 years old, 26 to 30 years old, 31 to 35 years old, 36 to 40 years old, and over 40. According to the study of this statistics, the distribution of workers within these age groups was as follows: Those between the ages of 18 and 25 made up 7% of the workforce, those between the ages of 26 and 30 made up 33.1%, those between the ages of 31 and 35 made up 32.9%, those between the ages of 36 and 40 made up 17.7%, and those beyond the age of 40 made up 10.1% of the studied population.

		Frequency	Percentage	Valid	Cumulative
				Percentage	Percentage
Valid	Single	54	33.75	33.75	33.75
	Married	106	67.19	67.19	100.0
	Total	160	100.0	100.0	

Fig.20: Marital Statistics

In order to comprehend the user population, it is essential to provide information on marital status. This dataset consists of two main parts that classify people as either single or married. According to the analysis, 33.75% of the participants were single, compared to 67.1% of the sample who were married and actively participating in the investigations.

		Frequency	Percentage	Valid	Cumulative
				Percentage	Percentage
	PTCL	160	100	100	100
	Total	160	100.0	100.0	

Fig.21: Company (PTCL)

In order to evaluate the application of Risk Management in connection to organizational performance, the researcher studied in depth

Pakistan Telecommunication Company (PTCL) as the selected organization.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	1 to 5 years	30	19.0	19.0
	6 to 10 years	25	15.8	34.8
	11 to 15 years	76	48.1	82.9
	16 to 20 years	18	11.2	94.0
	20 & above	11	7.0	100.0
	Total	160	100.0	

Fig.22: Employee Working Experience

Within organizational framework of this study, the length of an employee's employment history acquires a key significance. An employee's professional experience is evidence of their learned abilities, knowledge, and decision-making skills, all of which help to run business operations within the market effectively. The length of an employee's employment history is divided into numerous unique groups, including: 1 - 5 years, 6 - 10 years, 11 - 15 years, 16- 20 years & 20 years and above. According to the research, workers with 1 to 5 years of experience made up 19.0% of the workforce, followed by workers with 6 to 10 years of experience (15.8%), workers with 11 to 15 years of experience (48.1%), workers with 16 to 20 years of experience (11.2%), and workers with 20 years of experience or more (7.0%) of the workforce.

- Reliability Statistics

In Statistics, reliability is in order to measure the inner consistency among variables. This reliability statistic is known as pilot testing of investigation.

RS - Reliability Statistics	
Cronbach's Alpha	Number of Items
.9745	19

Fig.23: Reliability Test

In reliability statistics, Cronbach's alpha having value of .9745 which is considered as excellent for further proceeding of this investigation & N of items are 19. Reliability statistics values are good for further proceeding.

- Correlational Analysis

In the field of statistics, correlational analysis is employed to assess proposed hypotheses that stem from a theoretical framework model. The initial research hypothesis suggests that risk management

is positively associated with respect to organizational performance. The correlation coefficient for Risk Management and organizational performance is .158*, indicating a positive association. The level of significance is .000, and the sample size is 158 respondents.

		Correlations			
		Knowledge Management	Learning Orientation	Organizational Capabilities	Organizational Performance
Risk Management	Pearson Correlation	1	.349*	.070	.158*
	Sig. (2-tailed)		.000	.000	.000
Risk Management Strategy, Skills & Tools	Pearson Correlation	.349**	1	.143	.255**
	Sig. (2-tailed)	.000		.000	.000
Organizational Capabilities	Pearson Correlation	.070	.143	1	.913**
	Sig. (2-tailed)	.385	.074		.255
Organizational Performance	Pearson Correlation	.158*	.255*	.913**	1
	Sig. (2-tailed)	.000	.000	.000	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 24: Correlational Analysis

The second research hypothesis suggests that implementing risk management strategies has a positive effect on improving Organizational Capabilities. The correlation coefficient for Risk Management Strategy, Skills & Tools and organizational performance is .255**, indicating a positive relationship. The level of significance is 0.000, and the sample size is 158 respondents.

Third research hypothesis is about Risk Management Strategy, Skills and Tools moderates the relationship between risk management and organizational capabilities. The correlation value of Risk Management and organizational performance is .158* and having mediation effective of organizational capabilities is .913**, significant level is .000 and sample size n is 158 respondents.

Fourth research hypothesis is about Organizational Capabilities mediating between risk management

and organizational performance leads to having an organization having better and improved performance. The level of significance is 0.000, sample size is 158 respondents, and the correlational value between Risk Management Strategy, Skills & Tools and organizational performance is .255**. The moderating influence of organizational capacities is .913**. As a result, the framework of this investigation is supported by all of these research theories.

- Hypotheses

The hypotheses are derived by using correlational analysis. The outcome of hypotheses assessment summary is presented in the form of table are assumed below:

Hypotheses	Correlational Value	Significant Level	Remarks (Admit / Reject)
H1	.158*	0.000	Admit
H2	.255**	0.000	Admit
H3	.158* And .913**	0.000	Admit
H4	.255** And .913**	0.000	Admit

Table 1: Hypotheses Assessment Summary

Research hypotheses, correlational values, levels of significance, and statements designating acceptance or rejection are only a few of the important components that make up the summary of hypotheses evaluation.

According to the first research hypothesis, Risk Management and organizational performance are positively correlated. Risk Management and organizational performance have a .158* correlation value, which indicates a favorable link. The related comment recommends acceptance, and the level of relevance is noted as .000.

According to the second research hypothesis, Risk Management Strategy, Skills & Tools and organizational performance are positively correlated. Risk Management Strategy, Skills & Tools and organizational performance have a .255** correlational value, which indicates a very significant positive link. The significance level is shown as 0.000, and the comment that follows denotes approval.

According to the third study hypothesis,

organizational capabilities also have a mediating role in the relationship between Risk Management and organizational performance. Risk Management and organizational performance have a .158* correlation value, and organizational capabilities have a .913** mediating influence. The comment indicates acceptance and specifies the level of relevance as .000.

According to the fourth study hypothesis, organizational capacities have a mediating role in the relationship between Risk Management Strategy, Skills & Tools and organizational performance. Risk Management Strategy, Skills & Tools and organizational performance have a .255** correlational value, and organizational capabilities have a .913** moderating influence. The related comment denotes acceptance and the level of significance is noted as 0.000. As a result, each research hypothesis is verified, supporting the investigation's theoretical framework.

- Multiple Regression

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.367 ^a	.135	.118	1.57184

a. Predictors: (Constant), Organizational Capabilities, Risk Management, Risk Management Strategy, Skills & Tools

Table 2: Model Summary

Organizational performance was the dependent variable, and the findings showed that organizational capabilities, Risk Management, and Risk Management Strategy, Skills & Tools were the main predictors in the model summary. With a score of 36.7%, R indicates that a regression has occurred. The standard error of estimation is 1.57184, the R square value is 13.5%, and the adjusted R square is 11.8%. These values are regarded as acceptable and offer a strong foundation for the development of this inquiry.

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	59.276	3	19.759	7.997	.000
	Residual	380.483	154	2.471		
	Total	439.759	157			

a. Predictors: (Constant), Organizational Capabilities, Risk Management, Risk Management Strategy, Skills & Tools
b. Dependent Variable: Organizational Performance

Table 3: ANOVA Analysis

Frequency analysis is the main emphasis of this ANOVA analysis, as shown by the F value of 7.9%, which indicates that the variation within the model is significant at 0.000. These results are also supported by other related numbers. The findings show that the sum of squares and degrees of freedom are used to evaluate the regression and residual values, with values of (59.276, 380.483, and 3, 154) and mean square values of (19.759 and 2.471) correspondingly. These ANOVA analysis results give a solid foundation for continued development of this inquiry. The following results of the coefficient analysis are listed:

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.535	.690		3.673	.000

	Risk Management	.409	.118	.278	3.450	.001
	Risk Management Strategy, Skills & Tools	.675	.158	.349	4.289	.000
	Organizational Capabilities	.029	.102	.022	.288	.773

a. Dependent Variable: Organizational Performance

Table 4: Coefficient Analysis

The main goal of the coefficient analysis, which was developed using multiple regression analysis models, is to find the study variables' best predictors by using standardized coefficients. Using the Beta value, these standardized coefficients are measured. Risk Management Strategy, Skills & Tools, with a Beta value of .349, is the first and most significant predictor, according

to the results. With a Beta value of .278, the second predictor, Risk Management, follows closely behind, and subsequent predictors follow suit. All of these factors are therefore considered important and offer a solid foundation for continued development of this inquiry.

- Mediation Analysis

In statistical term mediation analysis plays an active role to properly analyze the real worth of mediation in framework model. The outcome of mediation analysis is presented in the form of table are assumed below:

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399 ^a	.159	.142	1.54985

a. Predictors: (Constant), Moderator Variable, Risk Management, Risk Management Strategy, Skills & Tools

Table 5: Model Summary

According to the findings, the moderator variable, Risk Management, and Risk Management Strategy, Skills & Tools are the main predictors in the model summary, with organizational performance serving as the dependent variable. R, which represents the regression and represents 39.9%, is used. The calculated R square value is 15.9%, the adjusted R square is 14.2%, and the estimated standard error is 1.54985. These values represent a solid basis for moving this inquiry forward. The following is a summary of the ANOVA analyses' findings:

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	69.948	3	23.283	9.693	.000
	Residual	369.911	154	2.402		
	Total	439.759	157			

a. Predictors: (Constant), Moderator Variable, Risk Management, Risk Management Strategy, Skills & Tools
b. Dependent Variable: Organizational Performance

Table 6: ANOVA Analysis

The F value of 9.693%, which shows the variation within the model at a significant level of 0.000, indicates that the main purpose of this ANOVA

analysis is to undertake frequency analysis. This judgment is consistent with other related values. With values of (69.848, 369.911 and 3, 154) and mean square values of (23.283 and 2.402), respectively, the sum of squares and degrees of freedom are used to evaluate regression and residual values. The results of the ANOVA analysis lay a strong foundation for the development of this inquiry. Below are the findings of the coefficient analysis:

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.534	.610		4.157	.000
	Risk	.393	.116	.267	3.377	.001

Management				377	.01
Risk Management Strategy, Skills & Tools	.711	.153	.367	4.637	.000
Moderator	.255	.120	.158	2.118	.039
Variable					

9. Dependent Variable: Organizational Performance

a. Dependent Variable: Organizational Performance

Table 7: Coefficient Analysis

The main goal of the coefficient analysis, which was built using mediation analysis models, is to determine the study variables' best predictors using standardized coefficients. The Beta value is a representation of these standardized coefficients. The results show that Risk Management Strategy, Skills & Tools, which has a significant Beta value of .367, is the main and most important predictor. Risk Management, the second predictor, follows closely behind with a Beta value of .267, and successive predictors continue this trend. All of these factors are therefore regarded as crucial and provide a strong foundation for the development of this inquiry.

V. CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH

- Conclusions

Organizations must identify, evaluate, and reduce any risks that could affect their operations, goals, and overall performance. This is done through the process of risk management. There are several ways in which an effective risk management system can enhance organizational performance. Detailed

justifications of how risk management is linked to improved organizational performance are provided below:

- **Enhanced Decision-Making:** A thorough risk management plan makes sure that decision-makers are aware of all potential hazards related to various business activities. This enables them to take well-informed decisions, reducing the possibility of unanticipated negative effects and maximizing the utilization of available resources to meet corporate objectives.
- **Enhanced Stakeholder Confidence:** Successful risk management procedures show a dedication to openness, responsibility, and the organization's long-term viability. In turn, this promotes confidence and trust among all parties involved, including customers, employees, and investors. Increased consumer loyalty, easier access to capital, and a more engaged workforce are all indicators of higher stakeholder confidence and all boost organizational performance.
- **Proactive Approach to Challenges:** Organizations can avoid or reduce the negative effects of various uncertainties by predicting potential risks and implementing proactive methods to manage them. Businesses can improve their competitive edge and overall performance by adopting this proactive strategy, staying ahead of the curve, adapting to shifting market conditions, and seizing opportunities that their rivals would pass over.
- **Cost reduction and efficiency improvement:** Organizations can prevent expensive disruptions and operational inefficiencies by identifying and resolving risks early in the process. Organizations can employ risk mitigation techniques to lessen their exposure to monetary losses, legal liabilities, and operational downtime. This reduces costs and increases operational effectiveness, all of which help to improve organizational performance.

- **Compliance and Regulatory Adherence:** Good risk management makes ensuring that businesses follow all applicable rules, laws, and standards. Organizations can avoid fines, reputational harm, and business interruptions by adhering to the law, preserving their good standing with customers and other stakeholders. The culture of ethical and responsible business practices that is fostered by regulatory compliance adds to the organization's credibility and helps it succeed in the long run.
- **Better Resource Allocation:** By prioritizing areas of possible risk and allocating resources accordingly, risk management helps companies utilize resources more effectively. This guarantees that resources are allocated to tasks that will have the biggest influence on the organization's strategic goals, resulting in the best possible resource utilization and increased performance overall.
- **Business Continuity and Resilience:** A strong business continuity plan is a key component of an efficient risk management strategy, ensuring that businesses can carry on even in the face of adversity like natural catastrophes, economic downturns, or unanticipated market developments. Businesses can lessen the effects of disruptive events and rapidly resume routine operations by ensuring business continuity, protecting their performance and reputation.

Organizations may improve decision-making, boost stakeholder confidence, approach difficulties proactively, decrease costs and improve efficiency, assure compliance and regulatory adherence, allocate resources wisely, and preserve business continuity by managing risks effectively. Improved organizational performance, sustainability, and long-term success are all outcomes of these elements working together.

Enhancing an organization's overall capabilities and guaranteeing its long-term success depend on implementing risk management techniques. Organizations can improve their capacity to adapt to

shifting environments, seize opportunities, and successfully handle challenges by recognizing, analyzing, and managing possible risks. The following are thorough justifications of how applying risk management techniques enhances and benefits organizational capabilities:

- **Strategic Planning is strengthened** as a result of the implementation of risk management methods, which drives businesses to conduct in-depth evaluations of their internal and external surroundings to find potential risks and opportunities. Organizations are better able to create strategic plans that are well-informed, efficient, and in line with their goals, strengths, and market conditions because to this thorough awareness of risks.
- **Improved Operational Efficiency:** Risk management solutions assist firms in identifying operational vulnerabilities and putting mitigation strategies into place. Organizations may optimize resource allocation, streamline their processes, and improve workflow by addressing inefficiencies and possible disruptions early on. As a result, operational capabilities of the organization are increased along with operational efficiency and the capacity to supply goods and services more successfully.
- **A culture of invention and creativity is promoted** within the organization as a result of risk management measures being used. Employees are given the freedom to think critically and come up with novel solutions to difficult problems by proactively addressing potential dangers. This encourages employees to experiment with new concepts and methods, creating a dynamic and flexible work environment that eventually improves the organization's capacity for innovation and market competitiveness.
- **Strengthened Resilience and Flexibility:** By equipping the organization to endure unforeseen disruptions, effective risk management techniques increase organizational resilience. Organizations can swiftly adjust to changing conditions and

recover from negative occurrences by creating contingency plans and putting risk mitigation measures into place. This increases their resilience and flexibility in the face of adversities.

- **Enhanced Decision-Making:** By putting risk management strategies into practice, decision-makers are given access to thorough and reliable data on potential risks and their potential effects on the business. This makes it possible to make more strategic and informed judgments, which lowers the possibility of making choices that could adversely impact the organization's capabilities and long-term success.
- **Better Resource Allocation:** Organizations can better allocate their resources by identifying and controlling risks. This entails maximizing investments in technology, human capital, and financial resources in a way that is consistent with the organization's risk tolerance and strategic goals. The ability of the organization to use its resources efficiently and effectively is improved through better resource allocation, which boosts overall performance and competitiveness.
- **Improved Stakeholder Relationships:** The application of effective risk management solutions creates confidence and trust among stakeholders, including investors, clients, and staff. Organizations may improve support, loyalty, and engagement from their stakeholders by showing a commitment to detecting and mitigating potential risks. Strong stakeholder relationships improve the company's capacity to draw in capital, keep consumers, and recruit top people, all of which contribute to its overall success and expansion.

Strategic planning, operational effectiveness, innovation, resilience, decision-making, resource allocation, and stakeholder relationships are all improved by putting risk management concepts into practice. These enhancements work together to strengthen the organization's overall capabilities, empowering it to adapt to change, grasp

opportunities, and experience sustainable development and success in a fast-paced, difficult business climate.

The efficiency of the risk management plan, the competence of the employed skills, and the use of relevant tools inside the business can all help to moderate the relationship between risk management and organizational capacities. The interaction of these variables has a big impact on how well a company can use risk management to improve its capabilities. The manner in which the risk management plan, capabilities, and resources control the connection between risk management and organizational capabilities is explained in more depth below:

Comprehensive Risk Management Strategy: The cornerstone for enhancing organizational capabilities is a well-developed and comprehensive risk management strategy. This plan should take into account risk identification, assessment, mitigation, and monitoring while coordinating with the organization's goals and risk tolerance. A strong risk management strategy guarantees that the company is prepared to proactively address possible risks and seize opportunities, so improving its overall skills to successfully traverse uncertainties and obstacles.

Competent Risk Management Skills: The organization's capacity to successfully implement risk management strategies is largely influenced by the competence of the persons participating in the risk management process. For the risk management strategy to be effectively implemented, qualified personnel with experience in risk assessment, data analysis, decision-making, and communication are required. Effective resource allocation, prompt risk response, and the ability to make educated decisions all help the organization increase its capacity to handle uncertainty and promote sustainable performance.

Tools for Effective Risk Management: The efficient implementation of the risk management plan depends on the use of appropriate risk management tools and technologies. These tools can aid with real-time risk identification, analysis, and monitoring and can include risk assessment software, data analytics platforms, and communication and reporting tools. Utilizing cutting-edge solutions, organizations may

improve their capacity to collect and analyze pertinent data, spot emerging hazards, and make data-driven decisions, empowering them to manage risks proactively and improve performance.

Integration of Risk Management into Organizational Culture: Improving organizational capabilities requires effective risk management integration into organizational culture. Risk detection and mitigation at all levels are fostered when risk management is integrated into an organization's core values and daily activities. By integrating risk management into strategic decision-making and operational procedures, the company is better able to react to changing external conditions, invent new solutions, and experience sustainable growth.

Continuous learning and adaptation within the organization are crucial for keeping up with changing risks and strengthening organizational skills. In order to do this, risk management processes must be continually updated, skills must be improved through training and development programs, and emerging technology and best practices must be incorporated. Organizations can improve their capacity to successfully manage risks, exploit opportunities, and maintain a competitive edge in dynamic business settings by cultivating a culture of constant learning and adaptation.

Organizations can successfully moderate the relationship between risk management and organizational capabilities by ensuring the presence of a thorough risk management strategy, competent risk management skills, suitable risk management tools, integration into organizational culture, and a focus on continuous learning and adaptation. With the help of an all-encompassing strategy, organizations can effectively manage risks, seize opportunities, and develop resilient capabilities that promote long-term performance and success.

Understanding how the efficient management of risks affects and enhances overall organizational performance depends on the mediating role of organizational skills between risk management and organizational performance. Organizational skills serve as the intermediary components that allow risk management procedures and procedures to transform into observable performance improvements. In order to better understand how

organizational skills, influence the relationship between risk management and organizational performance, we will first provide a full explanation:

- **Organizational capabilities** help with adaptive decision-making by using the knowledge gained from risk management procedures. Organizations can use risk management data to inform decisions that are in line with their strategic goals and market dynamics. By being flexible in its decision-making, the business is better able to take advantage of opportunities and reduce risks, which eventually improves performance as a whole.
- **Resource Optimization:** Organizational skills make it possible to make the best use of the information and insights that risk management procedures supply. Organizations may efficiently allocate resources, prioritize activities, and reduce resource waste by identifying and mitigating possible risks. This resource optimization boosts operational effectiveness, cost-effectiveness, and asset utilization, all of which help to increase organizational performance and profitability.
- **creativity and Agility:** By incorporating risk management insights into the organization's strategic planning and operations, organizational capabilities build a culture of creativity and agility. Organizations can spot emerging trends, foresee market upheavals, and create cutting-edge solutions that address changing client needs by utilizing the knowledge gathered via risk management procedures. This encourages innovation, fosters market responsiveness, and strengthens the organization's competitive edge, all of which contribute to greater performance and market position.
- **Effective Risk Mitigation:** Organizational capabilities make proactive actions based on the knowledge supplied by risk management processes possible. Organizations can protect their operations and improve their resilience by adopting effective risk mitigation

measures that reduce the impact of potential risks and uncertainties. A stable company environment, uninterrupted operations, and reputation protection are all made possible by this efficient risk mitigation capabilities, which ultimately improves overall performance and sustainability.

- **Trust and Confidence of Stakeholders:** Organizational competencies help to foster stakeholder trust and confidence by displaying a strong commitment to properly managing risks. Organizations can inspire trust among stakeholders, such as investors, customers, and workers, by incorporating risk management strategies into the organizational culture. The organization's reputation and market standing are improved as a result of this trust and confidence, which eventually has a favorable impact on the organization's overall performance and long-term success.
- **Operational Resilience:** By incorporating risk management insights into the organization's business continuity and crisis management plans, organizational capabilities improve operational resilience. Organizations may create effective contingency plans, ensure smooth operations during crises, and quickly recover from interruptions by identifying and managing potential risks. This operational resilience skill helps the organization keep up its performance and lessen the effects of unfavorable circumstances, assuring its long-term viability and success.

Organizations can use their risk management practices to improve adaptive decision-making, resource optimization, innovation and agility, effective risk mitigation, stakeholder trust, and operational resilience by understanding how organizational capabilities mediate the relationship between risk management and organizational performance. Together, these upgraded capabilities improve organizational performance, profitability, and sustainability, setting up the company for long-term success in a fast-paced, cutthroat market.

VI. FUTURE RECOMMENDATIONS

For organizations to perform at their best and remain viable over the long term, risk mitigation through effective management is essential. Here are some proposals for the future to better develop this strategy:

- Utilize cutting-edge data analytics and artificial intelligence techniques to improve risk assessment and predictive modeling. This will allow for proactive risk management and well-informed decision-making.
- Foster a culture where risk awareness and management are integrated at all organizational levels by highlighting the significance of recognizing, evaluating, and reducing risks as part of routine business operations.
- **Regular Training and Skill Development:** Conduct regular training sessions to improve staff members' risk management knowledge and abilities, enabling them to effectively support the organization's risk reduction efforts.
- Promote cross-functional communication and collaboration between departments to foster a comprehensive awareness of risks and to guarantee a coordinated approach to risk management throughout the business.
- Establish reliable monitoring and assessment procedures to continuously examine the efficacy of risk management techniques, allowing for timely corrections and enhancements as necessary.
- Develop a comprehensive risk management framework that covers many types of risks by implementing a diverse approach to risk management, incorporating multiple techniques like risk transfer, risk avoidance, and risk acceptance.
- **Enhance Regulatory Compliance:** Keep up of industry-specific rules and compliance needs, and make sure that the organization's risk management procedures comply with legal requirements to reduce the risk of fines and reputational harm from regulators.

- Invest in Resilience Planning: Create thorough business continuity and crisis management strategies to increase the organization's resilience against potential setbacks and guarantee the continuation of operations in the event of unplanned events.
- Regular Risk Assessment and Scenario Planning: Perform routine risk assessments and scenario planning exercises to identify potential hazards and create backup plans that will allow the organization to quickly address new issues and capture opportunities.
- Building trust and confidence with stakeholders through open communication, sharing information about the organization's risk management procedures, and demonstrating a commitment to risk mitigation and improving organizational performance can strengthen stakeholder engagement.

By putting these recommendations into practice, firms may develop their internal capabilities, and eventually improve their sustainability and overall performance in a business environment that is becoming more dynamic and competitive.

strengthen their risk management procedures even more.

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Blockchain-based Security Framework for IoT Devices in Industrial Automation: A Comprehensive Review

Karthik Kumar Vaigandla¹, Madhu Kumar Vanteru², Ranjith Kumar Siddoju³

^{1,2}Associate Professor, Electronics and Communication Engineering, Balaji Institute of Technology and Science, Warangal, Telangana, India.

³Assistant Professor, Electronics and Communication Engineering, Sree Chaitanya College of Engineering, Karimnagar, Telangana, India.

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Abstract— The widespread use of industrial automation Internet of Things (IoT) devices has seen great transformation in operational efficiency and decision-making. But these interconnected environments have nevertheless raised a major concern about their security challenges. Blockchain technology is a promising solution to the challenges of infrastructure because of its decentralized, transparent and tamper proof characteristics. We discuss in this paper how blockchain based security frameworks are being used in IoT devices for industrial automation right now. It first conducts an in depth analysis of existing approaches and their pros and cons before concluding with research gaps. In addition, it explores integration of blockchain with involving technologies for IIoT ecosystems' security.

Keywords— Blockchain, Security, IoT, IIoT, Industrial Automation, Smart Contracts.

I. INTRODUCTION

The development of Industry 4.0 has brought IoT devices into Industrial Automation allowing real time monitoring, predictive maintenance and control they're Industrial operations. Whilst these benefits are impressive, the interconnection of IoT devices in general opens industrial systems to a wide range of security threats, such as loss of data, unauthorized access, and system disruption. Industrial IoT environments suffer from their scalability, heterogeneity, and resource constraints, and these traditionally common security mechanisms are not sufficient to deal with such problems. Security using blockchain technology is achieved through a decentralized approach to security, including data integrity, authentication and fault tolerance without a central authority [1].

Industrial Internet of Things (IIoT) technologies have witnessed rapid growth and have provided transformative advantages to industrial

automation, which has led to smart factories, greater efficiency and smaller operational costs. At the core of this transformation is IIoT devices: sensors, actuators, and controllers producing massive amounts of data enabling real time monitoring and decisions. Yet as more and more devices link to the Internet the complexity, scope of security risk is growing. Consequently, IIoT systems are particularly susceptible to different types of threats such as unauthorized access, data breaches or attacks to device integrity [2]. Industrial sectors, including in manufacturing, energy, logistics and healthcare, are facing serious vulnerabilities that leave them exposed to serious financial loss, operational downtime as well as physical damage in case of an attack.

To address these challenges, blockchain technology has the potential to be something of a silver bullet, providing security for IoT devices in the industrial automation realm. Being decentralized and immutable, Blockchain provides a strong canvas to

ensure data integrity, confidentiality, and authenticity that is exchanged between IoT devices. The removal of central authority centralizes the authority in the blockchain, which improves transparency and accountability in IIoT networks, which is important for the identification of the malicious actors. One of the major security advantages of blockchain, enabling secure and verifiable transactions between devices, makes it a perfect tool to satisfy some, if not all, key security concerns: device authentication, data integrity, and secure communication.

