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