This review goes through the potential advantages blockchain based security framework provides for IoT devices in Industrial automation specifically with respect to security requirements of the IIoT environments. In the review of the current state of blockchain technologies for industrial automation is considered a range of use cases, advantages and thorny issues when using them. Additionally, it presents ideas on the critical components of a blockchain based security system including consensus mechanisms, smart contracts and decentralized identity management, as means of improving IoT devices security. This review identifies existing gaps in the research and specifies future directions to give an overall view of how blockchain can revolutionize IoT security in the industrial automation in order to ensure safe and protected industrial systems.

At the time the industrial sector has turned to IoT technologies and the need for robust and scalable security solutions has never been bigger. The combination of blockchain based security frameworks is a potential, mature and effective solution to address these requirements as it provides the decentralized trust, increased resilience and transparency at IIoT network level. While technically possible, implementation of blockchain in this domain faces questions that need to be addressed, including technical, operational, and regulatory barriers, these being the subjects to be covered by this review. Reviewing the challenges and solutions to integration of blockchain in obtaining security for IoT devices on industrial automation system can lead to a body of knowledge to support the integration of blockchain in securing IoT devices in industrial automation system.

In this paper, we propose to discuss in detail about blockchain based security framework for IoT devices in industrial automation. It assesses the present picture, acknowledges problems and envisages directions for research and policy work.

II. IOT SECURITY CHALLENGES IN INDUSTRIAL AUTOMATION

The complex interplay of devices, networks and systems makes IoT security in industrial automation a challenging problem. In the IoT ecosystem, industrial automation systems can proactively significantly enhance their security posture by solving these challenges.



Fig.1. Security challenges in IoT

2.1 Data Integrity and Confidentiality

Data integrity and confidentiality in industrial automation are of great importance to ensure operational stability, protection of sensitive data, and data access or manipulation integrity. Suffice it to say, IoT devices produce a ton of sensitive data, making them attractive points of cyber attack. A first priority is to guarantee data integrity and confidentiality when data is transmitted and stored. Data integrity ensures that data is accurate, consistent and that it hasn't been copied, tampered, or damaged while a message is being transmitted or being stored. Wired attackers intercept and modify data that is being transmitted between IoT devices and control systems. During transmission of data some noise or interference in the communication channels corrupt the data [5]. There may be

weaknesses in access controls in industrial systems, causing insiders, or strangers, to be able to modify critical data within such systems. Legacy systems often use outdated and unencrypted protocols, making data vulnerable to tampering. Data confidentiality ensures that sensitive information is accessible only to authorized users and entities. Data transmitted over insecure channels (e.g., HTTP instead of HTTPS) can be intercepted. Weak authentication mechanisms can allow hackers to access sensitive industrial data. Industrial IoT often relies on cloud platforms, which can be targets for data breaches. Attackers can exploit compromised devices to extract sensitive data.

2.2 Device Authentication and Authorization

For a successful industrial automation network, authentication and authorization are necessary to secure the network against unauthorized access and network operation only by trusted devices. These security mechanisms thwart foreign entities accessing until the integrity, reliability, and confidentiality of industrial systems [6]. IoT device needs to authenticate, that is if it is different from what it says it is. Without the proper strong authentication mechanisms, malicious actors can bring rogue devices into the network. So many IoT devices ship with default and often useless username and passwords which attackers can easily break into. Although devices may authenticate a server, the server may not authenticate itself to the device and become susceptible to vulnerabilities. When the number of IoT devices grows, we cannot manage authentication for thousands of devices easily. It decides the extent, above what the device is allowed to operate within the blanket network. If authorization mechanisms are not used properly, it can result in too much, or in no access at all, thereby endangering the security. We often also grant devices blanket access as opposed to having a device restrict itself to roles or functions. In an industrial automation environment, many times devices will join or leave the network and maintaining updated authorization policies becomes difficult. With the abundance of IoT devices comes the need for robust authentication mechanisms to protect against unauthorized access as well as to only allow trusted devices talk within the network. Current deployments of IoT in industrial settings are in

remote or unattended locations. Physical tampering with or theft of devices, inserting rogue devices into the network, and not having surveillance and monitoring, are the challenges.

2.3 Scalability and Interoperability

Industrial IoT networks are complex and, as such, offer great opportunity and challenge in security for the uniformity of security measures. They also transmit and store enormous masses of sensitive operational data, and breaches are a gaping vulnerability for them. Data breaches and exfiltration. Manipulation or corruption of data impacting decision-making. Non-compliance with data protection regulations. The absence of uniform security standards in IoT devices and protocols creates compatibility and security gaps. The various challenges are difficulty in integrating devices from different vendors securely, use of outdated or proprietary protocols and Inconsistent implementation of security features. As the number of IoT devices grows, ensuring security becomes increasingly challenging. There may be difficulty in managing and monitoring large-scale deployments, increased risk of DDoS attacks and insufficient resources to handle real-time threat detection [7].

2.4 Fault Tolerance and Reliability

System failures or attacks on centralized security architectures can lead to significant operational disruptions. Decentralized approaches are crucial for maintaining reliability and fault tolerance. Industrial automation often involves third-party vendors and systems. The different challenges includes supply chain attacks through compromised components, lack of transparency in vendor security practices and risk of backdoors or malware from external integrations. Many industrial automation systems are built on legacy infrastructure not designed for IoT integration. They are incompatibility with modern security solutions, unpatched vulnerabilities due to outdated software and high cost and complexity of upgrading legacy systems. Industrial systems require low latency and high reliability, often limiting the implementation of heavy security measures. But performance and security comes at a trade of price, the problem of finding real time intrusion detection is hard, and there is a risk of system downtime if a security breach occurs.

III. BLOCKCHAIN TECHNOLOGY: AN OVERVIEW

Decentralized and distributed ledger system that aims to work safely & transparently record transactions across multiple machines. First conceived in 2008 as the foundational technology behind Bitcoin, the first cryptocurrency, by an entity known as Satoshi Nakamoto, it initially emerged as open source in 2009. Blockchain has evolved to include multiple uses and is not only used for digital currencies, but also banking, supply chain management, healthcare and industrial automation.

Block chain essentially refers to a series of blocks, each with a bunch of transactions included. Because these blocks are connected using cryptographic hashes, once a block is integrated into the chain, its contents cannot be changed, without changing all other blocks afterwards in a computationally impossible way [8]. It's lack of immutability makes it highly resistant to fraud, it is essentially impossible to manipulate the blockchain. By consensus, such as Proof of Work (PoW) or Proof of Stake (PoS), blockchain transactions are authenticated, where all participating nodes must agree on the ledgers state.

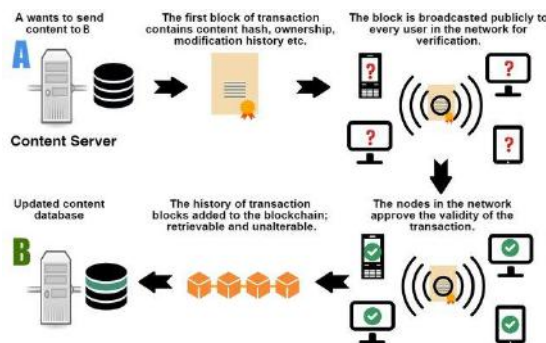


Fig.2. Overview of the blockchain working principle

Because blockchain operates on a peer to peer (P2P) network, it doesn't require the use of middlemen like banks or clearinghouses. It also makes for more transparency and less transaction cost. In addition, by employing state of the art cryptographic methods, blockchain ensures the privacy as well as the security of participants, who are able to preserve anonymity as they authenticate transactions. Built on blockchain, smart contracts self-executing contracts with terms encoded directly extend its functionality by building automated

operations and reducing intermediaries' dependence. There are some benefits to blockchain technology, however, it is facing challenges of scalability, as well as energy consumption (PoW systems specifically) and regulatory uncertainty. Yet advancements, including Layer 2 solutions, green consensus mechanisms and regulatory frameworks, have sought to solve these [9]. As the technology behind blockchain matures, it is having a major impact on industries by way of adding safety, transparency and efficiency to what it has introduced, pointing to blockchain as a transformative force of the digital age.

3.1 Core Features of Blockchain

- *Decentralization*: It removes the need for a central authority, making single points fail.
- *Immutability*: As a guarantee that data written on the blockchain won't be retrievable and then obsolete.
- *Transparency*: Allows all participants in the network to view transaction records.
- *Security*: Cryptographic mechanisms protect data confidentiality and integrity.

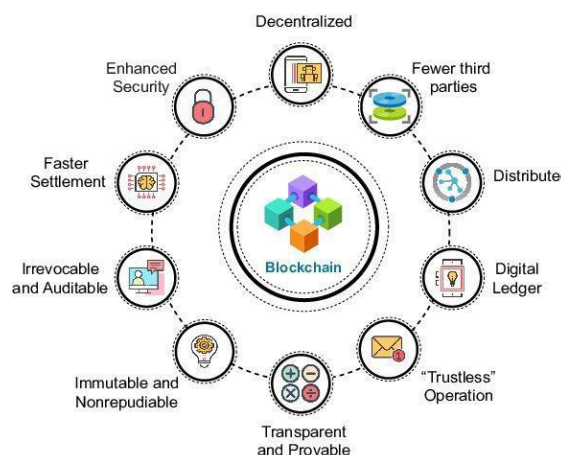


Fig.3. Core features of blockchain

3.2 Consensus Mechanisms

Consensus algorithm is used in blockchain to validate transactions. Common mechanisms include:

- *PoW*: Ensures security through computational effort but is resource-intensive.
- *PoS*: Minimizes energy usage by choosing validators according to their stake.
- *PBFT*: Suitable for private blockchains with high throughput requirements.

3.3 Smart Contracts

The term 'Smart contracts' refers to self executing programs that are stored on the blockchain and executes predefined rules to do something like authentication or access control.

IV. BLOCKCHAIN-BASED SECURITY FRAMEWORKS FOR IIOT

Currently, blockchain technology is being widely adopted as a solid security solution to the IIoT, especially in the aspects of data integrity, device authentication, and security communication. IIoT systems are made up of interconnected devices, sensors and machinery that collectively collect and share critical operational data in industrial settings. However, traditional centralized security models face challenges with scale, complexity and dynamic IIoT networks, making blockchain based models an attractive alternative.

The use of blockchain based security framework exploits the decentralized, immutable and transparent nature of blockchain to secure and trustworthy base operations in IIoT ecosystems. Work done in these frameworks rely on using distributed ledger technology (DLT) to remove probability of exploits occurring in the form of single points of failure. IIoT devices are recording transactions and data exchanges over tamper proof blocks for data integrity and traceability. Beyond, smart contracts can be used to automate and enforce security policies such as granting or revoking device access and make sure devices are indeed in compliance with operational protocols [10].

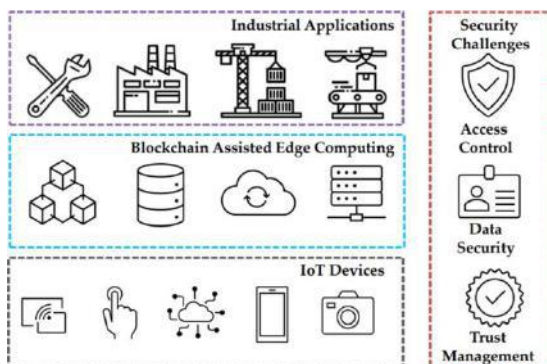


Fig.4. IoT systems and its security challenges

With device authentication and authorization being one of the critical IIoT applications of blockchain. The framework stores unique device identities on the blockchain and only trusted devices can access the network. The consensus mechanisms provide a mechanism to validate that devices are authentic and their activities and in addition prevent unauthorized entities from infiltrating the system. Moreover, the blockchain provides a secure means of sharing data between IIoT devices in encrypted and verifiable transactions so that sensitive information is not susceptible to interception or tampering.

However, current and potential IIoT blockchain deployments tend to struggle with high computational overhead, scalability limits, and incompatibility with existing IIoT systems [11]. But blockchain advancement efforts such as lightweight consensus algorithms, off-chain data storage and hybrid blockchain architectures will mitigate these problems. Potential solution to IIoT network security challenges can be provided by blockchain based security frameworks. Combining blockchain with IIoT allows industries to realize increased security, transparency, as well as operational efficiency, paving the way for smarter and more resilient industrial systems.

4.1 Architecture of Blockchain-based Frameworks

Specific use cases such as IIoT, financial systems, and supply chains are served by Blockchain based frameworks that are secure, transparent and decentralized frameworks. Other times, they are comprised of multiple layers and components that work together to create what wants to be achieved. Typical frameworks consist of

- *Blockchain Layer*: Stores transaction data securely and enables decentralized communication.
- *IoT Layer*: Comprises IoT devices, gateways, and edge computing nodes.
- *Application Layer*: Provides user interfaces and analytics tools.

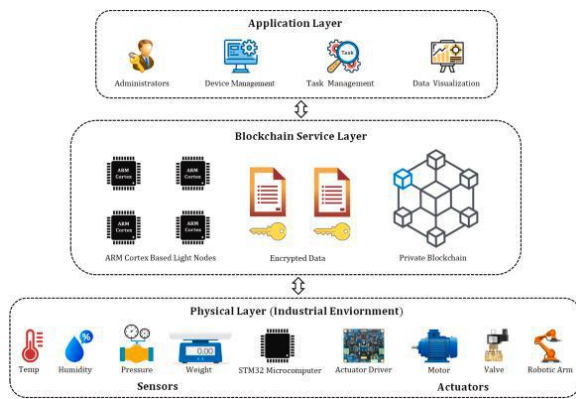


Fig.5. Architecture of Blockchain

4.1.1 Workflow in Blockchain-Based Frameworks

- *Transaction Initiation:* For example, a transaction (e.g, data sharing or smart contract execution) is submitted by a user or device.
- *Validation and Consensus:* Once the consensus is achieved the transaction is broadcasted to the network, validated by the nodes that participate and it will be included in a new block.
- *Block Creation and Storage:* An appended validated block will ultimately be added to the blockchain ledger, which means data immutability and this entire development process is repeatable.
- *Execution of Smart Contracts:* Smart contracts are used to enforce business rules or logic if needed.
- *Data Access and Reporting:* Data or interaction with the blockchain is retrieved by authorized users or systems using APIs or DApps.

4.1.2 Key Benefits of Blockchain-Based Frameworks

- *Security:* Tamper-proof ledger ensures data integrity and confidentiality.
- *Transparency:* Provides an auditable and immutable record of transactions.
- *Decentralization:* Eliminates reliance on a central authority, reducing vulnerabilities.
- *Scalability:* Advanced architectures enable scalability for large networks.

V. INTEGRATION WITH EMERGING TECHNOLOGIES

5.1 Edge Computing

Using Blockchain combined with edge computing reduces the latency and improves real time processing capabilities for IIoT applications. By merging the powerful cryptographic security of data decentralization with the best of real time data processing and edge computing, blockchain merge can be applied as a robust framework for modern digital ecosystem. This means that computational tasks are moved closer towards the data sources, like IoT devices, lowering latency and bandwidth utilization. This is where blockchain comes in to complement, and provide a secure, immutable, and decentralized way of checking data integrity, device authentication, and trustworthy communication across edge networks [12].

However, in traditional cloud centric architectures, data coming from edge devices is sent up to central servers to process and store the data, which creates high latency, scalability issues and potential security issues. The blockchain decentralized the data management process to address this challenge. They securely record transactions or device interactions at the edge in a distributed ledger, and are tamperproof and verifiable. This integration is especially important in the scenario of IIoT with real time decision making and high security standards.

Through the confluence of blockchain with edge computing, devices can securely communicate with one another and authenticate themselves, without relying on centralized authorities such as a human. As an example of this, smart contracts can be based on blockchain and can automate and enforce such access control policies at the edge, such that only authorized devices or users can access sensitive systems. Furthermore, it also helps in sharing data between edge nodes transparently and audibly log of interactions, and this raises the trust in the collaborative ecosystem like smart cities or the connected healthcare system. However, the integration of blockchain with edge computing suffers from computation overhead of blockchain operations and the resource constraints of the edge devices. To address these problems, solutions such as lightweight consensus mechanisms (e.g., Proof of

Authority) and hybrid architectures that offload critical blockchain function to more capable nodes, are being developed. Combining blockchain and edge computing opens up a powerful security, transparency, and efficiency-enhancing weapon in decentralized systems. With this integration poised to help advance applications ranging from autonomous vehicles, to industrial automation and to next generation smart infrastructures, it promises to become indispensable.

5.2 Artificial Intelligence (AI)

Putting blockchain data through an AI algorithm which detects anomalies and can predict potential security threats improves proactive defense. The combination of blockchain with AI enables powerful synergy by improving data security, transparency, and decision making within most applications. Blockchain's intrinsic decentralized and immutable characteristics are leveraged to solve many of the challenges surrounding AI, like data provenance, sourcing of trust, and participatory transparency, while AI helps optimize functions like consensus mechanisms, and fraud identification. Together, these technologies' solutions are more secure, more reliable, and more efficient.

Some great benefits of this integration are data integrity. Vast amounts of high quality data are needed to train and make decisions in AI systems, and determining authenticity and origin of data can be difficult. The data used by AI models is proven accurate and reliable due to blockchain's tamper proof record of data provenance [13]. In healthcare, finance and supply chain management, this is important because data integrity is critical.

Improving transparency and accountability of AI algorithm is another important advantage for others. And many AI systems fall into the category of "black box" systems, a reality which makes it difficult to understand or audit their decision making processes. With the ability to record AI Decisions and process on the blockchain, organizations can create an irreplicable audit trail that increases trust and ensures that regulations are followed. It is particularly useful for autonomous vehicles, credit scoring and legal decision making.

AI also helps Blockchain by optimising its functioning. Blockchain can be further secured using

AI to analyze the blockchain data and detect anomalies or any fraudulent activities. Moreover, AI can improve consensus mechanisms that would scale and improve the blockchain networks. For example, machine learning algorithms can forecast and counteract any network bottlenecks that may already exist, in real time. While there is much promise to integrating blockchain and AI, as with all decentralized technologies there are inherent hurdles such as the computational requirements for both and the integration with infrastructures being used. But lightweight blockchain protocols and edge AI are helping these problems.

Blockchain AI integration has the potential to be revolutionary by combining the trust and security of blockchain with the intelligence and efficiency of AI. It is creating a powerful combination that is reshaping industries in order to provide smarter and more secure solutions to an array of applications.

5.3 5G Connectivity

5G networks' high-speed and low latency communication complements blockchain's capability, allowing the seamless industrial automation. Blockchain integration with 5G connectivity has the prospect to revolutionize industries by delivering greater security, better efficiency and greater scalability for next generation networks as 5G provides faster data transfer speeds, lower latency and scales support massively connected devices - applications like autonomous vehicles, smart cities and industrial automated products. But, with more devices and data flows, security, data privacy and network management problems also increase. To overcome this challenge, Blockchain can offer a decentralized, secure and transparent solution for the management of the complex interactions within 5G networks [14].

Augmenting blockchain with 5G has one of the biggest advantages as it boosts the security. Blockchain's decentralized properties mean there are no single points it can be attacked from. It can be applied to secure authentication of devices, identity managing and the verification of transactions among devices in a 5G enabled ecosystem. This assures that only the allowed devices can access the network and thereby reduces the risk of cybercrime, data breach, and also fraudulence. Blockchain can also serve as a

secure and tamper proof ledger for network transactions and data exchange, then providing yet another layer of trust and transparency.

Moreover, blockchain makes it easier to manage network resources. Bandwidth, management becomes tricky and Quality of Service (QoS) more complex with growing number of devices in 5G network. According to Bisgaard, blockchain's smart contracts can execute the allocation and management of network resources according to certain conditions, which eliminates the requirement of manual interference and enhances the operation of the network. This is also possible by Blockchain: to support Decentralized and dynamic pricing models for network services that would allow users to pay for services in real time.

In addition, blockchain boosts the potential of 5G with regard to IoT, where billions of IoT devices will have to communicate securely and in a scalable manner. From a data exchange perspective, blockchain can form the backbone for the secure exchange of IoT data amongst IoT devices in a 5G network while at the same time guaranteeing data integrity, privacy and communication across devices [15]. But blockchain integration with 5G networks remains a challenge, as 5G networks require high computation from blockchain consensus mechanism and blockchain integration with different blockchain platforms need interoperability. To make the integration more feasible these issues, solutions such as lightweight consensus algorithms and hybrid blockchain architectures are developed. Using 5G connectivity in combination with the blockchain ensures that the network management deployed is secure, efficient and scalable and leaves open the path for full potential of next generation applications. The integration of autonomous vehicles and smart cities is only starting and the possibilities are endless in everything from audio systems to food delivery.

5.4 Cybersecurity

The integration of blockchain with cybersecurity provides a powerful solution to address the increasing threats and vulnerabilities in digital systems. Blockchain's decentralized, immutable, and transparent nature enhances traditional cybersecurity measures by ensuring data integrity, securing communications, and enabling decentralized

authentication and access control. In today's interconnected world, where cyberattacks are becoming more sophisticated and pervasive, this integration offers a robust defense mechanism to safeguard sensitive data and prevent unauthorized access [16].

One of the key advantages of combining blockchain with cybersecurity is its ability to ensure data integrity. Blockchain provides a tamper-proof ledger, making it nearly impossible for attackers to alter or manipulate data once it is recorded. This is particularly valuable in industries where data integrity is critical, such as finance, healthcare, and supply chains. Blockchain can also be used to securely store logs of system events and network transactions, creating an immutable audit trail that can be analyzed for signs of malicious activity.

Another significant benefit is in the area of identity and access management. Blockchain enables decentralized identity management, where users control their own identities using cryptographic keys. This reduces the risk of identity theft, phishing, and unauthorized access. Blockchain-based solutions, such as self-sovereign identities, ensure that user credentials are stored securely and that authentication processes are transparent and tamper-resistant [17].

Blockchain can also help mitigate DDoS attacks and other forms of network disruption. By decentralizing the flow of data and distributing it across a network of nodes, blockchain makes it more difficult for attackers to target a single point of failure. Additionally, blockchain can be integrated with smart contracts to automatically enforce security policies, detect anomalies, and respond to threats in real time, further enhancing the system's ability to defend against cyber threats.

However, integrating blockchain with cybersecurity is not a walk in the park. Consensus algorithms may be computationally expensive, or blockchain networks may be overly scaled for a high traffic environment. For this, while lightweight blockchain protocols and hybrid solutions which integrate blockchain with conventional approaches of security are being made.

By integrating blockchain, traditional security frameworks gain both decentralized, verified and

immutable solutions to prevent fraud, maintain data integrity as well as improve identity management. Together, this combination has the potential to secure digital assets, and mitigate against many cyber threats.

VI. RESEARCH GAPS AND FUTURE DIRECTIONS

For the past few years, we have seen a lot of attention paid to the integration of blockchain with IIoT for secure use cases. But unfortunately, there are still some research gaps which need future improvements in order to further exploit the application of blockchain as a means in securing IoT devices in industrial automation.

- **Scalability Challenges** : Scalability requires the development of lightweight consensus mechanisms well-adapted to IIoT environments.
- **Real-time Performance** : Research continues on optimizing blockchain frameworks for real time industrial applications.
- **Interoperability Standards** : Standardized protocols can improve adoption if we define them for integrating blockchain with heterogeneous IIoT systems.
- **Energy Efficiency** : For industrial deployment, blockchain operations need to be sufficiently sustainable and the energy consumption should be minimized.

Blockchain brings among them significant potential security improvement to IIoT environments, and however, the research gaps remain. To take these blockchain based security frameworks further will require them to address issues such as scalability, interoperability, privacy, real time security and resource constraints. Consequently, future research can explore the full potential of the blockchain to give us secure, efficient, reliable security solutions for industrial automation if we concentrate on these challenges.

VII. CONCLUSION

Blockchain technology has potential to increase IoT devices security also in industrial automation. The key to solving some of the problems with data

integrity, authentication and fault tolerance is the architecture which is decentralized, with features like immutability and smart contracts. Although great progress has been made, scaling, interoperability, and energy efficiency remain as challenges. There are gaps to be addressed in future research and the synergies with emerging technologies to unlock the full potential of blockchain in IIoT ecosystems should be once investigated.

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Energy Efficient Cooperative Quality of Service (QoS) Aware Routing Protocol for Wireless Body Area Sensor Networks

Fazal Ilahi

fazal.illahi@ptclgroup.com

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Abstract— Network Wireless Body Area Network (WBAN) is a promising technology for delivering quality healthcare to its users. Low power devices attached to the body have limited battery life. Nowadays the world is moving towards an era of wireless technologies for making the life of elderly people living alone in the houses easier. The latest innovative technologies improve and facilitates the daily life of human beings especially ambient assisted living. Internet [1] of Medical Things (IoMT) revolutionized the quality of life of people living in cities as well as in the far flung areas. Under the domain of IoT and WBAN integration, which leads towards a new emerging domain in technological Health care named as IoMT. The Main focus of this Research study is to improve the Quality of Service (QoS) in the Health care data transmission. Major problems in health care data transmission. It is desirable to have energy efficient routing protocol in WBAN that maintains the required reliability value for sending data from a given node to the sink Node. In this proposed research, the researcher intends to propose two routing protocols named as Improved Quality of service Aware Routing protocol for WBAN (IM-QRP) and Energy Aware Cluster based Routing protocol for Flying Ad hoc Networks (EA-CBRP-FAN). The performance of the proposed protocols will be compared with the existing routing protocols named as QPRD [1], CO-LAEEBA [2], E-HARP [3] and EEBSR [4]. IM-QRP will primarily concentrate on the enhancement of the fundamental metrics, including Signal to Noise Ratio (SNR), Path Loss Ratio, and Residual Energy of the Sensor Nodes. The Mat Lab Simulation tool will be used to create the IM-QRP results. The Simulation results will be compared with existing routing protocol. From the simulation results the researcher will try to observe the performance of IM-QRP Routing with existing ones in order to assess which performs better. Improving simulation results will be based on numerical percentage values. Better residual energy of the Sensor Nodes, reduction in path loss ratio, improvement in packet transmission (link reliability) towards the Sink nodes and improvement in SNR will be the aim.

Keywords— Wireless Body Area Network, Internet of Medical Things, Energy-efficient Routing, Quality of Service, Signal-to-Noise Ratio.

I. INTRODUCTION

1.0 Wireless Body Area Sensor Networks

Wireless body area network (WBAN) is a promising technology to provide intelligent health care services at remote locations. From the literature review, we have observed that since 2006 scientists and

researchers has focused more on Quality of service Aware (QoS) energy efficient routing techniques, network topology and Medium Access Control (MAC) layers used in WBAN. QoS aware routing techniques are based on a set of protocols which can maintain the routes efficiently and are capable of exchanging the data between sensor nodes effectively

[5].

The WBAN-related healthcare applications concentrate on enhancing medical infrastructure, particularly for senior citizens living at home. WBAN uses wireless computer devices to facilitate communication all over the human body [7]. As illustrated in Figure 1.1, the WBAN architecture is divided into three sub-tiers: Tier 1 is for intra-BAN communication, Tier 2 is for inter-BAN communication, and Tier 3 is for extra-BAN communication. The various types of sensor nodes that make up Tier 1 include ECG, EEG, and EMG sensors, glucose level sensors, blood pressure and temperature sensors attached to human bodies, to name just a few. The coordinator node inside the Tier 1 is capable for processing the data received from sensor nodes and transmits this information back to sink node located inside Tier 2. Sink node located inside Tier 2 directly communicates with Tier 3. Tier 3 consists of beyond body communication-based Network infrastructure [8]. In order to establish reliable communication between multiple tiers, Link reliability should be maintained between each Tier. Link reliability is an important QoS based parameter in WBAN. Optimal Link reliability is based on Received Signal Strength Intensity (RSSI).

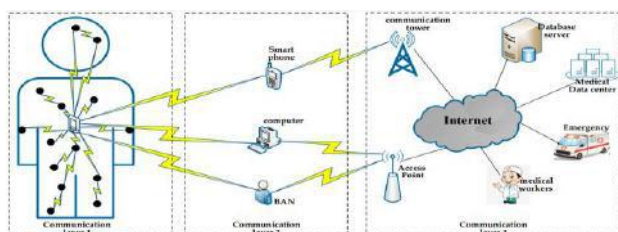


Fig 1.1: Three Tier Architecture of Wireless Body Sensor Networks [8]

A holistic healthcare system is becoming incredibly valuable as the world's population grows, the oldest, and increasingly more susceptible to health problems. Current healthcare expenditures will not be sufficient to satisfy future health needs. Indeed, most patients cannot receive treatment due to healthcare resources. Long-term hospital admissions result from financial restraints, employment obligations, and even familial responsibilities, regardless of whether their health must be examined immediately or on a short-term basis. There is much interest in developing wireless medical devices that can provide remote patient

monitoring in an invisible, efficient, and cost-effective manner to receive personalised, long-term healthcare [9]. More information about wireless communication standards research in healthcare settings may be found here. International interest in WBANs (Wireless Body Area Networks) for use in healthcare applications is growing as a result of its potential to both provide healthcare infrastructure and provide individuals with cost-effective and efficient healthcare options. WBANs, or wireless body area networks, are tiny networks comprising numerous small, lightweight sensors that can be worn as intelligent patches on the body or put nearby. These artificial nodes collect various physiological data, including heart rate and blood glucose levels. WBANs allow doctors and other medical professionals to constantly monitor the health of patients at risk of medical concerns, the elderly and chronically ill, those with disabilities, and others.

If high-reliability medical communications are to be provided, sensor nodes in such networks must communicate with each other. The development of good routing protocols in WBANs is a difficult undertaking. This is large because of the unique qualities of WBANs, but not exclusively. The first step is to determine how much energy each sensor node on the network can consume. Additional challenges arise because of the necessity for real-time data in many medical applications. Body temperature, heart rate, and blood glucose level are all examples of physiological data collected by a wide variety of commercially available sensor nodes. These sensors may not give the necessary data rate or battery life due to the illness. Because of this, the appropriate technology for transmitting data from the patient's body to medical personnel is dependent on several parameters, including dependability, power consumption, latency, weight, size and pricing. The continuous monitoring of the sensors allows medical workers to maintain track of the patient's condition. As a result, because the patients are not bound in bed, they can move around [10]. Four Tier based WBAN architecture developed for the health care systems. Four-tier body area network architecture is shown in Figure 1.2.

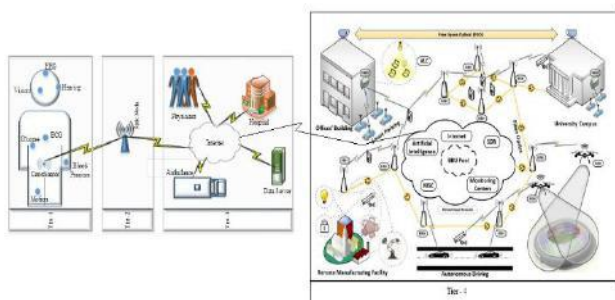


Fig 1.2: A 4-tier WBAN architecture [8]

The four-tier WBAN, which is connected to Tier 3 through the internet, adds new levels at Tier 4. Office complexes, college campuses, smart parking lots, and far-flung industrial sectors linked to the Internet of Drones make up Tier 4.

1.1 Classification of WBAN

Bio signals are detected by the WBAN detectors, which are then digitally translated and sent to an access point for further processing. Wearable sensors (on-body sensors) and implanted sensors (under-the-skin sensors) are both options (in-body sensors). Sensors are divided into two categories: those that only measure and transmit data and those that do both. The second kind, known as actuators, monitors and sends data the same way as the first, but it may also administer medication based on the data [11]. The information gathered is wirelessly forwarded to a medical server, evaluated, and saved. Depending on the system architecture and technologies used, this can be implemented in two, three, or four layers. Three layers are the most frequent architectural design for WBANs presented in the literature.

1.1.1 Intra WBAN

After PD communication, sensors communicate in Intra-WBAN. A wireless network at the first layer is unnecessary in certain existing approaches because sensors and PDs can be connected directly via wires. When using WBAN, the PD can transfer data wirelessly to a coordinator or master node, which then transmits data to an Access Point after processing, or to the PD can transmit data to an Access Point after processing (AP).

1.1.2 Inter-WBAN

Inter-WBAN refers to wireless technology communicating between the PD and AP. This layer

connects WBANs to other networks that are accessible via the Internet. Ad-hoc and infrastructure-based architectures are often employed in WBAN systems for secure transmission during inter-WBAN communication.

1.1.3 Beyond-WBAN

The link between AP and the local medical centre is denoted by the Beyond-WBAN symbol. A gateway is a device that facilitates data transmission to and from medical personnel through wireless or wired networks. After receiving the data, medical workers can monitor the patients and offer required health recommendations. This layer also enables the restoration of patient medical information, which may require proper therapy.

1.2 WBAN Applications

WBANs are already being used in the military, healthcare, sports, and entertainment. WBAN applications that need specific technology aim to improve people's quality of life. The sub-sections that follow show how WBANs are used in various sectors [9].

1.2.1 Medical Applications

WBANs indeed alter the future of healthcare systems by delivering a simple, safe, trustworthy, and rapid diagnosis of ailments. WBANs can diagnose and treat life-threatening illnesses at the moment, giving the patient immediate access to vital data. The introduction of microelectronics, sensors, the Internet, and wireless network technologies into healthcare has profoundly impacted the way people live and work. In conclusion, the broad adoption of WBANs will raise the bar for healthcare systems regarding illness management, diagnosis, and treatment. In medicine, it is common practice to employ WBANs to keep tabs on vital signs such as a patient's temperature, blood pressure, and heart rate under constant surveillance. The following WBAN subcategories are applicable to medical applications.

1.2.1.1 Wearable WBAN Applications

Two types of WBANs are used in wearable medical applications. a) Management of Human Performance and b) Disability Assistance, which we'll get into a bit more detail about next. Combat Stress and Combat Readiness Assessment of Military Personnel. When soldiers are on the front lines, WBANs allows for

precise tracking of their movements. An aggregation device integrated with WBANs can link cameras, biometric sensors, GPS, and wireless networking to connect with other soldiers and central monitoring units. To avoid ambushes, soldiers' ability to communicate securely is critical. WBANs may be used to regulate athletes' training schedules in both professional and amateur sports by monitoring metrics, motion capture, and therapy. All connectors and wires can be removed with WBANs, allowing the intelligence and instrumentation to be housed within the sensor nodes themselves.

1.2.1.2 Implant WBAN

This application involves implanting nodes into the human body, either beneath the epidermis or inside the circulation, to accomplish the following functions.

1.2.1.3 Diabetes Control

Diabetes afflicted around 6.4% of healthy adults globally in 2010 (a total of 285 million), with the amount expected to climb to roughly 438 million by 2030. (Almost 7.8% globally). Diabetes therapy, according to current research, is a long-term medical ailment that needs regular and extensive monitoring. WBANs may be used to test diabetes levels frequently, minimizing the risk of acute illness and allowing for ideal doses by removing the risks of blood circulation, blindness, and other complications.

1.2.1.4 Cardiovascular Illnesses

Almost 17 million people die each year from cardiovascular disease alone, a huge burden for the human health business. By utilizing appropriate healthcare, this number might be drastically lowered. For example, employing WBAN to screen for episodic occurrences and other odd scenarios might drastically reduce the number of myocardial infarction (MI) cases.

1.2.1.5 Cancer Detection

There will be a 50% increase in the number of persons dying from cancer by 2020. So, WBAN-based sensors can keep tabs on human cancer cells.

1.2.1.6 Remote-Controlled Medical Devices Based on WBANS

Ambient Assisted Living (AAL) is a home care system that uses Internet-enabled WBANs to connect to various equipment and services, including a remote medical network. Patient self-care can be extended at

home using the AAL, reducing dependency on costly personal care and expenses and improving quality of life. Because of its unique combination of anticipatory functionality, contextual sensitivity, user sociality, and flexibility, the AAL has great promise to create innovative new IT systems.

1.2.2 Non-medical Applications

Among the non-medical uses of WBANs, these subcategories are:

1.2.2.1 Real-Time Streaming

Video clips shot using a mobile phone camera can be streamed in real-time (2D and 3D) and used to advertise sports products and current fashion trends in e-commerce. You can listen (with headsets) to an art explanation in a museum or bus schedule information at a stop, as well as multicasting conference calls and musical samples in an audio CD store via audio streaming via voice communication. Real-time streaming signals can be used to identify body motions, vital signs, and other bodily information from remotely operated entertainment devices.

1.2.2.2 Entertainment Application

These programs are about gaming, listening to music, social networking, and other hobbies. Audio and video recording, playback equipment, high-tech computers, and networking hardware can be combined into WBANs. In addition to gaming, these devices can be used for virtual reality (VR), tracking personal belongings, exchanging digital profiles linked to business cards, and transferring consumer electronics-related data, among other applications.

1.3 Routing Mechanism Related to WBAN

Routing is a tricky problem in WBAN due to restricted resources such as memory, compute capability, and energy infrastructure. The physical layer of sensor nodes greatly affects WBAN energy consumption through radiofrequency (RF). Furthermore, the MAC protocols can enhance the sensor network's residual energy by changing the RF component's duty cycle. Physical and MAC layer techniques that improve network connectivity do not deal with end-to-end packet delivery, address allocation systems, or route selection procedures. In this case, the network layer is the best choice for addressing these challenges, and network layer routing options must be considered in energy savings. There are several aspects to consider

while building WBAN routing protocols, including the heterogeneous wireless nature (due to particular physiological data), higher energy Consumption, wider coverage area, reduced transfer dimensions, mobility, and quality of service. These factors are because WBAN transmits at a higher rate and transmits more data faster (priority-based data). According to all of the stated features, the temperature rise of implanted sensors has the greatest impact on WBAN performance. Sensor nodes might become dangerously hot due to radiation intake and energy consumption from the antenna. This damages heat-sensitive tissues and potentially causes tissue damage near sensor nodes. As a result, a WBAN routing algorithm that prevents body tissue from damage caused by a node's temperature rise requires extensive research. Data transmissions should be limited to reduce energy usage, and the proposed routing algorithm must choose the most efficient way from a list of options [12]. A network's life can be extended due to smart routing (considering temperature rise and residual energy).

1.3.1 Quality of Service (QoS) Aware Routing in WBAN

There isn't much discussion of QoS studies centered on WBAN applications in the literature. Numerous researchers have merely raised it as a concern without conducting any more research. In order to overcome channel degradation, the Researchers had tried and implemented QoS in WBAN. Due to the essential nature of the operations, the QoS concerns in WBAN require extra attention. The highest level of service is required in the functioning of a WBAN, for instance, which is used to monitor the health of an aged heart patient. QoS-Aware Wireless sensor network routing protocols have been developed, however no QoS-based standard routing method has been developed for WBAN [13]. In body area networks, routing protocols are often divided into three basic categories: temperature-based routing, cluster-based and cost-based routing. The most recent BAN network implanted on the human body is capable of sensing, processing, and storing information. Because of this, memory module, RF module, and microprocessor module are the most common sensor nodes utilized in medical applications.

Achieving QoS in WBAN is a difficult task. Received signal strength intensity (RSSI) at receiver side is the

key factor in achieving QoS. The core research challenges for achieving QoS requirement in WBAN are based on following motivational factors. The researchers have described the challenges for supporting QoS requirements including bandwidth minimization, limited energy consumption, and communication delay trade-off, handling limitation in buffer size, multiple traffic support, and redundancy removal. These all factors can apply to QoS constraints in WBAN applications.

Data packet priority and wireless channel conditions are examples of QoS indicators. Node ability to function as a router and data packet priority are further examples. RSM, APIs, PQSM, and System Information Repository (SIR) are all design components (SIRM). RSM, for example, can be used with the APIs module's capabilities. The APIs module includes four sub-modules: QoS-metric selection, which takes packet success ratio, power consumption, and the end-to-end delay into account. In this sub-module, received from the user program me, data packets are sent or received. It is up to the sub-module to set the priority level for data packets. A submodule is available for request processing and service level control, providing network conditions to user applications. There are eight categories of priority. Data and control packets are defined, with packets having the greatest priority [14].

In WBAN routing mechanism the data packets do not maintain and update their routing database based on information from their neighbors. Sensor nodes cannot connect to wireless channels owing to network congestion. Therefore, PQSM alerts user applications when buffer size reaches a certain level and advises them on lowering it. A router's willingness and service level must be high to minimize packet losses. Priority is granted to data packets in the submodule for setting packet priority levels. A separate sub-module can handle request processing and service level monitoring. The priority level setting sub-module prioritizes data packets. Request processing and service-level monitoring are provided in a separate submodule. Link health is monitored by latency, average packet success ratio, and channel bandwidth via the LS table. The RW database contains all nodes that can function as a forwarding node or router.

1.3.1.1 QoS-Aware Based Routing Protocols

QoS requirements for bio-medical sensors implanted in the human body necessitated the development of the thermal-aware targeted route (TLQoS). Communication loops are also prevented, and the protocol eliminates superfluous routes with large hop counts from the sink to reduce network latency. All neighboring nodes can be selected as forwarders using a technique called "targeted." Each of the three new peering routing protocols, the Energy-aware Peering Routing Protocol (EPR), the Quality of Service (QoS)-aware Peering Routing Protocol (QPRD), and the Quality of Service (QoS)-aware Peering Routing Protocol (QPRR), uses less power than the previous protocols in their respective functions. Some protocols don't allow for energy use, while others allow it [15].

Time-sensitive information can be delivered while maintaining reliability-sensitive information, such as with the data-centric multi objective QoS aware routing protocol (DMQoS). Protocols that consider the quality of service (QoS) requirements can be utilized or selected for that network. Quality of service is a critical component in developing a trustworthy network (QoS). When QoS is dependable, packets are transmitted properly and on time. Medical information transfer in WBAN relies heavily on Quality of Service (QoS) since vital applications demand the optimum QoS. High throughput is essential to achieving a high quality of service (QoS). Packet content is directly related to throughput, while transmission latency is directly related to throughput. There must be some lag for the sake of QoS (quality of service). To help WBAN systems achieve high QoS, 5G may be an attractive solution because it will provide high data throughput, dependability, and extremely low latency.

1.3.2 QoS based Routing Challenges in WBAN

The packet priority level setting sub-module prioritizes data packets. Request processing and service level monitoring can be done in a separate sub module. The priority level setting sub module assigns importance to individual data packets. A sub module for request processing and service level control is offered. WBAN's network environment is exceedingly complicated because it is applied to the human body. Since Designing routing for the body area network is crucial because the physiological data gathered

substantially influences human life and health [16].

The network's priority level setting sub module promotes data packets. There is a sub module for request processing and service level control. Dynamic topological changes in wireless transmission may be seen in body surface transfer, body transmission, and free storage transmission. It's challenging to comprehend the channel conditions. It is essential to take into account the shadows cast by human movement. As limbs move, the distance and location of nodes will shift. Given the topology's temporal fluctuation and potential issues a trustworthy routing system that responds to the dynamic topology should be designed.

WBAN includes implants that must be surgically removed and replaced. It is insufficient to only supply electricity using micro batteries. Energy efficiency design must be used at the source in addition to RF (Radio Frequency), EM (Electro-Magnetic), or energy harvesting. To maximize network lifetime, routing design must take the network's general metabolism and each node's energy efficiency into account.

The temperature of nodes: Heat produced by nodes during operation damages the body's vital tissues and organs. To prevent this kind of issue, the routing design must take node warmth into account. In order to reduce the amount of energy absorbed by the human body, sensors must retain their power efficiency [7].

When it comes to WBAN nodes, a wide variety of data is generated, and each type of data must be handled in a unique way to meet the quality of service requirements of different data types.

WBANs, as a subset of WSNs, inherit all WSN constraints. Furthermore, some special limitations and concerns associated with WBANs must be addressed. In contrast to standard WSN applications, which employ homogenous sensor nodes, WBANs use a variety of BMSNs. These BMSNs' data generating rates, energy consumption, storage capacity, and compute performance differ. Numerous types of BMSNs running at different frequencies cause interoperability concerns. The compatibility issue will be addressed using WBAN-specific data mining approaches. Similarly, the pace of data output in WBANs is high, necessitating effective data collection and processing systems [9].

The research challenges related to QoS support in WBAN routing protocols are mentioned as follows [16].

1.3.2.1 Lifetime of Biomedical Sensor Nodes

Lifetime of biomedical sensor nodes is important in healthcare applications. The tiny thermal and battery-powered sensor nodes working in ad hoc architecture offer the most value when they communicate with one another for as long as possible. How long a sensor network operates depends on how much energy the sensor nodes still have left. Residual energy is a vital component in achieving QoS [17].

1.3.2.2 Routing and Clustering Technique to be used

In the case of WBAN, routing strategy is crucial for QoS-aware, energy-efficient routing. The best routing technique for WBAN is shortest path selection across many clusters, which is applied within ad-hoc wireless infrastructure [17].

1.3.2.3 Scalability

If we were to add more sensor nodes to the network field, the routing protocol and clustering technique should be adaptable enough to be able to route data effectively from one sensor node to another within each cluster. Effective data transmission within each cluster or across numerous clusters significantly improves QoS [18].

1.3.2.4 Power Consumption Issues

The performance of the network degrades in many WBAN-based applications as the energy of the sensor nodes runs out. Recent WBAN systems have introduced QoS-based metrics to address this communication overhead [19].

1.3.2.5 Data Aggregation

The primary objective of the data aggregation method used by WBAN is to gather data from the sink node in an energy-efficient manner in order to extend the network lifetime. The QoS is greatly increased by WBAN lifecycle optimization [16].

1.3.2.6 Link Reliability in WBAN Traffic

The real time monitoring of patient depends on the patterns of data being transmitted in WBAN. Real Time monitoring of patients in hospital depends on improved link reliability. Link reliability is based on received signal strength intensity (RSSI).

Improvement in RSSI is based on optimal QoS [16].

1.3.2.7 Dual and Multiple Sink Approach

Multiples sink nodes within a network may directly increase the power consumption overhead for overall network. This results in increased energy consumption which may directly effects QoS [14].

1.3.2.8 Network Topology and Dynamics

Postural movements of patient body and energy consumption of sensor nodes causes a change in network dynamics and topology, which may directly effects QoS [20].

1.3.2.9 Deployment of Sensor Nodes on Human Body

Optimal Node deployment on the human body is considered to be an important parameter in achieving QoS [21].

1.3.2.10 Types of Network Traffic

Multimedia based high data rate Network traffic during peak and low traffic periods may directly effects the QoS [22].

1.3.2.11 Un-reliable Wireless Link and Connectivity in Packet Transmission

In order to achieve QoS, it is crucial to take packet transmission reliability across sensor, relay, and sink nodes in WBAN into account [23].

1.3.2.12 Maximization in Network Traffic Load

The suggested technique can choose alternate nodes from source nodes to relay nodes and from relay nodes to sink nodes, preventing the entire energy of any one node from being depleted and extending the lifetime of the network. Network life-time extension enhances QoS [16].

1.3.2.13 Data Duplication

Data aggregation and retransmissions at sink node may results in data duplication, which may affect QoS constraints [20].

1.3.2.14 Mobility Management

The mobility of patients with in-hospital environment directly changes the QoS of network based infrastructure. The route between the sensor nodes will be distorted or changed. If the network route is broken, there is a great chance of data loss, which may also result in power consumption overhead [24].

1.3.2.15 Resource Allocation

The resource allocation plays a vital role in designing any QoS based protocol application. The resources include memory capacity of sensor nodes, the residual energy of sensor nodes and network lifetime [18].

1.3.2.16 High Temperature and Interferences

Interferences in communication and increasing temperature of the overall wireless network degrade the performance of WBAN. This situation results in data loss, communication delay and route failure. Network Communication delay degrades the performance of WBAN, which may directly effects QoS [25].

1.3.2.17 Security and Privacy

Nowadays secure data interaction and maintaining the privacy of information in healthcare environments is considered to be an integral component in maintaining QoS in WBAN [6].

Table 1.1: Tabular representation of QoS aware routing parameters

QoS-Aware Routing parameters		Description of QoS Aware Routing parameters
Link Reliability (RSSI)	Reliability	Link reliability is an important parameter in achieving optimal received signal strength intensity (RSSI).
Residual energy (RE)	energy	Residual energy of sensor nodes for prolonged life time in WBAN is an important parameter in achieving QoS.
Signal to Noise ratio (SNR)	ratio	High Signal to Noise ratio in wireless communication is an important parameter in achieving QoS.
Path Loss ratio (PLR)	ratio	Minimum path loss in WBAN routing mechanism is an important parameter to achieve QoS.
Packet loss (PL)	loss	Packet loss is the total no of packets transmitted by sender node and eventually lost with in the network.
Effective throughput (ET)	throughput	Quantity of transported data or packets between the source and sink nodes of the relay.
Network criticality (NTC)	criticality	Parameter to determine the change in network effects its performance, related to sensitivity of the network.
Network Availability	availability	It is the measure of delay for components available within the Network.
Delay in packet transmission (DPT)	delay	It includes the packet transmission delay and queuing delay with in the Network.
Probability in connection outage	probability	Probability of outage of network connection at each link.

There are multiple routing challenges related to QoS support for energy efficiency in WBAN. The core challenge is the lifetime of the battery to operate the sensor nodes. Transmission power in case of WBAN is dependent on the distance from the source node to the destination node. To select the most optimal route, we can take the help from the routing protocols. Therefore, to provide reliable communication, we have to select energy efficient routing strategy. For example, Co-LEEBA routing protocol [2] is based on cooperative routing strategy in the case or normal and

emergency circumstances. M-ATTEMPT is thermal-aware routing protocol, which selects the routing path based on the thermal heat of hotspot [26].

Meeting QoS requirements in WBAN is an important task. For this reason, we have identified the core parameters for maintaining QoS in reliable routing mechanism. Table 1.1 describes about the distinctive parameters identified in QoS aware routing for WBAN applications [17].

The parameters which we had discussed previously in Table 1.1, we have selected the most relevant parameters for our proposed WBAN protocol based application scenario. Path Loss Ratio, Signal to Noise Ratio, Residual Energy of Sensor Nodes, and Link Reliability (Throughput) are the selected parameters. The IM-QRP suggested technique is based on the body's postural movements in medical settings. The foundation of postural movement routing protocols is link reliability, which is determined by the quantity of packets that are successfully sent to the sink node [27]. When using wireless sensor nodes in WBAN, managing the power source or residual energy of the nodes for the longest possible period of time is a crucial aspect to take into account. In WBAN, IM-QRP offers energy-efficient routing. Prolonging the network life time by introducing the arrangement of sensor nodes, relay nodes and sink node mounted on human body improves the energy efficiency. Path loss or path attenuation in case of electromagnetic signals over human body is reduced in case of proposed protocol by improving link reliability and signal to noise ratio [14]. Therefore, the importance of the above parameters discussed are based on proposed protocol IM-QRP. Rest of the parameters are also QoS Aware but they not strongly related to our proposed protocol based on modified cost function. Table 1.2 describes about the QoS parameters based on QoS-Aware routing metrics necessary to build efficient WBAN protocol based Application. The proposed methodology is based on the primary motivating considerations listed below [7].

Table 1.2: Tabular representation of QoS metrics related to WBAN

Layered description	QoS-Aware Routing parameters	QoS Metrics	Description
Network Layer	Path loss / residual energy - sensor nodes	Network congestion & network path latency	Minimizing the network path latency and congestion may directly reduce energy consumption and path loss.
Transport Layer	Link reliability (RSSI)	Network bandwidth reliability	Achieving Network bandwidth reliability is consider to be an important matrix achieved.
Application Layer	Residual Energy of sensor nodes	Life time of the network	Maximizing the life time of BAN may directly affect QoS based matrix.
Coverage layer	Path loss	Coverage area related to WBAN	Maximizing the coverage area related to WBAN on human body may directly affect path loss.
Connectivity Layer	Link reliability and SNR	Network connectivity	Improving network connectivity may result in RSSI and SNR.

1.4 Statement of Problem

QoS is considered to be an important issue in cooperative routing in WBAN. To Improve QoS, we have to achieve the maximum throughput. [28] Optimal throughput achieved in energy efficient routing protocols is based on maximum packet delivery towards the base station. Due to the multiple path losses during data transmission in WBAN. This results in increased energy consumption of sensor nodes and reduces the network lifetime [11]. Another reason for increase in communication delay is due to limited received signal strength intensity (RSSI) and minimum SNR [28].

1.5 The Purpose/Significance of the Study

The significance of the research is based on achieving the energy efficiency in routing mechanism based on improving the following factors.

- Algorithm Efficiency
- Communication Range
- Energy Efficiency in routing.

1.6 Research Objectives

- Transmission of the selected data by using cooperative low energy efficient routing technique.
- To improve the communication mechanism by maximizing the throughput by improving packet transmission ratio towards the sink node.
- To minimize the path loss ratio.
- To improve link reliability based on (RSSI) Received signal strength intensity.

1.7 Research Questions

The issues which are previously discussed degrades the overall performance of routing mechanism related to WBAN. There is a strong need for addressing these issues so that the proposed scheme will be more accurate regarding energy efficiency and reliability. The research questions related to these issues are as follows.

Research Question 1: How to improve the Quality of service (QoS) in WBAN routing Algorithm which results in minimum path loss and maximum throughput ratio?

Research Question 2: How to develop a protocol which is capable of selecting the appropriate scheduling scheme for data transmission in normal and emergency circumstances for static and moving bodies?

Research Question 3: How to maximize the Signal to noise ratio (SNR) ratio in WBAN routing mechanism and to achieve the maximum received signal strength intensity (RSSI) in a single hop and multi-hop communication?

1.8 Contribution to Knowledge (Academic Contribution)

Use of low energy efficient routing technique in order to improve the communication mechanism by maximizing the throughput by improving packet transmission ratio towards the sink node. Furthermore, it will minimize the path loss ratio in addition to improving link reliability based on (RSSI) Received signal strength intensity.

1.9 Statement of Significance (Practical Contribution)

The practical contribution is achieved by achieving algorithm efficiency, communication range and energy efficiency in routing.

1.10 Research Aims and Hypothesis

In this section, the hypothesis and the explanation for the observations are covered. We looked at WBAN's energy-efficient routing algorithms based on the following open research problems and driving forces [16].

- Transmission of the selected data by using cooperative low energy efficient routing technique.

- To improve the communication mechanism by maximizing the throughput by improving packet transmission ratio towards the sink node.
- To minimize the path loss ratio
- To improve link reliability based on (RSSI) Received signal strength intensity.

This Section presents the significance of our research study based on the critical evaluation of the literature studied during our research. Our work will be effective in successful data transmission. The existing algorithms in WBAN should be flexible and adaptable in the different regions and environments. The choice of a suitable communication protocol is essential for WBAN devices to operate as efficiently as possible. Sensing and computation require a significant amount of energy in WBAN wireless communication. For this reason, a low power cooperative energy efficient routing schemes for WBAN had been discussed in the literature review section. M-ATTEMPT [26], RE-ATTEMPT [29], IM-SIMPLE [30], and CO-LAEEBA [2] are the protocols that are most commonly mentioned in the literature review section. The preference of considering the significance of energy efficiency in routing mechanism can be made based on the following factors.

- Algorithm Efficiency
- Communication Range
- Energy Efficiency in routing

1.11 Research Methodology

The health care data will be obtained. The data will be obtained in the form of MS Office Excel Sheets. The daily patient's reports will be obtained by different Medical centers. The structure of data is based on patient's body related parameters. The comparative analysis will also be obtained on the basis of improvement of successful packet transmission ratio from source node to the Sink node.

The Real time health care data set will be very much helpful for us in identifying the patient health care condition in future. For this reason, we will choose the Ad hoc WBAN Architecture as a Model to collect Health care forecasting parameters via using Ad hoc wireless sensor Nodes.

The patient's heartbeat, pulse rate, and glucose levels are tracked in the data set. Ten nodes are distributed

on a moving body in the vicinity of the head, chest, center waist, left arm, right arm, left hand, right leg, left foot, and right foot. The experimental setup will be populated by using Mat lab. Simulation results will provide the brief detail about Improvement in Received Signal Strength Intensity (RSSI), Successful packet transmission ratio, energy efficiency, improvement in SNR (Signal to Noise Ratio), maximum throughput and minimum path loss and packet drop ratio [31].

This section also provides the administration of tools related to the Research. The QoS for the proposed scheme has been discussed. The maximum number of packets that can be transmitted to the sink node will determine the QoS.

II. LITERATURE REVIEW

2.1 Introduction

WBANs mark a turning point in the fight against disease and early diagnosis. On-body, on-clothes (wearable), and embedded sensor data, including temperature, heartbeat, pH-level, blood pressure, electrocardiogram (ECG), electroencephalogram (EEG), and respiration rate, is captured by WBANs, which reduces healthcare expenditures. Bio-Medical Sensor Nodes are the name given to these sensors (BMSNs). Identifying WBANs that match the basic needs of healthcare applications, such as mobility, secure and reliable data, energy consumption and the coexistence of many sensor nodes in a relatively small space, will be one of the primary goals of this research. Understanding the protocol stack and each layer is required to understand the specific needs in medical networks. On the outside or within the body, BAN sensors can be used on the body [23].

Any human safety approach must consider the biological effects of transmitter irradiation. The constant activity of the sensor nodes in the in-body scenario could lead to an increase in average temperature, which could damage human tissue when data is relayed or transmitted to nearby neighbors. One strategy is distributing data transmission over the network rather than relying on well-established channels. As a result, the sensors' temperature in some areas does not rise much. BAN routing algorithms can be grouped into several categories based on the aims they seek to achieve.

Because they aim to minimize local and system-wide temperatures, temperature-based routing systems fall within the first routing system category. To avoid temperature surges that could cause tissue injury and node deletion, these protocols transport data from many channels to avoid excessive temperature surges on particular sensors. However, as the number of nodes grows, these protocols' system complexity and overhead. With BAN nodes being divided into groups and each group having its own "cluster head," the data from the sensor is routed from the sink through these "cluster heads" in cluster-based routing protocols. Reduce the number of direct sensor-to-base station transmissions with these methods [32].

The exorbitant prices and extended periods of these procedures, however, greatly constrain Cluster selection. The third kind of BAN routing approach looked at in this study combines routing problems with limits on medium access. Despite high throughput, low energy consumption, and nearly constant end-to-end latency, these protocols cannot attain high performance in specific conditions due to body motion and severe route loss. Cost-effective routing protocols update their cost formula and choose the most cost-effective routes on a regular basis using cost-effective information. These protocols are tested by the massive amounts of data that must be transferred to maintain data current efficiently. As the fourth type of routing protocol, QoS-based routing protocols provide discrete modules for a wide range of QoS measures. End-to-end chain reliability is increased, latency is reduced, and packet delivery is improved. These protocols' substantial complexity is due mainly to numerous modules based on multiple Quality of Service (QoS) standards [17].

2.2 WBAN Architecture

WBAN can interface with a wide range of sensors and appliances within and outside the human body with a dedicated sensor. Components of the basic WBAN architecture are shown in the Figure 2.1. This section breaks down the network architecture into four main parts. There are several sensor nodes in the WBAN, the initial component. Inertial and biological sensors mounted on the human body make these low-cost, low-power nodes excellent for wearable and other applications. All equipment can be continuously monitored of vital factors such as heart rate, ECG, blood pressure, and the surroundings. Large-scale

cable-based monitoring systems are now in use. Wearing a monitoring system's cables might be a nuisance and limit movement. Thus, WBAN can be an excellent option in this area, particularly when patients need constant control and mobility, as is the healthcare case. Following the coordination, a node is the Central Control Unit, which connects all sensor nodes to the Central Control Unit (CCU). Sending sensor data to the next segment is the CCU's responsibility. Figure 2.1 describes Architecture [33].



Fig 2.1 Architecture of WBAN

It's impossible to use a wireless method to monitor a person's body activity. Medical monitoring systems often use WLAN, WiFi, GSM, 3G, 4G, and WPAN (Bluetooth, ZigBee) technologies. However, short-distance communication can also be accomplished via these other methods outside of mobile phone networks. Two alternative body monitoring systems use low transmission power: Wireless Medical Telemetry Services (WMTS) and Ultra-Wide Band (UWB). As a data conduit, WBAN communication is the final component. Email and other Ethernet-based services can be run from a router or a personal computer. Users' mobile phones, PCs, and servers will all be included in the control centre, monitoring and emailing them and saving database information.

2.3 Routing Protocols in WBAN

Routing in WBAN is problematic due to a lack of memory, computing power, and energy. The physical layer of WBAN sensor nodes has a considerable impact on energy consumption due to radiofrequency (RF). It is also possible to enhance sensor node density by altering the RF component's duty cycle in the MAC protocols that use the remaining energy. However, there are still unmet needs in improving network connectivity via the MAC or physical layer and addressing systems and route optimization. Procedures of determination are not discussed. The network layer should be employed to solve this problem. Research into network layer routing

methods must be addressed to conserve energy. Even though it is a subset of WSN, WBAN has its features and standards. It takes more time and effort to design an effective WBAN routing protocol than it makes a successful WSN routing approach [34].

WBAN routing protocols need to consider a number of important factors, including the heterogeneous network nature (because specific physiological data are transmitted), energy consumption (because transmission rates are increased), temperature rise (because transmissions are numerous), coverage area (because the transmission dimension is low), mobility and quality of service (because priority-based data are transmitted) for the WBAN routing protocols, among others. WBAN efficiency is negatively impacted by the temperature increase of sensors implanted in the body. WBAN performance is negatively impacted by implanted sensor temperature rise, which is the most critical aspect of all characteristics mentioned above. As a result of the absorbed radiation and the antenna's energy consumption, the temperature of a sensor node rises, possibly hurting nearby human flesh and injuring heat-sensitive portions of the body. When designing a routing algorithm that prevents human tissue from being harmed by the rise in temperature of an individual node, substantial research is necessary. Removing sensor nodes (particularly implanted sensor nodes) is not an option.

WBAN routing must also cope with energy consumption issues. Data sensing and monitoring consume less energy than the connection between devices. The suggested routing algorithm must select the optimum way from various possibilities while lowering the contact range for data transfer. Smart routing (which takes into account temperature rise and remaining power) can help extend the lifespan of the entire network [35].

2.3.1 Classification of Routing Protocols for WBAN

Over the years, several WBAN routing strategies have been put forth in the literature. Routing protocols based on postural movement awareness, QoS awareness, thermal awareness, energy awareness, cluster-based routing protocols, and cross-layered routing protocols are a few examples.

Figure 2.2 details the WBAN routing protocols, which are primarily categorised into the following groups: cluster-based routing, posture-based routing,

temperature-based routing, cross-layer routing, and QoS-based routing [12].

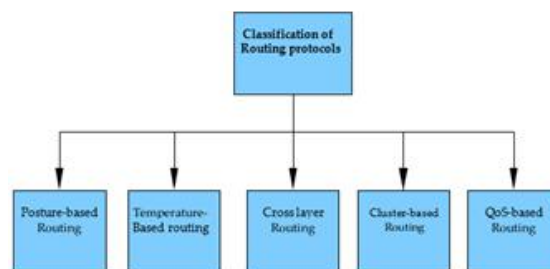


Fig 2.2. Classification of Routing Protocols in WBAN

2.3.1.1 Posture Based Routing Protocols

A proposed routing protocol for WBAN is based on postural movement [12]. By examining the network architecture of the human body in many dynamic settings, posture-based routing may construct a quick and trustworthy path. Assessment of diverse positions is vital. Every type of human movement has some degree of regularity. With this, the dynamic WBAN, which is already in use, could see a significant boost in its development. Dynamic environments alter network architecture and create a shadow effect because of the movement of the body parts. If the circumstance, which was highly passive and required a long period, arose, existing remedies could only be studied further. If the next activity in the current time slot can be predicted in advance, judgment and processing may be done in advance, particularly important for efficiently minimizing latency and boosting the data transfer rate [36].

The physical body's postural mobility influences WBAN transmission. Moving about causes many problems while trying to talk, yet it's still possible to communicate effectively. Several research studies have discovered the optimal cost function for sink routing. Table 2.1 describes about the standard Postural Movement Based routing protocols in wireless body area networks.

Table 2.1: Postural Movement Based routing protocols

Authors	WBAN Protocol/ Standard used	Strengths	Limitations
Y.Zhou et al [37]	Mobility handling Fault Tolerant based Protocol is developed.	Low delay and higher energy efficiency is achieved Used to predict heart beat rate.	Sacrifices human comfort, difficult to implement in normal daily life routines.
Y.Zhou et al [37]	Distributed Network Management routing protocol is developed which is capable to establish multiple connections in a single time unit	Minimization in network framework	More suitable for dynamic moving bodies.

It is advised to utilize the On-body store and flood routing protocol (OBSFF), which has a high energy consumption factor as a disadvantage but a superior ability to reduce packet delivery delays. An energy-efficient routing system based on postural movement is the Opportunistic Routing System (ORP) [38]. Today's QoS routing techniques are based on body posture changes within the WBAN framework. The Energy Efficient Thermal and Power-Aware Routing (ETPA) system is also recommended for identifying various postures related to the human body. When compared to current plans, the one that has been presented utilizes less energy. ETPA ensures secure and dependable routing with a maximum packet delivery delay ratio. The subsections that follow address a few particular subcategories of postural movement-based routing systems.

2.3.1.1.1 A Novel Mobility Handling Routing Protocol (MHRP)

It was designed to be a wireless, portable processing routing system for mobile devices. The method is designed to record heart rates. Seven nodes can be found on each side of the body. It's possible to create sets of nodes with symmetrical nodes in each of the three groups. It's now possible to create two fault-tolerant systems using identical but separate components. One of the design goals is to switch to a different group when the energy levels of the present working set diminish or the network topology is disrupted in order to assist reduce errors and increase data transmission reliability. The network architecture is examined by the MHRP protocol to identify the best route for four different elbow movements. The simulation results of this procedure show considerable reductions in end-to-end time, error rate, and energy consumption. It could be difficult to recognize the comfort of the body as being distinct. The human body is put under more stress even if this kind of substitution set produces consistent results [39].

2.3.1.1.2 Energy-Efficient and Distributed Network Management Cost Minimization (NCMD)

It is suggested to use a distributed opportunity routing NCMD with less network management. When used in a dynamic setting, WBAN causes significant transmission delays and higher network maintenance costs. The quality of service (QoS)

measurements decline when mobile data rates increase. This study addresses network administration and QoS challenges by presenting an opportunistic transmission link creation technique in postural movement routing strategy [40].

2.3.1.2 Temperature aware routing protocols

Sensors implanted in or attached to the human body in WBAN can have an impact on the human organism. Because the transmitted fields generate a temperature rise in the node's digital circuits, antenna radiation, absorption, and interaction are essential difficulties to solve while constructing a body sensor network. Radiation has a significant effect on the human body. It may cause tissue damage if exposed to it frequently. All temperature-aware protocols strive to avoid routing over hotspots, which reduces in-body sensor node temperature rise [32].

Route selection in temperature-based routing is dependent on node temperature. The fundamental purpose of this routing strategy is to steer clear of nodes with high temperatures and create pathways that allow the nodes with high temperatures to be rapidly decreased. Because of the primary focus on security when implementing WBAN, temperature-based routing is being explored first. Although temperature-based routing was extensively investigated throughout WBAN creation, many current studies have focused on energy. As a result, the routing method based on temperature has greatly reduced the growth of WBAN. Temperature Aware routing protocols plays a vital role in QoS Aware energy efficient routing in WBAN [41]. The antenna design and its radiation are the major challenging research issues in WBAN. Since the electromagnetic radiation causes the temperature to rise. The electromagnetic radiations have a strong impact on the human body which is dangerous to the human health. The motivation behind the design of all the temperature-aware routing schemes is to reduce the temperature rise of intrabody and extra body sensor node communication. The routing path is established by using hotspots which should be avoided in most of the schemes due to high-temperature rise. The analytical comparison among different protocols reveals that the performance comparison of Least Total Route Temperature (LTRT) is much better than Thermal-Aware Routing Algorithm (TARA) due to low-temperature rise. Hotspot preventive Routing

scheme (HPR) has a minimum temperature rise as compared with other schemes. The M-ATTEMPT protocol, which is ideal for heterogeneous WBAN, has demonstrated that it is one of the better thermally aware routing protocols. The M-ATTEMPT approach uses multi-hop communication. It is between the sensor nodes and sink nodes to select the most cluster heads in each round. Due of high energy costs, one hop communication is employed for emergency services. The majority of the time, packet transfer uses multi-hop communication. Unlike RE-ATTEMPT [29] protocol, M-ATTEMPT [26] protocol is thermally aware. The following describes the tabular representation of the temperature-aware routing system in Table 2.2.

Table 2.2: Tabular representation of Temperature aware routing protocols

Authors	WBAN Protocol / Standard used	Strengths	Limitations
N.javed et al [29]	M-Attempt protocol is developed	The suggested approach may investigate all feasible paths as it can identify thermal heat of hot spot throughout the routing process.	chooses the most cluster heads feasible via multi hop communication in each round.

The M-ATTEMPT [26] protocol allows for both sensor movement and human body motion. In order to potentially explore the most paths, the scheme is also capable of detecting the thermal heat of a hotspot throughout the routing process. Comparing the proposed strategy to existing ones, the proposed scheme uses the least amount of energy. When compared to multi-hop communication schemes, single hop communication schemes have a faster packet delivery ratio. The only purpose of the RE-ATTEMPT [29] system is route selection. Future considerations should also take into account route discovery and cluster head selection. In the case of current schemes, no actual framework has been created. There is currently no accurate way to distinguish between a source node, sink node, and the root node.

2.3.1.2.1 Thermal-Aware Routing Algorithm (TARA)

The TARA protocol is a classic work and a pioneering effort in this area. Temperature is utilized as a single path selection criterion, with the neighbor node with the lowest temperature chosen as the next hop. As soon as a target node has had a chance to cool down, data that has been sent to it is cached and then

retransmitted. If the target node waits too long, the cached data is destroyed. Using the retreat approach, data that has encountered a hotspot can be sent back toward their original path. The protocol's back-off method sparked new ideas for future research due to the protocol's back-off method [25].

A famous accomplishment in this field, the TARA technique was the first one to be a great success. Path selection is mostly based on temperature, with the lowest node on the thermometer being the next step in this method's chain. Delivered data is cached at the hotspot and deleted if the waiting time exceeds a specific threshold. It is possible to use the retreat strategy if a hotspot is encountered during data transmission and a new path must be found. There were strong results and ideas for future research based on the protocol's back-off mechanism at the time. According to our knowledge, these methods do not consider the temperature rise in the forwarding node. WBAN data transmission must be stable and fast at low temperatures. Adaptive Thermal-Conscious Routing (ATC) is a WBAN routing protocol that is supposed to be aware of thermal conditions (ATAR). For example, the ATAR aims to reduce heat generation and data transmission while prolonging the network's life span [41].

2.3.1.2.2 A New Energy-Efficient Routing Protocol (ER-ATTEMPT)

The RE-ATTEMPT protocol [29] avoids hot nodes and selects the shortest viable path with the fewest hops as an alternative. The ATTEMPT protocol does not consider the current path's inability, and the ER-ATTEMPT protocol is constructed around this premise. By exchanging HELLO messages with other nodes, the node initially finds all of the paths that it can take. The sub-optimal option ensures dependable transmission if the present transmission path is unavailable. Additionally, the ER-ATTEMPT protocol considers node positioning; it arranges nodes according to their energy levels. Relay nodes have more energy at the start, making it easier for other nodes to send data to them. With this technique, nodes generating normal data while routing can quickly find the alternative routing table's shortest path with the fewest hops. If a node generates erroneous data, the emergency transmission mode is activated. This routing system ensures that emergency data is delivered promptly and that general data is reliably

transmitted.

2.3.1.2.3 Trust and Thermal Aware Routing Protocol (TTRP)

TTRP, a routing method that considers both trust and heat, was proposed by [42]. Trust and temperature were the variables that were tested in this study. Relay nodes, which receive and send information, do not engage in information collection and have more energy to convey information from other nodes in this routing strategy than in others. The TTRP protocol consists of three steps: estimation of trust, the discovery of routes, and maintenance. The routing step determines the optimal route without using hotspots or reliable nodes. To speed up the routing process, TTRP has developed a composite function.

2.3.1.2.4 A Mobility-Based Temperature-Aware Routing Protocol (MTR)

MTR, a temperature-aware routing system based on mobility, was developed by [43]. Human mobility and posture are not considered by the present temperature-based routing method. A large amount of information will be lost due to topological separation. This protocol has been streamlined and modified to solve the difficulties raised above. That's not all; it also takes advantage of the DTN network's ability to store and transport heat. As a result, topological separation-related data packet loss is no longer an issue. Body area network nodes are classified as static or dynamic per the protocol.

2.3.1.3 Crossed-Layered Routing Protocols

Network performance can be improved by employing cross-layer routing protocols, which mix several protocol layers and take advantage of each stack's unique properties. According to the research, dynamic WBANs benefit from the cross-layer technique. Layer collaboration can achieve individual service for each data type and low latency, high dependability, and energy savings. Table 2.3 describes the tabular representation of cross layered routing protocols in WBAN [12].

Table 2.3: Tabular representation of cross layered routing protocols

Authors	WBAN Protocol / Standard used	Strengths	Limitations
B.Braem et al [44]	(WASP) for Multihop WBAN	High packet transmission	No suitable for moving nodes
B. Later et al [45]	Multi hop WBAN communication is achieved	Minimum delay	Limited packet delivery ratio
A.G.Ruzzelli et al [46]	scheme (TICOSS) To improve IEEE standard	minimum utilization of energy. High packet transmission	High delay

The detailed analysis of cross layered schemes is performed which is based on CICADA and TICOSS having limited energy consumption factor. WASP has improved packet delivery ratio as compared with other schemes. CICADA scheme has a minimum delay as compared with TICOSS and WASP. Biological communication scheme (Biocom) is used to optimize the overall network performance by utilizing a minimum amount of energy and satisfactory packet delivery ratio [46].

2.3.1.3.1 A Priority-Based Cross-Layer Routing Protocol (PCLRP)

This study uses three different categories of data: emergency (EM), delay-sensitive (DS), and general (GM). Medical video is referred to as DS, general data is referred to as P3, and cycle data is referred to as GM. There are three priority-based slots for children's competition access (CCAP) and free phase (CCFP). The service is tailored to varied priority data. For EM data to be prioritized, it must compete for CCAP access. CCAP and CFP are divided into three priority-based slots based on data, and the service is adapted to the needs of each kid. To ensure that P1 data transmission is given priority, EM data must compete for access across the whole CCAP network. When it comes to ensuring that emergency data is communicated quickly, a back-off strategy based on priority and the back-off duration is set by priority is used [47].

2.3.1.3.2 A Cross-Layer Design for Optimizing Transmission Reliability, Energy Efficiency, and Lifetime (CLDO)

A combination of transmission power and relays is needed to address the problems related to Routing Mechanism in WBAN. The Researchers around the world had conducted simulation studies, which showed that a proper transmission power and packet size might guarantee reliable transmission, conserve

energy, and extend network life [48]. The ideal relay can transfer data packets with low mistakes, reduce energy consumption by a significant amount, and meet acceptable latency requirements. Many theoretical inferences and stronger claims and proofs have been made as a result of this experiment.

2.3.1.3.3 Cross-Layer Retransmit Strategy (CLRS)

CLRS cross-layer retransmit protocol is proposed which is based on IEEE 802.15.6 standard [49]. Unlike prior cross-layer approaches, it was meant to retransmit data packets that failed to transport. In this experiment, when data transmission failed, separate waveforms showed up on the output waveforms of the receiving end due to collision and shadow effects. After determining the issue by analysis of data frame waveform characteristics, the MAC retransmission approach was chosen.

2.3.1.4 Cluster-Based Routing Protocols

It was motivated by WSNs to use the cluster-based routing approach. Studies suggest that clustering is better for WBANs than a standard WSN routing scheme, LEACH (Low Energy Adaptive Clustering Hierarchy). Clustering techniques can boost network robustness as the number of nodes, and their distance from each other grows. Clustering routing protocols are used to partition network nodes into groups. There is a cluster head and a number of other cluster nodes in a cluster [50]. The tabular representation of Cluster based routing protocol is mentioned in Table 2.4.

Table 2.4: Cluster Based routing protocols

Authors	WBAN Protocol / Standard used	Strengths	Limitations
A.Raza et al [51]	Cluster Based Body Area Network Protocol (CBAAP) is designed	Proposed protocol improves residual energy, network life time, throughput and residual energy.	Mathematic Model has not been designed

Consider both temperature and energy while designing a WBAN. Network life and power consumption are both reduced by using cluster-based routing. By dividing a network into smaller clusters, the network's nodes' total energy can be reduced. When found in a cluster head, these nodes are used to exchange information (CH). The CH is in charge of data transmission, collection, and aggregation. The low-energy cluster-based hierarchies and power-efficient sensor information systems' hybrid indirect

transmission waste less energy when few nodes (LEACH). Since Any Body does not scale linearly with the number of nodes like LEACH, it performs better than LEACH. The cost of setting up Any Body is likewise reasonably priced [50].

2.3.1.4.1 Dual Sink Approach Using Clustering (DSCB)

One of the most significant innovations of DSCB's dual sink node routing architecture is its usage of cluster-based DSCBs [52]. There is only one sink used for routing inquiries. These tests revealed several issues, such as high failure rates of data transmission and limited coverage and a lack of flexibility in NLOS communication in dynamic environments. Shadow effects can be observed in real-world situations, and because the transmission interruption they create must wait for the shadow effect to vanish before continuing to broadcast, the delay in transmission is significant. People's lives are at danger when there is an interruption in emergency data transmission.

2.3.1.4.2 An Cluster Based Energy Efficiency Routing Protocol (CRPBA)

CRPBA, a cluster-based routing system referring to sink nodes as gateway nodes, was presented by [24]. In some cases, nodes in a network may communicate directly with the gateway or with other nodes in a cluster. At the waist and neck, there are two entrances. The protocol mandates that some critical data interface directly with the gateway node to avoid transmission delays. Data from the leader of a group of cluster members is provided to the gateway to reduce energy usage while enhancing the success rates of data transmission.

2.3.1.5 Quality of Service (QoS) Based Routing Protocols

Presently, there are some QoS aware routing schemes which are designed for WSNs, but WBAN lacks any QoS based standard. The energy-efficient peer routing protocol (EPR), which minimizes energy use while reducing network traffic load, is suggested. QoS aware peering routing protocol (QPRR) for reliability sensitive data is also proposed for WBAN. The analytical comparison is performed among EPR and QPRR. The results predict that neither any routing scheme previously discussed supports optimal energy efficient routing in emergency circumstances. Figure 2.3 describes about the classification of WBAN routing

protocols based on QoS Aware Routing parameters.

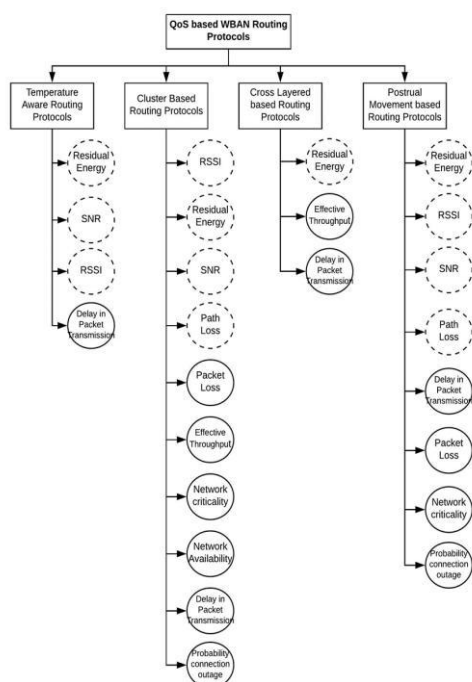


Fig 2.3: Classification of WBAN routing protocols based on QoS Aware routing parameter

Various QoS aware protocols can be deployed in WBANs, but only if considered. WBAN data formats require various levels of Quality of Service (QoS). EPR, QoS-aware peering routing protocol (QPRD), and QoS-aware peering routing protocol for reliability-sensitive data (QPRR) consume less electricity than other protocols. Some methods don't include energy use, but other ones include. As one of the most widely used protocols that consider QoS considerations, DMQoS can help reduce latency for time-sensitive data while still ensuring reliable routing for reliability-sensitive data. Some protocols do not account for energy use, whereas others do. The data-centric multi objective QoS routing protocol (DMQoS) is one of the most extensively adopted QoS protocols for data that must arrive quickly and reliably. Other QoS-aware protocols are utilized or selected depending on a given network's data type and QoS requirements.

In this regard, the data-centric multi-objective QoS-aware routing protocol (DM-QoS) is designed to reduce the delay for sensitive information. However, the proposed scheme provides the optimal routing strategy for reliable-sensitive information. The

researchers had proposed the routing table construction algorithm and path selector algorithm for maintaining the quality of service in packet transmission towards the base station. WBAN and Cognitive Radio Technology (CRT) are merged to achieve efficient and reliable WBAN solution. This novel approach can lead towards a considerable improvement in energy efficiency and routing schemes.

Zahoor Energy Efficient-Quality of service aware (ZE-QoS-aware) routing scheme for communication of sensor devices in the healthcare domain is proposed. The scheme is based on high energy consumption, which is a major drawback. The protocol QoS refers to maximum packets sent towards the base station. QoS aware peer routing protocol (QPRD) for delay sensitive data in case of WBAN is designed. The protocol is capable to handle delay sensitive data in WBAN.

WSN as compared with WBAN, minimum energy consumption is the major constraint to be considered. In WBAN cluster based routing schemes are proposed to reduce the energy consumption and to maximize the network lifetime. QoS based routing schemes now a days are based on cluster based routing protocols. Fault detection and discovery (FDR) is a fault tolerance based routing strategy, for alternate route selection in case of faulty or dead nodes. In a cluster-based routing strategy, the FDR parameter is based on QoS. If there are fewer sensor nodes in the cluster, hybrid indirect transmission (HIT) in WBAN uses less energy than low-energy adaptive clustering hierarchy (LEACH) and a power-efficient collecting in sensor information systems (PEGASIS). Given that the number of clusters stays constant as some sensor nodes are added, any technique in WBAN is preferable to LEACH [21]. Anybody's installation and deployment costs are significantly lower than those of other cluster-based routing techniques. Cluster-based body area protocol (CBBAP), which is based on LEACH, is created to maximize WBAN performance throughput while also having a minimal network energy footprint [51]. The tabular form of QoS-aware routing protocols in WBAN is described in Table 2.5.

Table 2.5: Tabular representation of QoS aware routing protocols

Authors	WBAN Protocol / Standard used	Strengths	Limitations
X.Liang et al [53]	(RL-QRP) Reinforcement learning based routing protocol with QoS support.	High packet delivery Ratio.	High average delay
M.A.Razaque et al [54]	(DM-QoS) Data Centric Multi objective QoS Aware routing protocols	High packet delivery ratio, minimum delay	Large network size results in high energy consumption
Z.A.Khan et al [55]	(ZE-QoS) Health care system QoS-based routing.	high ratio of packet deliveries	high level of energy use
Z.A.Khan et al [1]	(QRPD) QoS aware peer routing protocol for delay sensitive data in case of WBAN is designed	Protocol is capable to handle delay sensitive data in BAN	Framework has not been designed in the proposed scheme

WBAN's resource limitations make the quality of service (QoS)-based routing all the more critical, which is a big problem. Quality of service (QoS) considerations for the WBAN include data priority and energy efficiency, connection dependability, low latency, node temperature, and data security.

2.3.1.5.1 Designing Lightweight QoS Routing Protocol (LRPD)

Delay QoS is a primary goal of the LRPD protocol developed by [56]. The protocol's objective optimization is achieved through a modular technique. Priority is given to sending data from the higher layers to the categorization module. There are two kinds of data packets: general (GP) and delay-sensitive (DSP). It is impossible to overestimate the importance of DP. After passing the GENERAL and DELAY MODULES, the queue processing module receives the DP and GP data. Low priority DP data must, however, wait until a good time to transmit it in order to prevent any transfer delays.

2.3.1.5.2 Hybrid Data-Centric Routing Protocol (HDPR)

An solution was put up in the form of HDPR, a modular data-aware hybrid routing protocol [57]. Once there, it is classified as delay-sensitive data (DSD), normal data (ND), or critical data (CD) (RSD) by the Data Classification Module (DCM). The four data priority levels are CD, DSD, RSD, and ND, with the CD being the highest and ND the lowest. The QoS perception module uses data modules to organize data. They will be routed to the appropriate module based on each module's requirements by this one.

Using DSD data as an example, a delay estimation module identifies the most efficient route. As soon as the estimating module receives this data, it can then determine the optimum route. Many quality of service (QoS) metrics, such as route loss, connection dependability, latency, and temperature, are the primary focus of this protocol. One of the main advantages of this technique is that it considers the quality of service (QoS) related Routing Mechanism in case WBAN. This protocol's relay node only performs receiving and transmitting functions, reducing the acquisition node's energy consumption and increasing the network's lifespan. The Strengths of the Research work is based on improved Link reliability increasing QoS in routing mechanism. Along with the ability to send the maximum number of packets sends towards the base station. The Limitations of the research work is based on increased energy consumption of sensor network in maximum packet transmission and retransmissions.

Improved Quality of Service (IM-QRP) Aware Routing Protocol for WBAN

In the disciplines of medicine and health, wireless body area networks (WBAN) are a subset of wireless sensor networks (WSN) [58]. With WBAN, patients are liberated from wired monitoring and given access to a variety of medical services everywhere. These services include clinical medical monitoring, chronic disease monitoring, daily monitoring of the elderly or particular groups, and chronic disease monitoring. As a result, development in WBAN is gaining momentum and will soon rank among the most active research topics in the field. WBAN is a network with numerous levels that covers the complete body [59].

III. MOTIVATION AND PROPOSED SOLUTION

3.1 Motivation

Investigating various energy-efficient routing techniques is the goal of routing challenges. The issue of power usage with WBAN is among its biggest issues. Typically, WBAN uses medical sensors, which have restricted power sources. As a result, it is highly challenging to recharge or replace a sensor node that is part of the WBAN system. The processing of query queries, sending the data to nearby sensor nodes, and transmitting data are the sources of useful power usage.

In order for wireless sensor nodes to communicate data with one another, the routing protocol is essential. Energy-efficient routing protocols offer the best way to maintain a reliable path for data transport among WBAN. Due to the connectivity of sensor nodes on the human body, routing techniques used in WSN cannot be employed in WBAN directly. The mobility management paradigm, which is utilized to track patients' movements inside healthcare facilities, serves as the foundation for the patient healthcare monitoring system. The WBAN framework makes use of network communication range to offer the maximum levels of connectivity, coverage, and network lifespan. The data routing requires a lot of energy from the sensor nodes that are farthest from the sink node. These sensor nodes fail more frequently due to their high power consumption, which reduces network performance. In WBAN, fault-tolerant communication takes place at the node level. Data faults, hardware faults, and software faults are its three subcategories. The network failure can be avoided by removing the causes of errors in WBAN transmission. An ideal failure prediction system is required by the network for precise fault tolerance.

Wireless communication with contemporary technology allows users to exchange information at any time and from any location. Intelligent mobile communication networks and WLAN, or WiFi, are used in various settings, including education, health care, and industry, to allow people to engage with one another easily [10]. As the search for ubiquitous networks intensifies, so do household, business, and other information device gadgets that can connect wirelessly over short distances. The development of universal network standards and methodology has propelled it quickly into the global market. As a result, the Wireless Body Area Network subset is formed (WBAN). There are numerous ways WBAN differs from previous sensor networks (WSN). It's the mobility that separates a WBAN from a WSN. Compared to WSN, which tends to stay put, WBAN allows users to move in sync with sensor nodes that do the same thing. We can save much money on electricity by using WBAN.

WBAN sensors are therefore less expensive than WSN sensors. WBAN nodes adhere to the traditional model in terms of dependability, node complexity, and density. The particular needs of internet backbone

body connections cannot be managed by WSNs. How quickly and precisely the system responds to data being sent and received between nodes, which is ultimately controlled by the routing protocols or algorithms used, is a key indicator of WBAN dependability and efficiency. As part of the data transfer from a sensor node positioned inside or on the body, wireless transceivers, which are comparable to WSNs, emit radiation.

In WBAN the sensor node is responsible for gathering vital information from the body. Sensor nodes in a WBAN system must have low average power consumption, are small, and can operate within a specific type band. Every WBAN sensor node is made up of the same hardware. Important patient data is gathered through the use of sensors. Signals gathered from the human body are typically not archived. Forceful and partly due to the loudness of other noises within the body, such as the heartbeat. An Analog to Digital (ADC) stage that can be adjusted over structures to help with advanced handling is experienced when the sensor detects a signal, strengthening it to make it more grounded and separated to eliminate undesirable sounds such as cacophony. This aids in advanced handling. After that, the digital sign is handled and inserted into the microchip. The sensors provide an inconspicuous check on a patient's health. You sing human services technology in their daily life activities. Each sensor node has all of the necessary equipment [11].

3.2 The Proposed Routing Protocol

Improved Quality of service Aware Routing Protocol (IM-QRP) for Wireless body area Network is proposed. Priority-based routing and QoS support are available to users in WBAN framework. These factors are considered when determining a node's readiness to serve as a router. Data packet priority levels and wireless channel status are also taken into consideration. QoS metrics are selected based on packet success rate, end-to-end latency, and power consumption issues [27]. Figure 3.1 depicts the proposed routing protocol's technique, which consists of four clusters

A. CONTRIBUTION AT LAYER 1

Relay-based routing Layer 1 is chosen with following main factors.

1. **Reliability:** The framework delivers at least 90% of end-

to-end packets when a route is present, even in challenging network conditions. The proposed scheme has a 99.9% packet delivery rate.

2. Robustness: The framework can be used in a wide range of network scenarios, including ones with dense network topologies, environments, and workloads.

3. Effectiveness: The framework can send packets across the wireless network in the shortest amount of time.

4. Independence from Hardware: The framework may run on a wide range of hardware systems.

B. CONTRIBUTION AT LAYER 2

Home automation systems make up Layer 2. An effective solution for smart houses is offered by this smart infrastructure [60]. In smart homes, we are implementing WSN solutions. Typically, Smart Homes are made for senior homeowners who live alone. Almost every household appliance and human body are equipped with sensor nodes, which may lead to the formation of an ad hoc network within a definite, predefined range. There is no established routing system for moving data between devices in smart homes [61].

The second layer of research builds on the motivational variables listed below.

1. Smart Homes use a relay-based routing scheme.
2. To efficiently send information from numerous sensor nodes to the relay node (RN).
3. Information on the health status of the elderly can be sent from one sensor node to another with the use of smart homes, which offers an effective and dependable solution.

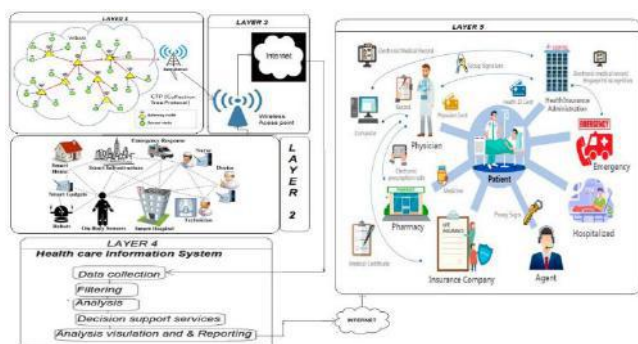


Fig 3.1 Proposed routing protocol for WBAN application

C. CONTRIBUTION AT LAYER 3

Base Station and Access Point (AS) make up Layer 3.

(BS). Typically, relay-based routing is utilized for sending data to AS/BS. Relay-based routing provides a low average end-to-end delay and strong communication dependability. Data from AS/BS in Layer 3 can be properly routed using relay-based routing. A successful packet delivery ratio from Layer 3 to Layer 4 is achieved by the suggested scheme. Based on a patient's health, relay-based routing makes effective use of clustering. 150 sensors have been placed in the Layer 1 network field to support the current circumstance. By using a relay-based routing strategy, layer 3 packet loss ratio can be minimized. Data from AS/BS can be successfully forwarded through the Internet to Layer 4 via relay-based routing. The third layer of research contributions is motivated by the following criteria. Guarantees for relay-based routing.

1. QoS
2. Energy conservation
3. Maximum packet delivery ratio; 4. Minimal end-to-end delay
4. Relay-based routing can extend the life of the network and improve load balancing and scalability by detecting wireless signals.
5. For relocating doctors or nurses working in a medical context, relay-based routing offers an efficient means of data transmission and routing.
6. Relay-based routing helps Layer 3 and Layer 4 successful packet delivery rates.

The People's lifestyle data is taken from Kaggle (Kaggle, an online community of data scientists and machine learning engineers, is a subsidiary of Google. It provides a platform where users can access datasets for building AI models, share their datasets, collaborate with other experts in the field, and participate in competitions to tackle data science challenges) which is based on Table 3.1 as mentioned as follows.

Table 3.1. Sample Distribution for Disease Classification

Disease	No of samples
Heartbeat	3193
Pulse rate	927
Glucose level	660

3.2.1 Communication Flow Chart and Route Selection Algorithm of IM-QRO Routing Protocol

Figure 3.2 depicts the communication flow-chart for the QoS-aware routing strategy-based IM-QRP routing protocol.

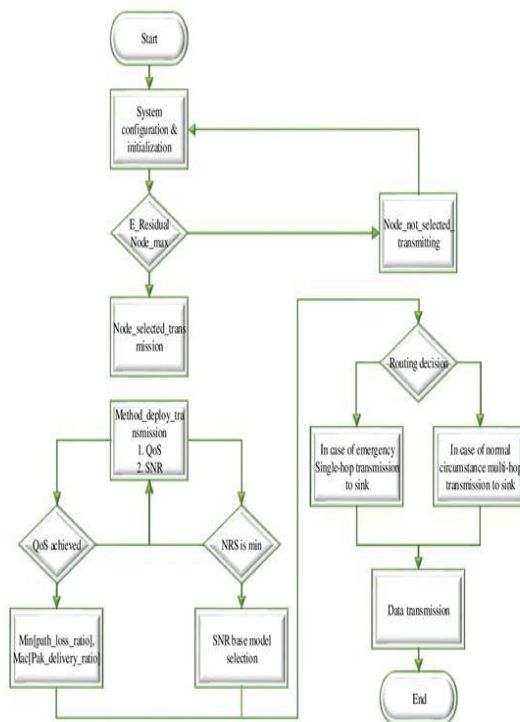


Fig 3.2. Flowchart description of IM-QRP routing protocol

The IM-QRP flowchart is shown in Figure 3.5 for both regular and emergency situations.

In WBAN communication, cooperative routing plays a key role. Relay node will be added in order to establish cooperative links and lower the overhead power usage [3]. Following is a discussion of how the proposed protocol's sensor and relay nodes perform under both normal and emergency conditions.

In the case of Emergency: When sensor nodes detect heartbeat, pulse rate, glucose level, and temperature scales to the fullest extent feasible, an emergency has occurred. The sensor nodes and sink nodes exchange data directly. A single hop communication occurs when the patient's health situation is concerning.

$$\text{sensor\_nodes} \xrightarrow{\text{sends(data)}} \text{sink\_node} \dots \dots \dots (3.1)$$

Initial Phase:

1. All the sensor nodes transmit test messages.
2. All the sensor nodes and relay nodes update their neighboring nodes and routes to the sink nodes.

Routing Phase:

3. SN=sensor node
4. SN=SNK; all sensor nodes send the data to the sink node
5. For each (SNi ∈ SN)
6. //Routing algorithm for sensor nodes deployed on the human body
7. //Start
8. //system initialization and configuration
9. if (SNi=Receives_signal_([Residual_energy_max]))
10. Node_selected_transmitting()
11. // Methods deployed for transmission to sink node
12. L1: QoS
13. if (SNi=(QoS_max_IM-QRP))
14. [Min_path_loss_ratio_model_selection ()
15. +Max_link_reliability_model_selection(+
16. Max_residual_energy_model_selection() 17. +Max_SNR_model_selection())
18. Else
19. Jump to L1
20. if (routing_decision_normal_QRP)
21. Selection_optimal_route_normal()
22. Transmits the data in multi-hop to sink node
23. if (routing_decision_emergency_QRP)
24. Selection_optimal_route_emergency()
25. Transmits the data in single-hop to sink node
26. Else
27. Node_not_selected_transmitting()
28. //start again from system initialization and configuration
29. End
30. // Energy consumption algorithm procedure in the selection of the optimal route
31. NNF=Neighbouring node as a forwarder
32. all candidate nodes as neighboring forwarder node
33. REin= residual energy of sensor node i in case of normal data transmission
34. REie= residual energy of sensor node i in case of emergency data transmission
35. ECNi=Energy consumption of node i
36. switch (NNFi ∈ NNF)
37. case: 1
38. (In case of emergency)->REin=(REi - ECNi) Energy consumption of each sensor node in emergency
39. case: 2
40. (In case of normal Trans)->REie = (REi - ECNi) Energy consumption of each sensor node in normal
41. end case

In the case of normal daily life: When sensor nodes detect temperature scale, pulse rate, glucose level, and heartbeat to an acceptable degree, the situation is normal. The relay node receives the data from the sensor nodes. The relay nodes cooperate with each other and maintain a close proximity to the sink node. The data is sent to the sink node by the cooperative relay node. Compared to standard sensor nodes, relay nodes use less power. When the patient's health is in good shape, a multi-hop communication situation arises.

$$\text{SensorNode} \xrightarrow{\text{sendsdata}} \text{relayNode}(\text{co-operativeNode}) \dots \dots \dots (3.2)$$

$$\text{relayNode}(\text{co-operativeNode}) \xrightarrow{\text{sends(data)}} \text{sink\_node} \dots \dots \dots (3.3)$$

3.3 Simulation and experimental results

IM-QRP is contrasted with the current routing protocols QPRD [1] and CO-LEEBA [2]. Results were obtained using MATLAB, and the classification of sensor nodes implanted on the human body is reported in Table 3.2.

Table 3.2. Classification of Sensor Nodes Mounted on a Human Body

Type of Sensor Node	Abbreviation	Functionality
Sink Node	SN	Positioned in the center of the body and able to receive data from relay and sensor nodes.
Sensor Node	S1	Assessing the patient's body's glucose levels.
Sensor Node	S2	Electro Encephalogram (EEG) sensors are used to track the signals the human brain sends out.
Sensor Node	S3	ECG (Echocardiography) is a technique for tracking heartbeat.
Sensor Node	S4 & S5	The method of electromyography (EMG) for capturing muscle activity.
Relay Node	R1, R2, R3, R4	Ability to cooperate with sink node and receive data from sensor nodes.

The network in Figure 3.3 employs a fixed number of nodes that are connected to the human body, but we can alter this number based on the patients' health and postural changes.

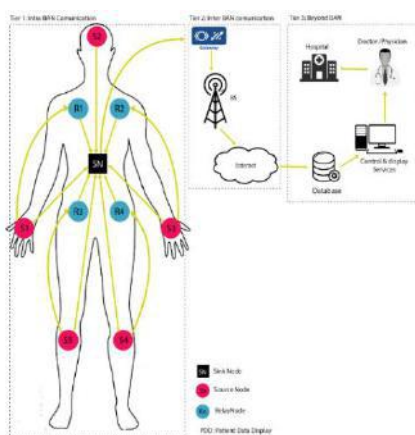


Fig 3.3. A Schematic for IM-QRP routing protocol

According to Figure 3.5, the sink node in the IM-QRP routing protocol is placed in the middle of the user's body.

According to [5] assessing vital electric sensors and their subsequent administration, including extraction, enhances the accumulation of consistent physiological indications obtained, which may provide a general estimation of the client's well-being state at any random time. The table depicts the many sensor nodes used in the WBAN system and their location (which body part they are in) and function. These are the most common types of patient vital data monitoring; however, just one or two types monitor specific symptoms in certain cases. When developing any monitoring system, it is critical to priorities sensor manufacturing quality and chip requirements to ensure that all sensors are consistent and that receiver devices can receive patient data without difficulty during transmission and receive. The following sensor nodes are classified inside Tier 1, along with the

functionality of each sensor node.

Sink Node (SN) placed at the centre of the human body

Sensor Node (S1): Glucose level

Sensor Node (S2): Electro Encyplograms (EEG)

Sensor Node (S3): Electromyography (EEG)

Sensor Nodes (S4 & S5): Electromyography (EEG)

Relay Nodes (R1, R2, R3, R4)

3.3.1 Initialization phase

Table 3.3 lists the energy-related factors and the ideal values that should be employed in a Situational simulation. Due to the heterogeneous nature of the WBAN, it allows two alternative types of sensor nodes that are categorized as follows.

1. Advance nodes are further divided into (Relay nodes)
2. Additional categories of normal nodes include (Sensor nodes)

A minimum distance must exist between the sink node and the relay nodes positioned on the patient's body. To gather essential information about the patient's health status, normal energy sensor nodes are mounted at random on the patient's body.

Table 3.3. Energy parameters with Desired Values

Energy parameters	Desired values
$E_{initial}$ (Initial Energy)	4 millijoules
Supply voltage	2.0 volts
Frequency (f)	2.4 GHZ
$E_{transmission-amp}$	2.0nJ/bit
$E_{transmission-circuit}$	17nJ/bit
$E_{receiver-circuit}$	10nJ/bit
DC Current (Transmission)	10.5 Ma
DC current (Reception)	18 mA
Wavelength (λ)	0.125 m

3.3.2 Selection of next-hop in routing

Based on the IM-QRP routing protocol, the next-hop selection criteria employed in this section to select the forwarder node.

3.3.2.1 Computation of cost function for the selection of the relay node

We use the multi-hop routing strategy because it increases network throughput while consuming less energy. In an emergency, a single hop route is chosen. For each round, IM-QRP chooses a new forwarder or relay node. The sink node is aware of the ID, distance, and remaining energy of the nearby sensor and relay

nodes. These presumptions make it possible for the cost function to decide if a node is a forwarder or a relay node. Equation 3.4 [13] contains the formula for determining the cost function.

$$C(F) = \frac{d(i)}{R_E(i)} \dots \dots \dots (3.4)$$

Where i is the node ID, $d(i)$ is the separation between the sensor node and the sink node, and R_E denotes the sensor node's residual energy.

Equation 3.5 gives the following definition of the cost function based on the optimization model used in WBAN.

$$\text{cost\_function} \xrightarrow{\text{elect\_optimized}} \text{forwarder\_node}(\text{relayNode}) \dots \dots \dots (3.5)$$

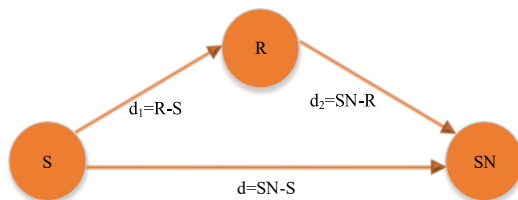


Fig 3.4. A Distance calculation for sink node

These presumptions are used to modify the cost function in both regular and emergency situations. The equations shown below provide the updated cost function. The following describes the cost function for multi-hop transmission in the situation of regular data transmission using Equation 3.6.

$$CF_n(i) = \frac{(SN-R)-(R-S)}{R_E(i)} = \frac{d_2-d_1}{R_E(i)} \dots \dots \dots (3.6)$$

The Cost-based function in single-hop transmission is explained as follows in case of an emergency in Equation 3.7.

$$CF_E(i) = \frac{(SN-S)}{R_E(i)} = \frac{d(i)}{R_E(i)} \dots \dots \dots (3.7)$$

WBAN operates at low energy levels to prevent hotspots on the human body, and the suggested method also steers clear of high data transfer rates to prevent negative impacts [68]. Overhead power consumption rises as a severely reduces the WBAN framework's QoS. According to one body propagation model, when sent signals travel through the body, diffract around the body, and are reflected off of nearby surfaces.

Smaller wireless networks use fewer sensor nodes, a smaller network, and a shorter communication range than WBAN. Given the limited energy budgets of

sensor nodes, energy efficiency is a key concern in WBAN. There is no easy way to replace or charge body sensor batteries. Even if sensors are worn, changing batteries will be cumbersome and time-consuming. On the other hand, physical wireless networks are among the most significant energy consumers [35].

Furthermore, power transfer should be maintained to a minimum to maximize network longevity. It should be noted that network apps should endure several years before being refreshed or paid. The other element is lower power usage due to less network traffic disturbance. Furthermore, radio signal specific absorption rate strongly links with radiation power density. The radiation energy is converted to heat, and if there is too much of it, the tissue will be harmed. To avoid the influence of radio waves on the human body, high transmittance is prohibited [69].

Although the communication range of the WBAN is restricted, incident electromagnetic attenuation is significant due to the lost path. Tree-based, chain-based, and cluster-based protocols are all examples of multi-jump protocols. Nodes in the first and second groups transmit data to their parent nodes, and the data is delivered step by step to the good node. As a result, the node closest to the good node consumes more energy because it must acquire network information and transport it to the well after processing. Cluster-based protocols organize nodes into multiple clusters [70].

Each cluster has a node responsible for collecting data from other nodes, compressing it, and transmitting it. As a result, clusters consume much more energy than regular nodes. Certain protocols require that the cluster change regularly to balance the energy use across the nodes. To achieve WBAN criteria, we must use multithreading when removing nodes from the hole to move the data. As a result, relay nodes may be used to increase lifespan and performance. It is worth noting that the additional relay nodes in the body can significantly improve network stability since data is transported across several alternative paths. Relay nodes are also employed in wireless sensor networks and WiFi communication. Relay nodes typically do not feel anything and only transport data. Because data transmission consumes much power, it has the potential to reduce sensor node power consumption [71].

To reduce energy consumption and boost network throughput, we favour a multi-hop routing method. In an emergency, a single-hop route is used. IM-QRP selects new forwarders and relay nodes for each cycle. The sink node is aware of the sensor node, relay node, IDs, distances, and collected energy. From this sink node, each node in the IM-QRP cost function is derived. B The link reliability in the BAN is dependent on the quality of service. SNR is another important factor to be considered in a WBAN routing strategy [3]. Now the proposed equation for cost function for energy efficient routing in WBAN is defined as follows in Equation 3.8.

$$\text{cost}(F) = W_1[\text{residual\_Energy}] + W_2[\text{link\_reliability}] + W_3[\text{path\_loss}] + W_4[\text{SNR}] \dots (3.8)$$

Where, W_1, W_2, W_3, W_4 are weighting to provide the importance of these parameters [13]. The weights are optimized by using a genetic algorithm. The genetic algorithm based cost function performance based on fitness function with each weighted vector value assigned one is described as follows in Equation 3.9.

$$\text{cost}(F(\text{performance})) = 1. \left[\frac{\text{residual\_energy}}{\text{Total\_Energy}} \right] + 1. \left[\frac{\text{link\_reliability}}{\text{Max\_value\_link}} \right] + 1. \left[\frac{\text{path\_loss}}{\text{Max\_path\_Loss}} \right] + 1. \left[\frac{\text{SNR}}{\text{Max\_SNR}} \right] \dots (3.9)$$

The possible weight vector range and maximum simulation time for each weighted vector are computed by using following Table 3.4.

Table 3.4: weighted sum classification

Weights	Possible weight range	Maximum simulation time (ms)
W1	0.507 ... 1.90	34.01
W2	0.508 ... 1.91	35.03
W3	0.509 ... 1.92	36.06
W4	0.510 ... 1.93	37.09

Cost function in WBAN routing mechanism, it is to be decided whether the node becomes a forwarder/relay node or not.

3.3.3 Energy consumption model based on routing mechanism

WBAN communication is divided into two forms based on the location of the radio signal: in vivo communication and in vitro communication. Vivo communication in WBAN is based on real world Telemedicine based Infrastructure. Vitro

communication in WBAN is based on communication tests in real word outdoor environments including ranges calculation in meters based on frequency calculation in hertz. Body-coupled communication is a revolutionary kind of in-person communication in which the human body serves as a transmission channel [72]. The literature was searched for the best simulation technique for in vivo communication. Data collection, transmission, reception, and inactive interception consume the bulk of node power. The energy consumption of data transit causes the majority of them. Because this work focuses on inter-node communication, only sending and receiving energy utilization is addressed, leaving out data collecting and idle listening [72].

Path loss in the IM-QRP Routing protocol can happen in a variety of situations based on how the body is positioned and how close or far the sensor nodes and relay nodes are to one another. The variable that directly correlates with path loss is RSSI. When the patient positions his body differently, especially when his legs and arms have path loss, the transmission distance between sensor nodes, relay nodes, and sink nodes may increase. For IM-QRP, our proposed model allows for a little degree of route loss. The cause is related to the patient's position when the sensors on the arms and legs are close to the washbasin node deployed on the belly side of the human body. A few millimeters of minimal communication space between sensor, relay, and sink nodes may cause a minor amount of route loss on the sides of the arms, legs, and abdomen [73].

The proposed model for energy consumption is feasible [71]. The following model defines the energy consumption for transmitting and receiving k bit data:

$$E_{tx}(k,d,n) = E_{TXelec} * k + E_{amp} * k * d^n \dots (3.10)$$

$$E_{rx}(k) = E_{RXelec} * k \dots (3.11)$$

3.3.4 Path loss model in routing mechanism

Path loss shows the effect of route loss on discourse in WBAN. The Authors [74] had investigated and presented findings using channel route loss model to solve the issue of statistics loss or variation in scientific implants and conversation waves. The authors proposed sensor units for machine monitoring and established a server-based architecture for in vivo speech transmission channel loss. As the world's population grows, so does the demand for

appropriate healthcare device features in WBAN, particularly for the elderly, who are more prone to fitness issues. Many scientists have presented services to the elderly; for example, prototype structures that use Bluetooth as a wireless physique region network (WBAN) to show location and fitness status and smartphones outfitted with accelerometers as intelligent central nodes have been used to design healthcare systems. This system gives family members and healthcare practitioners real-time access to patients' whereabouts and health status over the Internet. ZigBee is used for low-data-rate applications because it consumes less energy than Bluetooth. The most significant challenge with WBAN to date has been recorded loss or transmission corruption; new protocols or schemes are required to demonstrate the efficacy of receiving entire records without loss; the loss is caused by free-space impairment of the propagating sign (e.g. refraction), fading, absorption, and reflection, among other things. It is also determined by the distance between the transmitter and receiving antennas, the top and position of the antenna, the propagation medium, such as moist or dry air, and the antenna's rural or city location, among other factors. In the case of WBANs, the loss of the route depends on distance and frequency.

Equation 3.12 defines the Friis formula for Path Loss Model PLd, which determines the path loss between two communicating nodes depending on the distance, d, between the sensory nodes in the network field.

$$PL(d) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) \dots \dots \dots (3.12)$$

Where d is the distance between the sending and receiving nodes along with the reference distance of 10 cm. PL is path loss coefficient, which varies in different environments. In physical wireless networks, in areas with a direct line of sight, between 3 and 4, while in environments with an indirect line of sight, we are between 5 and 7.4. X represents the random variable of Gauss with standard deviation σ .

Equation 3.13 can be used to compute the route loss ratio necessary for the sensor node to communicate with the sink node in an emergency.[74].

$$P_{Loss(emergency)} = \frac{PLk_{emergency}max}{PLmax} \dots \dots \dots (3.13)$$

In an emergency, the path losses ratio factor will be as low as possible. The ratio of the shortest paths between a sensor node and a relay node, as well as

between a sensor node and a sink node used in Equation 3.14

$$P_{Loss(normal)} = \frac{PLk_{normal}max}{PLmax} \dots \dots \dots (3.14)$$

. $PL(d_0)$ is path loss in dB at distance d_0 , and n is the path loss exponent is defined as follows in Equation 3.15.

$$PL(d_0) = 10 * \log(4\pi * d_0 f) * C \dots \dots \dots (3.15)$$

Where f is the frequency of operation, and C is the speed of light. The equation gives the total path loss in Equation 3.16.

$$PL = PL(d) + X_6 \dots \dots \dots (3.16)$$

Where X_6 is the shadowing factor in dB.

In WBAN framework node failures, may occur, which results in routing path disconnection and overall network topology will change. In this regard early detection and recovery of routing path is feasible in emergency situations. Due to minimum battery life of sensor nodes, the performance of overall network degrades. In this regard IM-QRP scheme may adopt Cluster based Fault Detection and Recovery mechanism (FDR) [75] on exiting framework in Figure 1. The mathematical modeling of this scheme is based on our future work. FDR is an energy efficient routing mechanism designed for fault detection and recovery. The scheme achieves minimum packet loss by replacing faulty sensor nodes with in routing path with the newly selected alternate routing paths. Network topology is designed in such a way by mapping a virtual grid over the human body sensor network, which is capable to identify the node failure detection and its possible recovery as soon as possible in normal and emergency circumstance. FDR scheme may also achieve fault tolerance capability and enables the network to route the data on shortest path between sensor nodes, relay nodes and sink nodes. The FDR scheme may also generate a query path leading towards the faulty node. The query can be a request for information. In order to get information about the energy level of sensor nodes the request based query is generated. Agent based technique is used to implement the query path. Agent based packet is created at sink node which is traversing the entire WBAN [76]. Sink node is responsible to

generate an Agent packet and Agent generates a query path towards the faulty node. The sink node is responsible for sending the Agent based packets to all its neighboring sensor nodes. The Agent based packet contains the following Information.

Message-ID: Message identifier for agent based packet generation

Sender-ID: Agent packet based sender node ID

Receiver-ID: Agent packet based receiver node ID

Active-node: Active node based query path

Stamp-time: Calculation of time when the packet is sent by agent.

When Agent packet is received, the sensor nodes stores the above mentioned information in Query list and returns ACK packet to the sender node. The ACK packet consists of following information

Message-ID: Message identifier for agent based packet generation

Sender-ID: Agent packet based sender node ID

Active-node: Active node based query path

Stamp-time: Calculation of time when the packet is sent by agent.

The mathematical modeling of Fault detection and discovery in case of faulty nodes and dead nodes is to be handled in our future work. At this stage we have suggested an Agent based descriptive framework for Fault tolerance and node failure in case of QoS Aware routing mechanism in WBAN.

3.4 Proposed Protocol (IM-QRP) comparison with existing Protocols

The outcomes results are based on the sensor nodes' remaining energy, the path loss ratio, the quality of service, and the SNR ratio vs 6000 rounds.

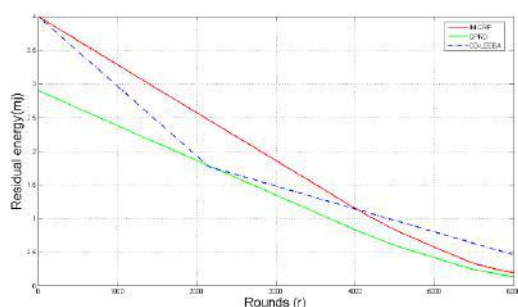


Fig 3.5. Residual energy

On the basis of residual energy for sensor nodes implanted on the human body, Figure 3.6 compares QPRD, CO-LEEBA, and the proposed IM-QRP.

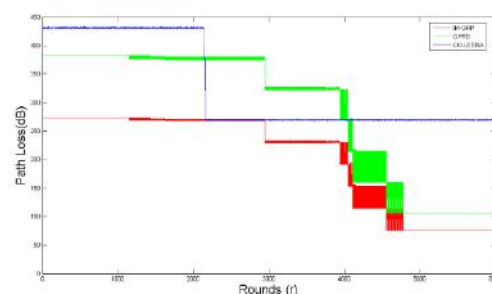


Fig 3.6. Path loss ratio

Path loss ratio has been determined for 6000 rounds in Figure 3.7. The highest route loss ratio for the CO-LEEBA system at the initial number of rounds is 440 dB.

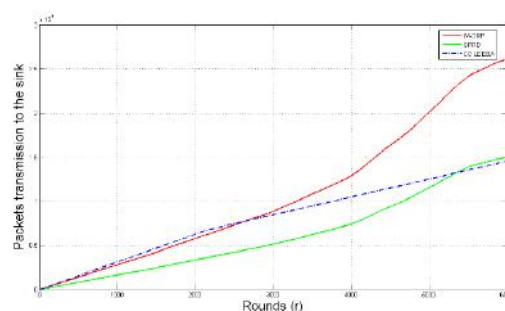


Fig 3.7. Link reliability (packet delivery ratio)

In Figure 3.8, the QoS for the suggested design is mentioned. The maximum number of packets that can be transmitted to the sink node affects QoS.

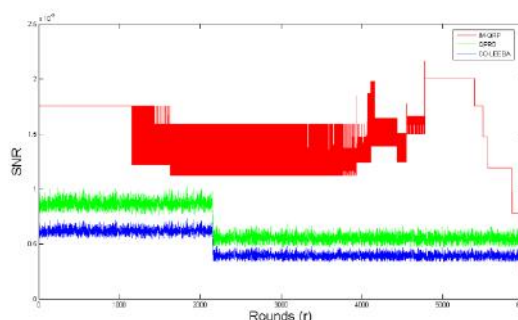


Fig 3.8. Signal to noise ratio

The proposed IM-QRP QRP's is shown in Figure 3.8. Comparing the IM-QRP to the QPRD and CO-LEEBA, the highest SNR of the IM-QRP is 2.2×10^8 dB. Table 3.5 compares the QPRD routing protocol with the IM-QRP routing protocol.

Table 3.5: Comparison of IM-QRP with CO-LEEBA and QRPD Protocols

WBAN Routing Protocols vs Evaluation parameters	Residual Energy	Path loss	Link Reliability	SNR
Co-LEEBA	YES	YES	NO	NO
QRPD	YES	NO	YES	NO
IM-QRP	YES	YES	YES	YES

Table 3.6 provides more information on the WBAN routing protocols' comparative study. The temporal complexity of the CO-LAEBA, QRPD, M-ATTEPT, and RE-ATTEMPT algorithms is compared to that of the IMQRP Routing Protocol Algorithm. The complexity of routing protocol algorithms varies depending on their benefits and drawbacks. Analysis of the existing protocols reveals that the M-ATTEMPT routing protocol achieves temporal complexity as Best case.

Table 3.6: Comparative Analysis of Complexity of Routing Protocols in WBAN

Algorithms	Contributions	Limitations	Time Complexity
1. M-ATTEMPT [39]	- Select thermal heat of hot spot during Routing Mechanism. - Temperature Aware Routing Protocol for WBAN	Maximum power Transmissions is utilized by sending maximum number of packets directly towards the sink Node.	$O(n^2)$
2. RE-ATTEMPT [24]	- Selects the Route for data transmission with minimum hop count and lesser delay as compared with M-ATTEMPT. - Routing Path quality is better than simple M-ATTEMPT	- Minimization in Network Life time due to increased energy consumption. - Short range transmission using IEEE 802.15.6 Standard	$O(n)$
3. QRPD [67]	- QoS Aware Routing Protocol in WBAN. - Ensures Higher data transmission rate (maximum throughput) and limited packet drop with stable Network Traffic	- Less coverage rate and exploration - Transmission link failure can occur.	$O(n \log n)$
4. CO-LAEBA [43]	- QoS Aware Routing Protocol for WBAN having minimum path Loss. - Having Low Energy Consumption and High packet delivery ratio	Minimized Network life time, i.e. limited number of alive nodes for maximum amount of time	$O(n * m)$
5. IM-QRP [proposed]	- Improved QoS Aware Routing protocol for WBAN. - Higher SNR, Maximum throughput, maximum residual energy of sensor nodes, Maximum number of packets transmissions, Enhanced Network life time	Integration with 6G wireless framework is future research challenge.	$O(n)$

The suggested routing protocol by IM-QRP has a time complexity of. Time complexity is made possible thanks to reliable data transfer increases Network lifetime, including the maximum residual energy of each cluster's sensor and sink nodes. With the

exception of RE-ATTEMPT, the algorithm we've suggested has a lower temporal complexity than the ones listed in Table 3.6. Our restriction is for future sixth generation (6G) wireless framework in the case of WBAN communication infrastructure, if we compare the limitations of both Re-ATTEMPT and IM-QRP.

IV. CONCLUSIONS AND FUTURE WORK

4.1 Conclusion

Many applications in WBANs are concerned about QoS Aware Routing. Patient's vital signs and physiological factors are constantly monitored in healthcare applications, which can be difficult. WBAN-driven technology is also needed to implement the data aggregation technique related to patients. WBANs-related resource constraints and a lack of relevant real-world data are the issues raised by the study's findings. Energy consumption, fault tolerance, and reliability are major concerns in current WBAN technologies. Reactive Routing Protocols can be improved by increasing the reliability of the network. High bit-error rates, packet drop ratios, and delays reduce the system's reliability [101]. WBANs' increased resiliency benefits greatly from the addition of this QoS parameter. The research objectives and major challenges have been met by developing three schemes for WBAN fault tolerance and reliability improvement.

Cluster-based routing schemes outperform non-cluster-based routing schemes in terms of network lifetime, packet delivery ratio, end-to-end delay, and path loss when node densities are high, according to simulation results. Non-clustered schemes do not take into account cooperation-based communication [102]. The data packets that each sensor node holds take center stage in cluster-based schemes.

4.2 Research Contributions

Research contributions have been summarized in this section. As a result of the literature review and the proposed solutions, this research gap has been filled. The following is a list of the contributions made by this thesis to the field of research:

The IM-QRP scheme, a new QoS-based Multi-Path Routing Protocol, has been proposed and presented in order to increase the QoS insider network. The

proposed system prioritized traffic and classified paths within the network. Various matrices such as residual energy, path loss ratio, Link reliability, packet delivery ratio, and Signal to Noise Ratio are used to evaluate the proposed scheme's output. ACCORDING TO THE RESULTS, QoS-based IM-QRP has maximum residual energy after 3000 rounds. IM-proposed QRP's QoS-based QoS scheme uses the least power in comparison. The QPRD and CO-LEEABA schemes are less efficient in terms of energy usage. In the long run, it will extend the network's lifespan compared to the current one. Like the QoS-based routing protocol, its path loss ratio is reduced as compared that of QPRD and Co-LEEABA routing protocols respectively. Signal to Noise ratio for the proposed scheme is higher than existing schemes. The higher signal to noise ratio leads towards better and stable data transmission mechanism.

With the proposed cooperative network routing scheme, it was found that there was a significant improvement in packet transmission towards the Base Station. Additionally, the cooperative communication approach results in a significant power gain within the network itself. Cluster based Routing strategy and cooperation in (WBAN) has also increased FANETs energy efficiency towards maximum number of alive nodes for maximum duration of time. Objective function is also used in order to improve the performance of reactive routing protocol via using FANETs. It is possible to achieve significant improvement in the energy efficiency and minimum delay with the maximum number of sensors working together in cooperative communication with in each cluster.

4.3 Future Works

WBANs are becoming increasingly popular, particularly in healthcare applications, in the broader context. Health care technology has grown so quickly that remote patient monitoring is now feasible in smart healthcare. WBANs provide researchers with a brand-new field of study. Since WBAN is still an emerging technology, there is always room for new ideas in this era of technological advancement. It is possible to extend this research in the future to fill in the gaps that have been unearthed. Following are a few potential future paths for research in the following areas:

Real-time IoT systems can benefit from the proposed research's collaborative architecture. The system's available computing resources will be utilized in this collaborative architecture. Combining the sensing and processing capabilities of WBAN and FAN systems, the result is a novel network design that includes multiple levels. IoT-based WBAN systems, on the other hand, can use predictive resilience models for the available resources and service discovery mechanisms to make less-than-optimal decisions.

WBANs have unique characteristics such as self-healing, self-organization, fault tolerance, low duty cycle, dynamic network topologies, and flexibility. It is because of these characteristics that these networks have expanded their reach. Their wide range of applications has resulted from this. Battery power, storage capacity, computation power, data rate, and transmission range all suffer in WSNs where nodes are lacking. As a result of the sensor nodes' limited resources, these networks face a slew of difficulties. WSNs have drawn significant academic and industrial research to address these problems. As a result of the sensor nodes' resource limitations, scientists are constantly tackling new problems. At first glance, it seems that structure-based data aggregation techniques using various functions are the optimal energy management solution for WBANs. Although these techniques have some drawbacks, the possible directions for future research includes Lightweight and energy-efficient data aggregation [103], Accuracy of the aggregated data [104], Reducing packet loss ratio [105], Security and integrity of the aggregated data [106], Optimization [107], Practical implementation [108] and Challenges faced by the Internet of Vehicle (IoV) [109].

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Connectivity Restoration in Wireless Sensor Networks

Rashid Blouch

Institute of Communication Technologies (ICT)

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Abstract— Wireless sensor networks (WSNs) and services, especially those under hostile environments such as battlefield, are at greater risk because of failure of nodes. In Wireless Sensor Network (WSN), node failure is of significant concern. The node failure creates breakup in a network and leads to problems relating to the isolation of the affected node. It is important that the nodes are always live and communicate with uninterrupted network connectivity. The rapid detection of failure of node in the network is essential for inter-node communication. Recently, a number of methods for the restoration of inter nodes connections have been proposed. Replacing the node is one of the sustainable solution to address the issue. Another way is that a gateway node can take control of the functionalities of the affected node. Similarly, the residual energy available at each node can also be used to detect the faulty node in the wireless sensor network. In addition to this, the performance of the network should not degrade in case of any such failures for which right mechanisms have to be put in place as outlined in this research work. The usefulness of the proposed solution is authenticated by the results of the simulation. The performance was validated using experimental analysis and better performance was achieved. This research study fills the gap existing in this domain. A novel method to address this issue is suggested in this work.

Keywords— Networking, Wireless Sensor Networks (WSN), Network Restoration.

I. BACKGROUND

1.1. Background

Wireless Sensor Networks (WSNs) have received a lot of focus in recent years. Majority of WSNs applications have opened up varied areas of research and is considered to be the most advanced technology in present day communications. Extensive research is being done on various WSN sites. The Wireless Sensor Network is a new communication technology that has shown major impact on the latest wireless sensor technology. Sensors have less power and energy resources and are responsible for transferring important information from the area of interest (node) & transmitting it to base station. Fig below shows the basic structure of a WSN connection, where the sensors hear the data from the surroundings and send it to the subsequent nodes.

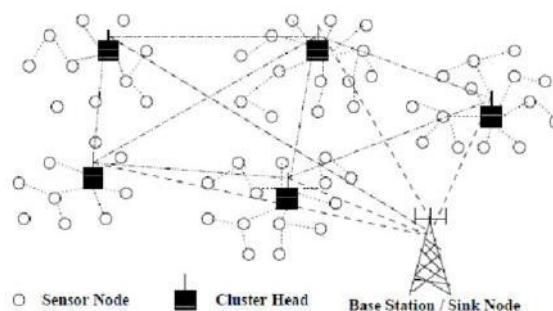


Fig 1.1: Typical WSN

The sensor nodes may fail because of battery failure, hardware issues, or some external intervention. Because of which, network is divided into various segments, leading to reduced performance. Therefore, the reconnection process has to be performed. Human contact is very limited in such applications and no one is watching or looking at the network all the time and making a timely decision. It is a difficult task to install the nodes at affected locations, especially in a difficult area such as a battlefield. It is therefore necessary to

have a comprehensive approach that replaces a failed node with any of its neighbors. Interaction between healthy nodes is needed to restore communication to initial level. Node monitoring/navigation can improve overall network performance such as connectivity, coverage and network health. These recovery processes also create more text messages. Usually, these algorithms deal with the failure of a single node, and do not take into account resource efficiency and lack emphasis during recovery.

The use of WSNs has become very common in real life in recent years due to major advances in its wireless technology. Applications such as field intelligence, border protection, space exploration, etc. applies to the most difficult areas, where sensor nodes reduce the risk to human life. The sensor node however is

restricted to its power consumption and connection issues as a large amount of sensor nodes are involved to ensure the availability of a network at a sensitive area therefore reliability of the data collected is important. Due to power limitations, the sensor is at high risk for failure. In case of hostile environments where the network sometimes encounters serious damage to the serving nodes thus leading to network fragmentation. Some node sensors may be damaged under snow or sand after a storm or battlefield or part of the transmission area may be attacked by enemy explosives and, thus, a collection of sensors node in the surrounding area will be destroyed. Some of the applications of the WSNs in today's world around us are shown in the Fig below.



Fig 1.2: WSN Applications

1.2. WSN Network Restoration

WSN is still widely distributed in difficult areas such as the battlefield, dense forest or large areas. These networks are usually installed in remote areas, so the restoration of an effective connection is a very difficult process. The process of restoring communication should be disseminated, treated and localized. Additionally, the process should be so fast that it minimizes the impact of node failure. If the node is too slow to reconnect, then it will consume a lot of power and may also affect other network disconnections. Therefore, restoring connectivity is a daunting task in a distributed, localized, and effective way. Effective recovery strategies work tirelessly and begin when node failure occurs.

Nodes can only communicate with each other if S/N (Signal-to-Noise Ratio) is not below the threshold. Signal strength decreases as we increase transmission. Some algorithms used for recovering a single failed node use a collaborative communication method to restore the connection. Many techniques are available to determine whether a node is cut and uses the information of the hop neighbors. When a fault occurs, the neighbors of the error node will select the most suitable backup node. It will look at node, distance and inform its sibling locations. Improved algorithms provide details of specific location in advance of whether a split has occurred. Nearby neighbor decides whether it is out of service or not. Distributed distribution detection algorithms detects sensitive information in advance on the basis of local

knowledge and places the neighbor as backup. When a node failure occurs, the backup initiates a process of immediate recovery.

Recovery algorithms for multi-node failure handles the failure of two nearby nodes at the same time. It is

thus called a hybrid delivery system. Detailed comparisons of various strategies for the connectivity restoration are shown in the table below:

Table 1.1: Strategies for the Connectivity Restoration

Sr	Name of Technique	Year	Objective	Centralized/ Distributed	Movement Type	Node Type	Node Mobility	Node Failure Type
1	C ³ AP	2007	Connectivity	Distributed	Cascade	Any node	Mobile Sensor/ Actor	Single node
2	DARA	2007	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor	Single node
3	NN	2008	Connectivity	Distributed	Direct move	Any node	Mobile Sensor	Single node
4	C ³ AM	2009	Connectivity	Distributed	Cascade	Any node	Mobile Sensor	Single node
5	RIM	2010	Connectivity	Distributed	Cascade	Anyone	Mobile Sensor	Single node
6	C ³ R	2010	Connectivity and Coverage	Distributed	To and fro movement	Any node	Mobile Sensor	Single node
7	NORAS	2010	Connectivity and Coverage	Distributed	Cascade	Cut-Vertex	Mobile Sensor	Single node
8	DORMS	2010	Connectivity with partial coverage	Distributed	Cascade	Any node	Mobile Sensor	Multi nodes
9	PADRA	2010	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Node/ Robot	Single node
10	MPADRA	2010	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Node/ Robot	Multi nodes
11	LeMoToR	2011	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single node
12	DCRA	2011	Connectivity	Distributed	Block movement	Cut-Vertex	Mobile Sensor	Two nodes
13	DCR	2012	Connectivity	Distributed	Cascade	Cut Vertex	Mobile Sensor/ Actor	Single node
14	PCR	2012	Connectivity	Distributed	Cascaded or shifted	Cut Vertex	Mobile Sensor/ Actor	Single node
15	RAM	2012	Connectivity	Distributed	Cascaded or shifted	Cut Vertex	Mobile Sensor/ Actor	Two nodes
16	AuR	2012	Connectivity with partial coverage	Distributed	Cascade	Any node	Mobile Sensor	Multi nodes
17	LeDIR	2013	Connectivity	Distributed	Block movement	Cut-Vertex	Mobile Sensor/ Actor	Single Node
18	NNN	2013	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single Node
19	DPCRA	2014	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single Node
20	CC-IC	2016	Connectivity and Coverage	Distributed	Cascade	Any node	Mobile Sensor	-
21	CSFR-M	2016	Connectivity	Distributed	Cascade	Any node	Mobile Sensor	Single node
22	CCRA	2016	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor	Multiple nodes
23	SFR-RNR	2017	Connectivity with partial coverage	Distributed	-	-	Mobile Sensor	-
24	HCR	2017	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single node
25	EAR	2017	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single node
26	DEENR[22]	2018	Connectivity with partial coverage	Distributed	Cascade	Any node	-	Single node
27	DCRMF	2018	Connectivity	Distributed	Cascade	Cut-Vertex	Mobile Sensor/ Actor	Single/ multi nodes
28	PRACAR	2018	Connectivity and Coverage	Distributed	Cascade	Any node	Mobile Sensor/ Actor	Single node

It covers the strategies presented and their objectives, type of nodes, type of movement, and type of node failure. It also indicates whether the techniques are split or distributed and what is the most powerful process to restore normal node connections. This table also shows the movement of nodes and which processes have the potential to restore a single or multiple connection. The framework adopted in line with the above table is shown below for taking the right approach towards the recovery.

Advanced network recovery models are designed having 2 main objectives in mind. The first goal is to increase utilization of network resources, and the second to protect the network from failure. In recognizing the purpose of increasing resource utilization, a distinct feature of WSNs is exploited, i.e., their ability to remain active even if one or more of the active (sensor nodes and / or connecting links) fail. For advanced recovery models, researchers adopt

processes that collectively look at the minimum lengths, sustainable topologies, and the energy requirements to achieve new energy recovery solutions.

1.3. The Research Problem

The problem associated with wireless sensor networks is the sensors nodes connection failures during deployment or low power issues leading to breakup of communications. Restoration costs, restoration time and reliability of the networks are compromised in case of node failures.

1.4. Objectives

The research contribution is focused on the following points:

- Restoring inter-node connectivity in WSNs.
- Designing a diverse mechanism for restoration of connectivity.

- Performance analysis during WSNs deployments.
- Performance validation

1.5. Simulator

Simulation is a cost-effective way to develop, deploy and manage network systems. Users can test basic network performance and test a lot of network

features. Simulator, NS2 in this case, provides a complete environment for creating and highlighting network conditions, and analyzing performance. Thus, NS2 simulator is used which gives the best results. It is an open source simulation tool that works on Linux. It focuses on network parameters and provides valuable simulation support.

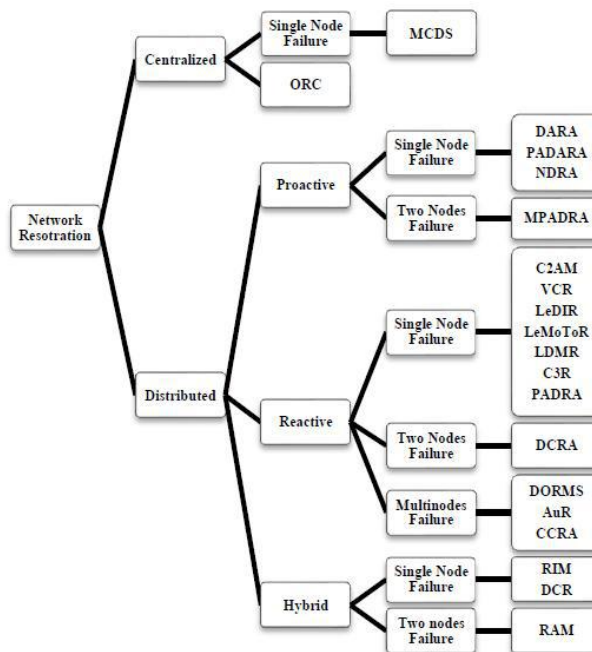


Fig 1.3: Restoration Framework

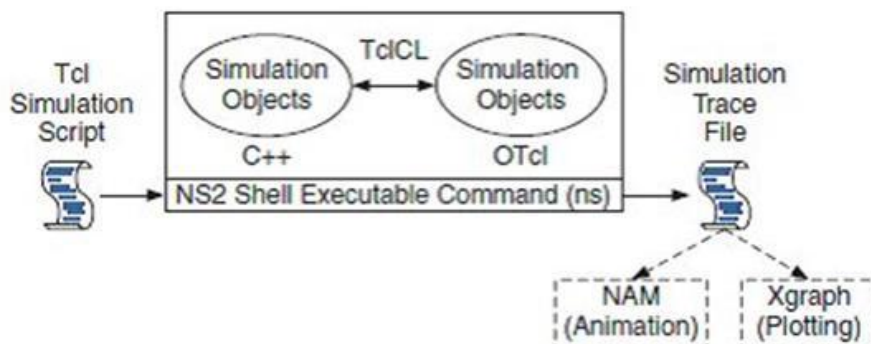


Fig 1.4: Basic Architecture of NS2 Simulator

II. Literature Review

2.1. Literature

In research, RCR (Relative Citation Ratio) algorithm has been suggested for the reconnection of WSNs based on the locations of the transmitted character [1]. In CBMAR (Connected and Balanced Mobile Actor

Relocation), the authors proposed to solve the problem of load balance and connectivity [2]. The NSCRA (Node Stability aware Connectivity Restoration Algorithm) process is proposed to address the problem of network fragmentation using an efficient power method and the node is selected for migration based on the storage capacity of the

survival nodes [3]. A practical process is proposed to handle connection recovery on WSNs based on the configuration method algorithm [4]. The novel process is suggested to improve the performance of WSNs based on linking of locations [5].

Node Recovery is a method used to detect the failures of the most widely used sites in WSN, where it has become increasingly important to fix these nodes from failures and from a situation where another part is uncontrollable. The flow of information is greatly affected by node failure. To solve this problem, we learn the LEDIR (least-disruptive topology repair algorithm) and how it comes in comparison to RIM. Researchers compare the two algorithms on the basis of three parameters: no of nodes delivered, total distance traveled and complete exchanged [6]. C3R (coverage conscious connectivity restoration) includes one or more neighbors of a node that failed to recover from a failure.

Internal motion retrieval (RIM) [7], is a distributed algorithm to effectively restore network connectivity after node failure. Instead of performing a comprehensive network analysis to assess the impact of node failure and set the course of action, RIM triggers a local retrieval process by relocating lost node neighbors. RIM (Recovery through Inward Motion) reduces over-sending and reduces the distance traveled by individual nodes during recovery [8].

Number of schemes have been proposed for the network connections relating to WSN. Some schemes change the nodes having additional transmission areas and other some schemes reset the failure node to save network connection. Younis et al. (2008) suggested a way of restoration by internal movement (RIM) redirecting nodes for retrieval of communication. This way it handles the failure of a single node through neighbor's node which is adjacent or one-hop away. In this work, the total distance traveled and movement of nodes over time is relatively higher than other schemes [9]. (Imran et al., 2010) suggested connection recovery schemes to manage a node failure. The PCR system selects the appropriate backup nodes. The backup is used to find the failure node and the initiation of the recovery process [10]. In multi-node recovery schemes, (Younis et al., 2008) explored multiple-node failure issues for

situations where the distance between each pair of sections is more than double the range of node [11].

Mahmood et al. (2018; Sharma and Sharma, 2016) explains that the RN failure can cause a new split in the network. The algorithm returns to communication by building reinforcement mechanisms that can achieve the following three objectives: Tolerance, delay reducing and reducing energy consumption. The verification method allows the network to last longer having more connection time for various components [12].

Boudries et al. (2016) suggested a novel approach by switching a failed node in the wireless network. This method reveals the selection based on node strength, its distance from other nodes, login, trust and navigation. These clusters maintain the redundant list of sensor nodes (RSL). However, node search and detection process generates multiple messages when the communication distance is small [13].

Singh and Jinila (2016) describe an alternative to node modification error using test point recovery algorithm for detecting node failure. This way error is detected by sending messages to the location. If no response was received from the node, it is considered that the strength of the node is low and it will fail and will replace the sensor node with the node having high power [14].

Tseng et al. (2018) introduces Resource Constrained Recovery (RCR) method in which the network disconnects due to node failure using a limited number of relay nodes. Each component in the network has only a minimum number of referral nodes available for access

Process [15].

Buyahia and Benchaïba (2016) developed a communication correction process which was named as CRVR9. It restores the communication by building constructive paths to tolerance to failure, delay reduction and reduced energy consumption [16].

III. SIMULATION DESIGN

3.1. Model Design

A network of "n" nodes is designed whereas all the nodes are accessible to each other through single or through multiple hops. These nodes are designated as end nodes. These nodes are deployed in an area which can be vulnerable to any hostile environment. All these nodes in turn have a connectivity with a

gateway. We can call this gateway as a server where all the information relating to each node is transferred or sent. It is a good idea to divide the network into different regions for clarity and as a design aspect of having a distributed network design. The network consisting of these nodes is fully up and running with all its functionalities. However, the end nodes may not be capable of reestablishing a connection in case any fault occurs. In order to resolve the issue of node failures and their restoration, a mobile relay node is introduced. These are low powered nodes which provide enhanced coverage. These are basically used for the enhancement of the coverage areas.

The researcher has deployed one such relay node in the wireless sensor network area or field in order to provide seamless connectivity and network coverage. The established node has rich features including the option of mobility in the WSN area or coverage. The mobile relay nodes can be multiple and can be assigned to a particular region the researcher defined. It can be any area of interest. In case the area is small, only very few relay nodes can be placed. In case of larger areas, many more relay nodes can be installed.

The main focus for this network design is that in case of failure of any node, these mobile relay nodes can be deployed in that particular region with the aim to maintaining the required connectivity for the restoration of the services. It is a must that connectivity between the nodes is maintained at all the nodes and the internal designed network architecture works in harmony and coordination systematically. The deployment in the application area is based on multiple regions deployments.

The mobile relay node is only deployed in case of failure of any node. When a node fails, it communicates a message for neighboring nodes including the gateway node/server. Status of the affected node is conveyed to the neighboring nodes and the gateway node in case of its failure hence even when the alert message is not sent and the node becomes dead or out of service, the status of that node is recorded in the network. The designed network architecture is shown in the Fig below:

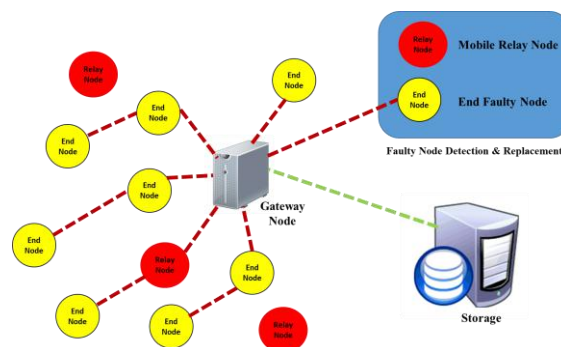


Fig 3.1: Designed Network Architecture

3.2. Faulty Node Detection

There are two ways to detect the faulty node.

- Through Alert Message
- Through Residual Energy

3.2.1. Alert Message

The issue of determining if a node is down or otherwise can be done by sending an alert message to all the nodes in the wireless sensor network. In response to this alert message, nodes in network send an acknowledgement message to the gateway which subsequently informs the mobile relay node in the network. The acknowledgement message sent by

nodes to the gateway contains the following information.

- Residual Energy of the node
- Time Stamp (Date/Time)
- Services

When this acknowledgement message is received by the gateway, it means that the node is working properly. Otherwise, the node is faulty. However, the node can be alive and working at times but the acknowledgement message somehow failed to get delivered because of the network congestion. To avoid this, multiple alert messages are sent periodically by the gateway and in case of any response, the relay node is informed accordingly. If the

acknowledgement message is still not received after sending repeated alert messages, then the node is

considered to be out of service. Fig below shows the requisite messaging:

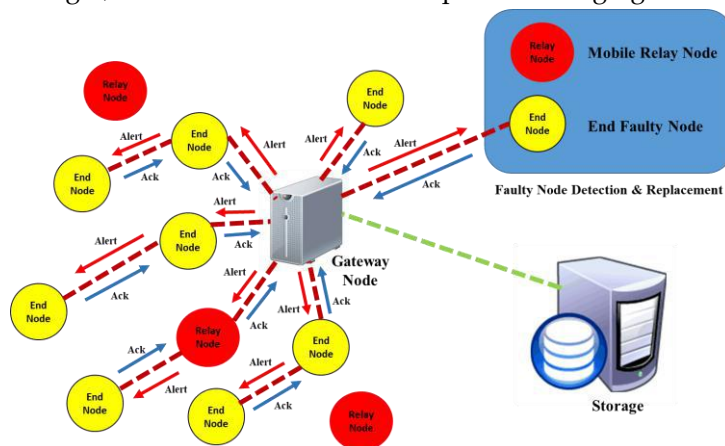


Fig 3.2: Alert/Acknowledgement Messaging

The sequence of commands is shown below:

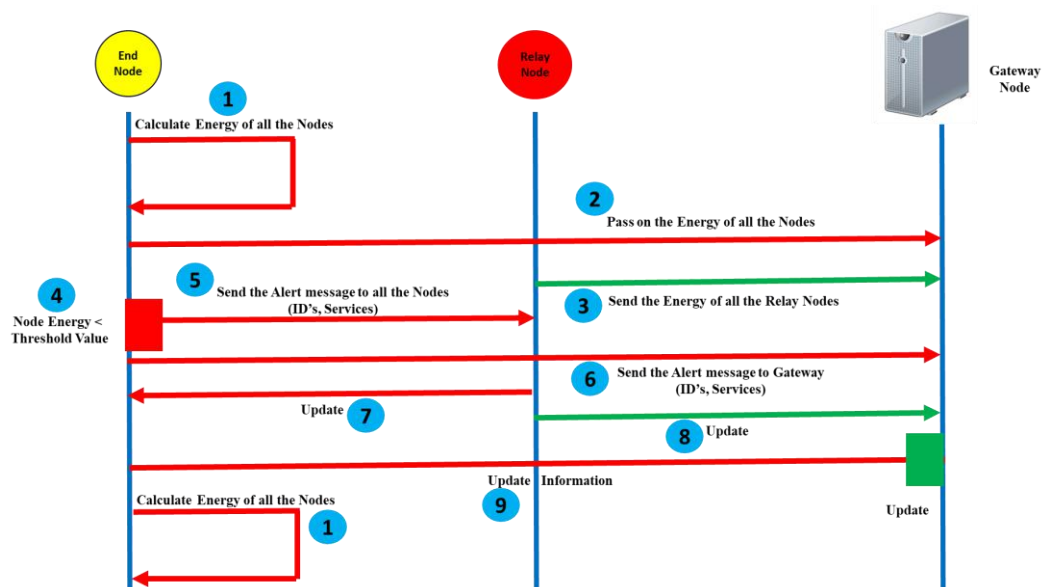


Fig 3.3: Alert/Acknowledgement Messaging Fault Detection Sequence

3.2.2. Energy (Residual)

Using this method, the residual energy of the node is analyzed. Depending on defined threshold value, a node is declared faulty or otherwise. The following two factors are of importance.

- Minimum value of the energy needed for the node to be considered alive.
- Residual energy of the node.

If,

Residual Energy $\leq$ Threshold Energy = Faulty Node

Once a node is declared faulty, the next step involves starting the recovery process so that the network connectivity can be ensured. This leads to the initiation of the alert messages to all the neighboring nodes in addition to the gateway node. The alert message carries with it the details about the node and region identification in addition to the relay node identification deployed in that particular region. This triggers the gateway to inform the relay node with faulty node parameters. The sequence of events is shown in the Fig below:

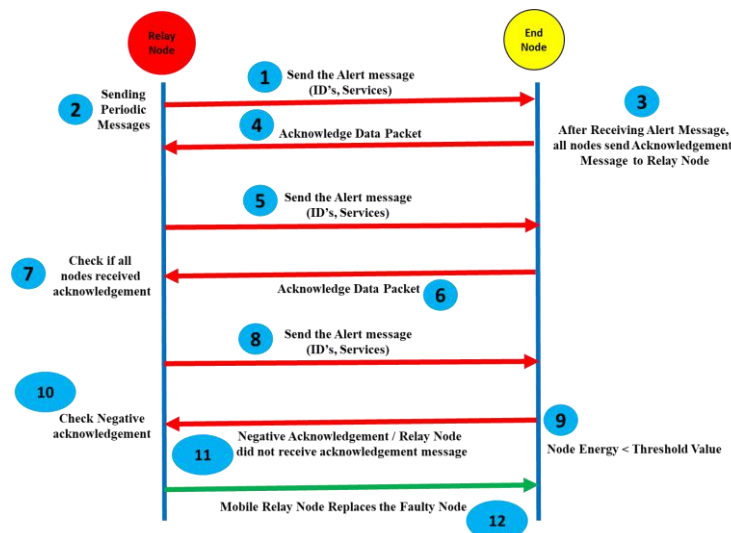


Fig 3.4: Residual Energy Fault Detection Sequence

As seen in the above sequence, the gateway checks if the relay node in the region is idle or not. If it is not idle, this information from the gateway is passed to other relay node which is idle. Gateway directs the relay node deployed in the region to work in place of the faulty node and continues to work at its place till

the time the faulty node becomes active again. Once the faulty node is active, the relay node goes back to its idle state.

The Fig below shows the taking over of the relay node of the faulty node in the researchers designed model.

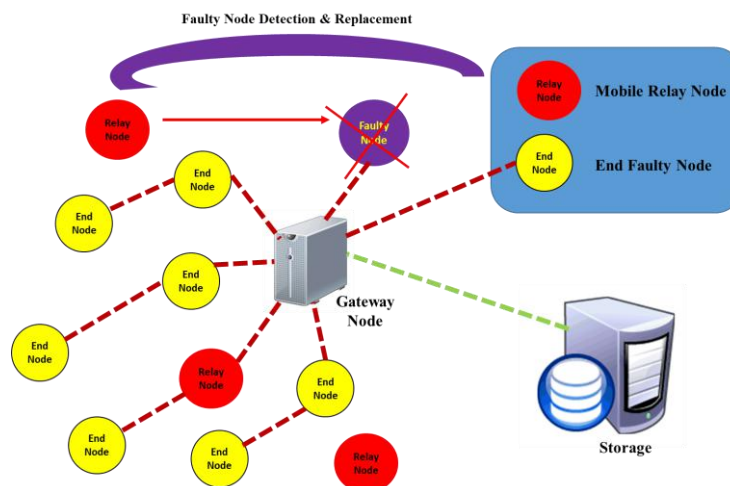


Fig 3.5: Faulty Node Detection and Replacement

3.3. Simulation

The simulation was done using NS2 for analyzing the performance, energy and packet network communications.

IV. SIMULATION ANALYSIS

This section looks at the design of the network and analyzes the performance of the network in terms of system overheads, data or messages communicated

between the nodes inside the designed network, relocation of the failed nodes and the recovery processes.

4.1. Performance Evaluation

Performance evaluation is what validates the design of the conceived network. The proposed scheme needs to be compared and analyzed in terms of the system load (average), amount of data or messages communicated between the nodes, overheads, node relocations, failed nodes and their recovery. As per the

design of the conceived network, the communication range within the network is the same.

4.1.1. Messages Sent, Relocated Nodes

The graph shown below shows the Average no of message sent between the nodes against the no of nodes in the deployed network.

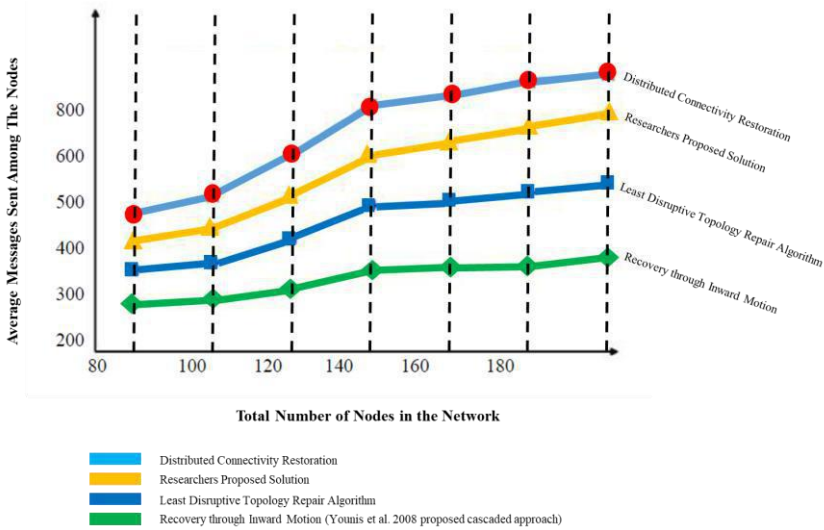


Fig 4.1: Average number of messages sent among the nodes

Fig above depicts number of messages (average) which were communicated or sent across the network between the nodes during the process of recovery. In case of Least Disruptive Topology Repair and Distributed Connectivity Restoration algorithms, the number of messages to be sent for the recovery are

more as compared with researchers proposed scheme/model. Also the number of nodes deployed is less (298) as compared to that of Distributed Connectivity Restoration (498). The validity of the performance can be easily judged through the simulation model.

```
// EVERY NODE BUILDS ITS SHORTEST PATH ROUTING TABLE (SRT) BASED
// ON THE ROUTE DISCOVERY ACTIVITIES THAT IT INITIATES OR SERVE IN, E.G.
// WHILE EXECUTING A DISTRIBUTED ROUTING PROTOCOL..
```

LeDiR(*J*)

```
1 IF node J detects a failure of its neighbor F
2   IF neighbor F is a critical node
3     IF IsBestCandidate(J)
4       Notify_Children(J);
5       J moves to the Position of neighbor F;
6       Moved_Once  $\leftarrow$  TRUE;
7       Broadcast(Msg('RECOVERED'));
8       Exit;
9     END IF
10  END IF
11 ELSE IF J receives (a) notification message(s) from F
12   IF Moved_Once || Received Msg('RECOVERED')
13     Exit;
14   END IF
15   NewPosition  $\leftarrow$  Compute_newPosition(J);
16   IF NewPosition  $\neq$  CurrentPosition(J)
17     Notify_Children(J);
18     J moves to NewPosition;
19     Moved_Once  $\leftarrow$  TRUE;
20   END IF
21 END IF
```

IsBestCandidate (*J*)

```
// Check whether J is the best candidate for tolerating the failure
22 NeighborList[]  $\leftarrow$  GetNeighbors (F) by accessing column F in SRT;
23 SmallestBlockSize  $\leftarrow$  Number of nodes in the network;
24 BestCandidate  $\leftarrow$  J;
25 FOR each node i in the NeighborList[]
    //Use the SRT after excluding the failed node to find the set of
    //reachable nodes;
26   Number of reachable nodes  $\leftarrow$  0;
27   FOR each node k in SRT excluding i and F
28     Retrieve shortest path from i to k by using SRT;
29     IF the retrieved shortest path does not include node F
30       No. of reachable nodes  $\leftarrow$  No. of reachable nodes + 1;
31     END IF
32   END FOR
33   IF Number of reachable nodes < SmallestBlockSize
34     SmallestBlockSize  $\leftarrow$  Number of reachable nodes;
35     BestCandidate  $\leftarrow$  i;
36   END IF
37 END FOR
38 IF BestCandidate == J
39   Return TRUE;
40 ELSE
41   Return FALSE;
42 END IF
```

Fig 4.2: Least Disruptive Topology Repair Algorithm

Algorithm

```

DCR(A)
1. if(Is-Critical(A)==True) Then
2. AssignBackup(A)
3. If(A energy goes under the critical-level) Then
4. Broadcast DistressMessage
5. End if
6. End if
7. If(A receive DistressMessage) Then
8. Failure Detection(A,F)
9. End if
10. If(A received Recovered Message) Then
11. Send Buffered Data

Failure detection(A,F)
12. If(A detects missing Heartbeat Message from F) Then
13. If(A->BackupStatus()==Failed) Then
14. Buffer Data
15. Else
16. Recover(A,F)
17. End
18. End if

Recover (A,F)
19. If(Is-Critical(A)==True) Then
20. If(A->BackupStatus()==Failed) Then
21. AssignBackup(A)
22. End if
23. NotifyBackup(A)
24. End if
25. Move to location (A,F)
26. Notify New Neighbors with send Recovered Message

AssignBackup(A)
27. //Assign noncritical neighbor with highest degree and least distance node as Backup

```

Fig 4.3: Distributed Connectivity Restoration algorithm

The algorithms of Least Disruptive Topology Repair Algorithm and the Distributed Connectivity Restoration are shown in the above Figs. The graph

shown below is between average number of relocated nodes and the total nodes in the designed network.

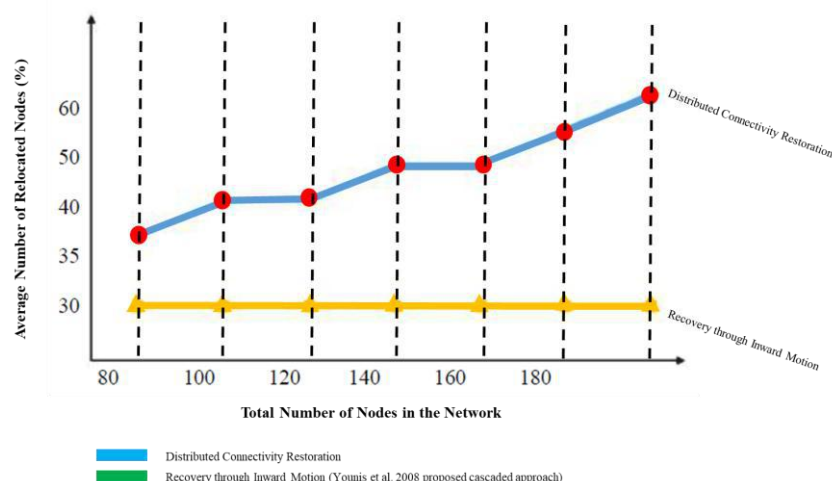


Fig 4.4: Ave No Relocated Nodes Vs. Total No of Nodes

As seen in the above simulation result, the relocated nodes minimum in case of researcher's analysis in

comparison with that of Distributed Connectivity Restoration scheme.

4.1.2. Energy levels

The other performance analysis/measurement factor in the research is that of energy levels. Normal and Low energy levels are shown below.

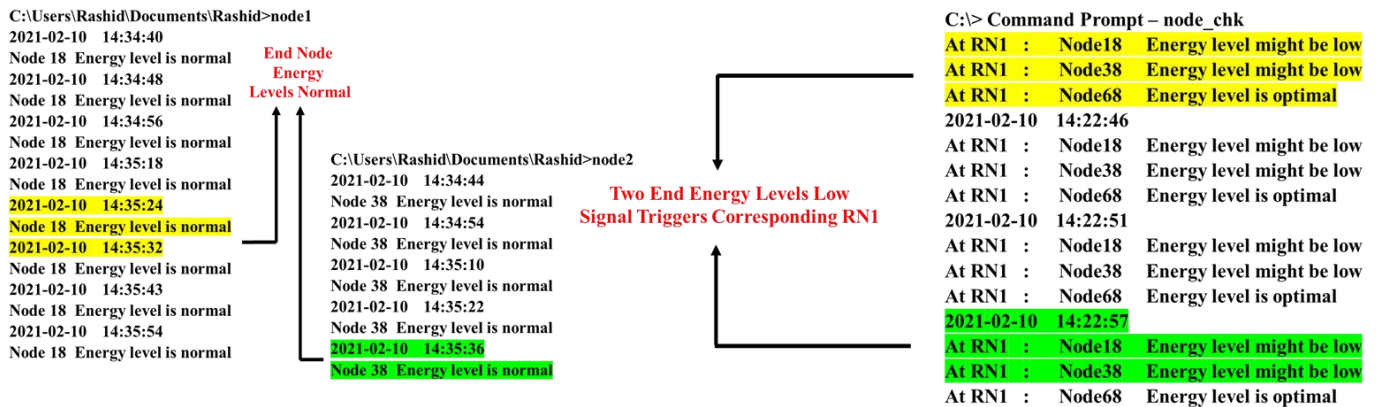


Fig 4.5: Normal-Low Experimental Energy Levels

V. CONCLUSIONS

5.1. Conclusion

Following are concluded from our simulation results.

- WSNs under hostile environments are at greater risk because of nodes failures.
- Detection of node's failure is must for seamless inter-node communication.
- Node replacement node is one of the sustainable solution.
- Residual energy management can detect node failures.
- Performance of the network degrades in case of node failures.
- Fault detection and connectivity restoration scheme is designed.
- Concept of mobile relay node introduced to restore the faulty node.
- Node failure can be detected by sending alert messages.
- Energy thresholds measurements lead to faulty node detections and its handing over to the active relay node.
- Proposed scheme validated through performance evaluation.
- Low cost, minimum resource, rapid node restoration management achieved.

- Complexity reduction achieved in WSNs.
- Effective power management achieved.

5.2. Contribution to Knowledge

The researcher looked at WSN architecture to address node failure issues. This work can be extended to incorporate mobile networks where the network nodes can be considered as sensor nodes and similar detection and restoration mechanisms can be used.

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A Review of the Factors Motivating the Rural and Urban Consumers in Haryana

Manisha Dalal

Assistant Professor in Commerce, Government College for Women, Jind, Haryana, India.

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Abstract – Marketers have to fulfill the following social responsibility while offering products to the consumer online Safety to users, Long run satisfaction of consumers, Quality of product, Equal marketed product would be environment friendly to ensure clean and better environment, It should be real it must not Spam user so that they can trust that online environment is safe and shop online without any doubt, Privacy Policy should be strong so that the consumer should trust in online shopping, Unit price of the product may be higher but all type of products should be available online so that user can purchase all the products online. The product should be easily available, the buyer generally buys the product from the nearby shops so the nearby shop product should be available online so that they motivate users for a better environment. Installation should be good and product quality should be satisfactory. For example, if the order is given to a company for purchasing a product online so that it must be available to customers in the required amount of time so that the consumer must be satisfied and motivated so that he can trust on online shopping.

Keywords – consumers, online shopping, motivating factors, Product, Quality.

I. INTRODUCTION

As we all know that every consumer has a different thinking in the matter of online shopping. The psychology of the consumer influences the decision for purchase, choice of the products, retails and brands purchased by them. Similarly, the acceptance of technology can also influence the consumers buying behavior. The chapter on review of literature revealed that affordable prices and offers, secure online transactions, comparison shopping, convenience, different payment methods and delivery options are some motivating factors to shop online.

This section will focus on the study of the factors which motivate the rural and urban consumers in Haryana to purchase online.

Motivation has a close relationship with the behavior of human beings. Motivation may be defined as a complex or force inspiring a person to intensify his willingness to use his capacity for achievement of certain objectives human needs. Satisfaction is the

most important thing in motivating consumers to do online shopping.

II. REVIEW OF LITERATURE

>Morganosky and Cude (2002) organised a research to discover the reaction of consumers with regards to online grocery purchasing. Information for the research was gathered from 243 people in the US who purchase their groceries online and percentage analysis was used as a device for reviewing the gathered information. The study concluded that more than 70% consumers steal online grocery purchasing to be more easy and less time-consuming. But many of them were of the view that they were encountering physical matters which made it appropriate to go to grocery stores for purchasing. There were very few people who purchased all the groceries online.

>Prasad and Aryasri (2009) researched the elements regulating online buyer nature. Primary information

was gathered from top five software organisations in Hyderabad from a sample of 135 online buyers. The information has been studied using statistical tools like standard deviation, mean, multiple regressions, multiple correlation, ANOVA and T testing. The outcomes disclosed that comfortable surroundings of the Web, services to consumers, and online store convenience are the elements that impact consumers to shop online. It was advised that since there are few searches organised in India in the context and the research will be advantageous to the students and marketers in future.

>Law and Bai (2008) in their research surveyed 862 visitors at the Hong Kong International airport who traveled often to decipher the elements which attract them by taking advantage of a particular travel website. The outcomes stated that consumers of travel websites grant significance to merits of assistance endued by the travel websites. The journalists tendered advice to academic researchers and respectable tourism apprentices that study shall be of sapidity to reckon consumer's nature in a preferential way.

>Das (2012) in his research "Growing Trends of E Commerce and Its Role in Consumer Buying Pattern" focused on various features of e-commerce and internet connectivity towards the online shopping pattern of consumers. The author organised detailed research including case studies that have altered the definition of selling and buying nature of consumers. It was wound up that online consumers can be captured by providing value of money, maintaining the quality of the product, assuring about the secured transactions and focusing on branded products.

>Vidhya and Dhevan (2014) in their research "Electronic Commerce - The Emerging Trend in India" organised SWOT analysis of e-commerce to learn about its development. The research wound up that assurance of purchasers will ultimately improve because the product and services are manufactured as when they are required. The trade of e-commerce has also been increased by the users of social web pages who play the role of opinion heads in giving their likes and dislikes in the products and services demanded for. It was advised that technological approach should be correctly handed out with the persons who are included in e-commerce authorising them to appreciate advantages of the business in trouble free

and error free methods. The quick penetrating worldwide internet market will further study the positively rising number of users day by day.

III. RESEARCH GAP

As we take a look in the past, there are very few studies which are done to show the online purchasing behaviour of online shopping buyers in India. There is a fact that most of the population of India is included in rural areas. Therefore, there is a wide gap in the marketing study of India because the research is bounded in rural areas. There were few researches which were done on the consumer attitude towards online shopping in Dharampuri district and consumer nature of rural and urban consumers while shopping online in Pune. But no research has been found in the context of Haryana.

IV. RESEARCH METHODOLOGY

Methodology is a collection of concepts or structural strategy of method so that the study can be managed and consists of investigational procedure, philosophy, approach and techniques.

V. HYPOTHESIS OF THE STUDY

There is no significant difference in the motivating factors responsible for online purchase behaviour of rural and urban online consumers of Haryana.

VI. TARGETED POPULATION

The target population for this study is 4 districts of Haryana, according to the Census of India- 2011.

6.1. Selection of Geographical Region:

The samples were selected from different regions of Haryana. Different regions were selected according to the literacy rate of urban and rural sectors from each selected city. The selected geographical regions are Kaithal, Hisar, Jind and Rohtak because these cities acquire the maximum area of rural region.

6.2 Sample Unit:

Respondents are chosen equally from each region of selected cities as the above respondents from the population who have done online shopping were identified for the aim of the research. Sample units

involve the address of the selected cities and villages in respect of their place of work or study. Respondents who didn't go for online shopping even once were excluded from the study.

6.3 Scaling Technique:

Some of the items of this section are self-framed and some of them are adapted from the research conducted by Faldu, R.B. (2013).

Ho: There is no significant difference in the motivating factors responsible for online purchase

behaviour of rural and urban online consumers of Haryana.

An independent sample t-test was then applied on the factors to study if there is significant difference between the rural and urban online consumers with regards to the factors motivating them to purchase online. Before applying t-test, normality of any information is required, so it is to be tested that this table shows the kurtosis and skewness values are in between -2 and +2. Therefore, it is within the satisfying limit of normality.

Motivating factors		Mean	Total no.	Standard deviation	Kurtosis	Skewness	Minimum	Maximum
Personal benefits	Urban	7.63	220	2.102	.655	-1.137	2	10
	Rural	5.92	220	2.060	-.499	-.126	2	10
Website features	Urban	7.71	220	2.040	.671	-1.112	2	10
	Rural	5.89	220	2.069	-.572	-.165	2	10
Promotional features	Urban	7.60	220	2.017	.546	-1.001	2	10
	Rural	5.84	220	2.237	-.849	-.074	2	10
Product information	Urban	7.77	220	1.978	1.286	-1.285	2	10
	Rural	6.05	220	2.172	-.784	-.141	2	10
Social	Urban	7.74	220	1.964	1.051	-1.163	2	10
	Rural	6.07	220	2.150	-.631	-.058	2	10

Comparison of motivating factors for online purchase between rural and urban area customers

Region		N	Mean	Std. Deviation	t-value	p-value
Personal Benefits	Urban	220	7.63	2.102	8.614	.000
	Rural	220	5.92	2.060		
Website features	Urban	220	7.71	2.040	9.306	.000**
	Rural	220	5.89	2.069		
Product information	Urban	220	7.60	2.017	8.662	.000**
	Rural	220	5.84	2.237		
Promotional features	Urban	220	7.77	1.978	8.675	.000**
	Rural	220	6.05	2.172		
Social Characteristics	Urban	220	7.74	1.954	8.498	.000
	Rural	220	6.07	2.150		

This table shows that the means of promotional features and social characteristics majorly influenced the purchasing behavior of urban and rural consumers respectively.



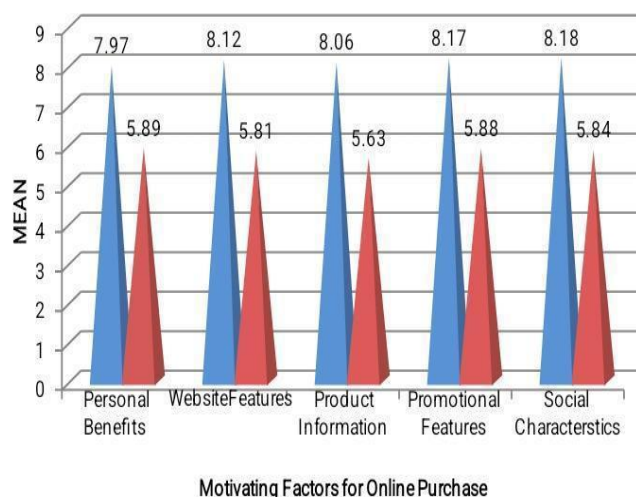
This Bar Graph shows that the motivating factors for online purchase behavior for urban consumers mostly affected by social characteristics, followed by website features, personal benefits, promotional features and product information; similarly, the online purchase

behavior of rural consumers' mostly affected by social characteristics, followed by promotional features, product information, website features and promotional features respectively.

Comparison of motivating factors for online purchase between rural and urban male customers

Region		N	Mean	Std. Deviation	t-value	p-value
Personal Benefits	Urban	127	7.97	1.873	8.584	.000
	Rural	154	5.89	2.135		
Website features	Urban	127	8.12	1.767	9.490	.000
	Rural	154	5.81	2.229		
Product information	Urban	127	8.06	1.774	9.746	.000
	Rural	154	5.63	2.295		
Promotional features	Urban	127	8.17	1.717	9.470	.000
	Rural	154	5.88	2.233		
Social Characteristics	Urban	127	8.18	1.743	9.599	.000
	Rural	154	5.84	2.241		

This table shows that mean value of social characteristics and personal benefits majorly influenced the purchasing behavior of urban and rural male consumers respectively.



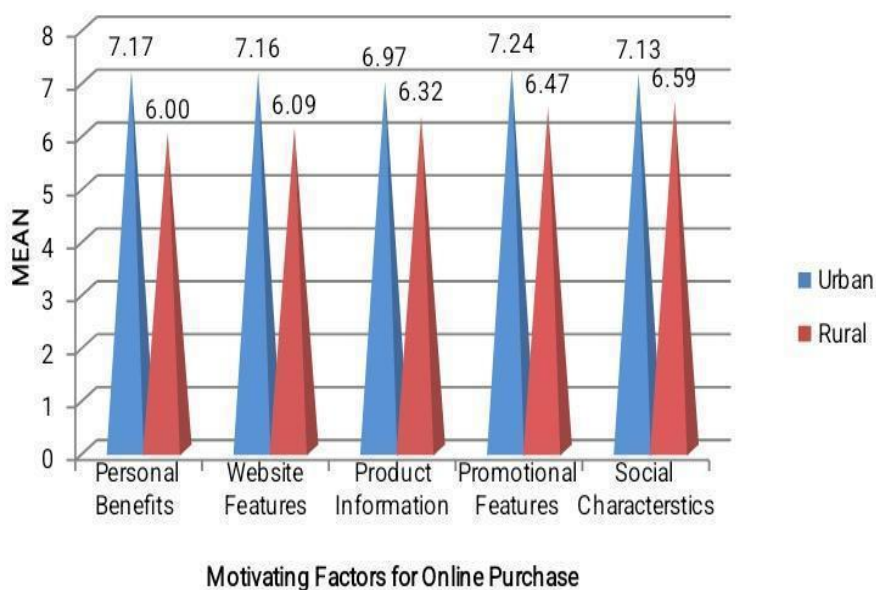
This Bar Graph shows that the motivating factors for online purchase behavior for urban male consumers mostly affected by social characteristics, followed by promotional features, website features, product information and personal benefits; similarly, the

online purchase behavior of rural male consumers' mostly affected by personal benefits, followed by promotional features, social characteristics, website features and product information respectively.

Comparison of motivating factors for online purchase between rural and urban female customers

Region		N	Mean	Std. Deviation	t-value	p-value
Personal Benefits	Urban	93	7.17	2.311	3.393	.000
	Rural	66	6.000	1.889		
Website features	Urban	93	7.16	2.257	3.289	.000
	Rural	66	6.09	1.634		
Product information	Urban	93	6.97	2.164	1.912	.000
	Rural	66	6.32	2.032		
Promotional features	Urban	93	7.24	2.184	2.267	.000
	Rural	66	6.47	1.978		
Social Characteristics	Urban	93	7.13	2.092	1.682	.000
	Rural	66	6.59	1.831		

This table shows that mean value of social characteristics and promotional features majorly influenced the purchasing behavior of urban and rural female consumers respectively.



This Bar Graph shows that the motivating factors for online purchase behavior for urban female consumers mostly affected by promotional features, followed by personal benefits, website features, and product information; similarly, the online purchase behavior of rural female consumers' mostly affected by social characteristics, followed by promotional features, product information, website features and promotional features respectively.

After observing the data of motivating factors of urban and rural female consumers of Haryana, there is significant difference among motivating factors of rural and urban consumers. Therefore, the null hypothesis H_0 has been declined.

VII. CONCLUSION

This paper is based on the comparison of elements motivating rural and urban consumers in Haryana to buy online. Differentiation of rural and urban male and rural and urban female were also done in regards to the elements which motivate to purchase online. It was discovered that there is significant difference in the purchase behaviour of male respondents in rural and urban sectors regarding the factors: - website features, promotional features whereas there is no significant difference regarding elements personal benefits, product information and social characteristics. In female respondents' case, it was discovered that there is significant difference in the purchase behaviour of female respondents in rural

and urban sectors regarding the elements: - website features, product information and promotional features whereas there is no difference regarding the elements:- personal benefits and social characteristics. Total differentiation of rural and urban consumers represents that there is no significant difference in the purchase behaviour of the rural and urban consumers regarding the elements - personal benefits and social characteristics, i.e., both these elements motivate the respondents in the same way to purchase online. Whereas, there is significant difference in the motivating elements between the rural and urban respondents regarding the factors - website features, product information and promotional features.

From the above discoveries, it can be analyzed that the elements representing significant differences between the rural and urban online consumers are more than the elements representing no significant difference. Thus, it can be summarized that the elements propelling online purchase behaviour among rural and urban consumers are not the same. Therefore, we are cancelling the null hypothesis H_0 , that is, elements motivating the rural and urban consumers to make online purchases are the same.

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Business Continuity & Disaster Recovery

Suhail Kausar

suhailkausar@live.com

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Abstract— The world around us is moving at an extremely fast pace than ever before and Information technology plays a pivotal role in driving this momentum forward. With its growth and innovations, the biggest challenge information technology brings is its Security, which is commonly known as Cyber Security. From Small Organizations to massive government infrastructures, Everyone takes exceptional measures to prevent cybercrimes So that businesses can continue to Operate Smoothly. This paper mainly focuses on Business Continuity & Disaster Recovery after a Cyber Attack. It also explains the latest Cyber Security Techniques, trend changes & Threats.

Keywords— Cybersecurity, Information Technology, Business Continuity, Disaster Recovery, Threats

I. INTRODUCTION

As of 2024, 5.4 billion people globally have access to the Internet. There is an Estimated 2.5 quintillion (2.5 million Tera Bytes) of data created every day. With each click, Swipe, or share, businesses are using that data to make decisions in the future. Businesses have real-time data from any virtual source and then combine that to make smart decisions. Managing that much amount of data is a big ask but securing it is an even bigger challenge. From booking a Taxi to transferring money, Today every part of our lives is dependent on information technology, it's estimated that 70% of commercial transactions are done online today and with these emerging technologies we are unable to protect our information in effectively ways and cyber criminals take full advantage of that.

The answer to this problem is cybersecurity. Protecting Critical information & infrastructure can be achieved by Enhancing Cyber Security which is crucial to every nation's Security & economic well-being. Cyber experts spend the majority of their time & resources on tightening the security. Cybercriminals are not sitting idle waiting for you to make a mistake; they are proactive and highly motivated. In the cyber world, the criminals are

always one step ahead. As businesses can't afford a second of downtime, In this paper, we will talk about Business continuity & disaster recovery which is an organization's ability to maintain or quickly resume acceptable levels of product or service delivery following a cyber-attack that disrupts business operations.

II. LITERATURE REVIEW

With the sophistication and frequency of cyber attacks growing rapidly, in modern times cybersecurity has gained a center stage for the businesses. Business continuity planning has become core part of modern day organizations and disaster recovery to achieve resilience from cyber security incidents. According to Business Continuity & Disaster Recovery by Susan Snedaker BCP focuses on the sustainability of core business operations during the incidents & crisis while DR is mainly responsible for recovering data and IT infrastructure after a cyber security incident or natural disaster. These approaches setup the basis of minimizing to no operational disruptions and securing revenue in the event of cyber events.

Importance of BCP and DR within Cybersecurity

The frequent worldwide cyber-attacks, as well as unusual Small, Medium & large cyber disasters in Organizations, have shifted the focus away from the traditional disaster recovery which is by no means enough to control unforeseen circumstances. There must be educated plans ready for business continuity. In Tech terms we call it BCP or business community plan. Disasters can occur for multiple reasons such as Natural Disasters, Technical Failures, cyber-attacks, Human Error, etc. The seemingly unpredictable uniqueness of the disasters demands dynamic, real-time, efficient, and cost-effective solutions, hence making BC extremely suitable. It is therefore extremely important to ensure that the correct procedures, policies, and plans are in place to protect an organization's ICT infrastructure and data. Business continuity aims to keep the organizations running, regardless of the potential risk, threat, or cause of a disaster.

Susan Snedaker explains that BCP and DR strategies remain one of the most important factors in the current digital world, hence enabling all forms of businesses to quickly move out of cyber incidents and reduce both operational and financial losses. Because we understand that businesses have become so interconnected that no form of downtime will ever be affordable.

Best Practices and Frameworks for BCP and DR

The literature highlights a few best practices for implementing very effective BCP and DR frameworks. The most important part of any BC is the formational structure of recovery metrics, commonly known as Recovery Point Object (RPO) & Recovery Time Object (RTO). Recovery time objective (RTO) is the amount of time it takes to recover from an outage (scheduled, unscheduled, or cyber-disaster) and resume minimal or normal business Operations. Recovery Point Object (RPO) is the time in the past when your data can be restored from the backup. Let's say a 5-minute RPO means that in case of a disaster, you can recover your data from the recovery site that was backed up 5 minutes earlier.

Business continuity often requires Zero downtime which essentially is extremely costly but more often than not the cost of a disaster outweighs the cost of Zero downtime. The key element for business

continuity planning is how much of a disruption a business is tolerable and what are they willing to spend to avoid disruption. If huge costs weren't a factor every business in the world would want fully redundant & zero downtime in their ICT environment. But Money is the main player here. A small business with a revenue of 2 Million USD per year will be spending approx. a hundred thousand dollars per year for a fully redundant system might not be justified but if a 5 billion-dollar revenue business is spending a million-dollar investment in fully redundant systems it might well be justified because a small disruption/attack might cause their business loss of millions of dollars, so there is nothing like "one size fits all" approach. We can conclude that the BC/DR plans must be appropriate to your organization's size, budgeting & financial impact in case of a disaster.

The next step in planning is to look at the business processes used by the companies in day-to-day operations. These processes need to be evaluated and prioritized in business-critical order. What processes are critical to the ability of the company to conduct operations? What is the minimum & maximum impact of a certain disaster on a business process? What processes can be put on hold during an emergency? Timing is another critical factor, for example, if a bank's ATM services are disrupted during the start of the month on Salary Day, the impact could be far more than the same service disruption happening in the middle of the month.

Susan Snedaker says that one of the most Critical part of BC/DR planning is to look at your use of technology and as per of implementation team, you need to understand which elements of your environment are vulnerable to which types of disasters. For example, An electricity outage will impact all the technology in a data center but considering there is a battery backup for servers & network equipment, no power for air conditioning in a country like the United Arab Emirates will quickly overheat all the equipment.



A bad plan or incomplete plan is often worse than no plan at all. Now I will go through a case study of a disaster where I was first hand witness of events.

III. CASE STUDY

Arab Authority for Agricultural Development and Investment Data Center Disaster

Organization Introduction

Arab Authority for Agricultural Development and Investment known as AAAID was Established in 1976, with head Quarter in Khartoum, Sudan. The AAAID is composed of 21 Arab member states which contribute to its capital. It Contributes to the Capital of 52 Major Agricultural Companies Across 12 Arab Countries. AAAID Data center was hosted in their Head office building in Capital City of Sudan, Khartoum.

Background

From 1989 to 2019, Sudan was ruled by military and was somewhat a stable country. But after 2019 mass protest, a reform path was laid out for civilian government to rule the country. With different Stake holders making their best efforts to come into the power the country, the situation was moving towards destabilization. At this point in time AAAID doesn't have any DR or business continuity solution in place.

Post 2019 Protests: In a Board Members (Consist of different Arab states secretaries of finance & agriculture ministries) meeting later in 2019, with keeping in mind on the current mass protest situation in Sudan, an agenda was proposed to setup a DR in another Country outside Sudan. The proposed location was in Dubai, UAE where AAAID already has a regional office. However when the financial cost of DR was brought to table, most members voted against the DR setup.

2021 military coup: As the fight to power continued which kept leading the country towards further destabilization. In Oct 2021, Military once again took over the country. Following the coup, mass protests erupted across Sudan. At this point AAAID realized the situation in Sudan is getting out of Hands, a Virtual Emergency board meeting was called & budget for a DR in Dubai was approved by board members. The process to procure the DR setup started somewhere at the end of 2021. The major challenge

during this time was Covid-19. Hardware unavailability was a concern as the silicon chips were extremely short because of mass closure of factories during Covid-19. The easy way would be to setup DR on a public cloud but it was against AAAID policies to setup DR on any Cloud, Considering the secretive nature of their financial documentation. Even with a lot of availability challenges, travel restrictions for DC experts from Sudan to travel to Dubai because of Covid-19, By mid to late 2022, the AAAID DR in Dubai was completed.

Civil War April 2023: In mid of April 2023, on a Saturday morning Sudan was shell shocked when clashes broke out between the Sudanese Armed Forces and their paramilitary Rapid Support Forces. These violent confrontations, primarily in Khartoum, intensified the crisis, displacing millions and resulting in mass civilian casualties.

AAAID despite having a DR in Dubai, never had a business continuity plan in place. With in few hours of war started the communication from Sudan to the rest of the world was lost. Electricity was cut down, Mobile towers were taken down. By the end of the day on Saturday it was clear that DR needs to be activated by AAAID, but as I mentioned there was no business continuity plan in place. There was no one assigned the role to start the recovery process in case of Disaster. Moreover the sole person in Dubai office who was responsible for DR was on annual leave in Sudan. When Dubai office IT team started recovery process, to their shock, they realized that there was a major error during the sizing of DR as the storage wasn't enough to recover all the servers.

Another core issue they figured out while recovering that replication was not working on some servers from last few months leading to loss of data for that specific period. With in few weeks of Civil war AAAID started the process to shift their employees from Sudan to UAE office. Another major setback was that most employees had desktop computers & their data was saved on those desktop. The backup of those desktop was setup in a server which was never replicated over to DR. But IT team was hopeful that the lost data will be recovered once the Civil war ends & Situation normalizes. Their hopes further received a shock when 4th week into the civil war a Rocket which was meant to hit another building hit the AAAID office in Khartoum leading to fire in entire

building. It was later reported that the data center was on fire & whatever was remaining or survived the rocket impact, it was looted.

Mistakes & lessons from their Approach by AAAID:

1. Lack of a Business Continuity Plan (BCP)

- **Mistake:** Although AAAID had a DR setup, it lacked a comprehensive BCP to ensure smooth operation and recovery in case of a disaster. No Proper defined roles or a structured plan, there was no one assigned to initiate DR when disaster happened.
- **Lesson:** Without an established BCP a DR is not going to be helpful. Designate backup personnel who can initiate DR process if the primary person is unavailable, with each person well educated in DR protocols.

2. Policy Constraints Against Cloud-Based Solutions

- **Mistake:** AAAID's policies against Public/Private cloud-based DR prevented the use of a more flexible and scalable solutions, which could have addressed hardware availability challenges during the COVID-19 pandemic.
- **Lesson:** While policies are necessary, they should be adaptable, especially in crisis scenarios. Consider Private or Hybrid DR solutions or assess the security capabilities of cloud providers to ensure the support critical functions if on-premises solutions are infeasible.

3. Insufficient DR Sizing and Capacity

- **Mistake:** The DR setup in UAE was undersized, leading to insufficient storage to recover all servers. This compromised the AAAID's ability to restore some of the critical data and functionality.
- **Lesson:** Perform a thorough assessment & sizing. Better analysis to ensure DR infrastructure can handle the full scale of services that are important for business continuity.

4. Replication and Data Management

- **Mistake:** Some servers had not been replicating data for months, resulting in significant data loss.
- **Lesson:** Implement continuous monitoring of replication processes and set up alerts to detect failures.

5. Data Storage on Desktop Computers Without Offsite Backup

- **Mistake:** Most if not all employees saved their data on desktop computers without a offsite backups, leading to data loss when these computers were destroyed or stolen.
- **Lesson:** Always ensure the Implementation of policies that encourage storing data on network drives that are regularly backed up to the DR site.

7. Failure to Regularly Test DR Capabilities

- **Mistake:** The issues with DR sizing and replication could have been identified earlier if regular DR testing had been conducted
- **Lesson:** Conduct regular DR testing, including end-to-end drills, to identify any weaknesses in infrastructure, personnel, or procedures. The management has to be blamed for this for not going for a DR solution back in 2019 when it was first identified. BCP & DR takes time to get mature.

8. Reliance on Physical Financial Documents and Lack of Digital Copies

- **Mistake:** As organization the AAAID stored critical financial contracts and documents only in paper form, resulting in the complete loss of these assets when the Khartoum office was destroyed. Without digital backups, these irreplaceable documents could not be recovered.
- **Lesson:** Digitize all critical documents, particularly financial contracts, and store them in a secure, redundant digital archive. Software solutions like Microsoft SharePoint or OpenText Documentum should be used in such cases to avoid such major loss of documentation.

IV. CONCLUSION

AAAID's Data center Disaster goes to show that despite spending a major chunk of amount on DR, the financial loss that caused because of some Major & some minor miss management caused a great loss. A comprehensive BCP coupled with regular testing and redundancy, having policies enough to adapt to situations that may not be correctly anticipated, are of prime importance. For any organization, DR and BCP need to be viewed as an ongoing evolution of processes subject to repeated re-visitation and reinforcement for resilience during crisis situations.

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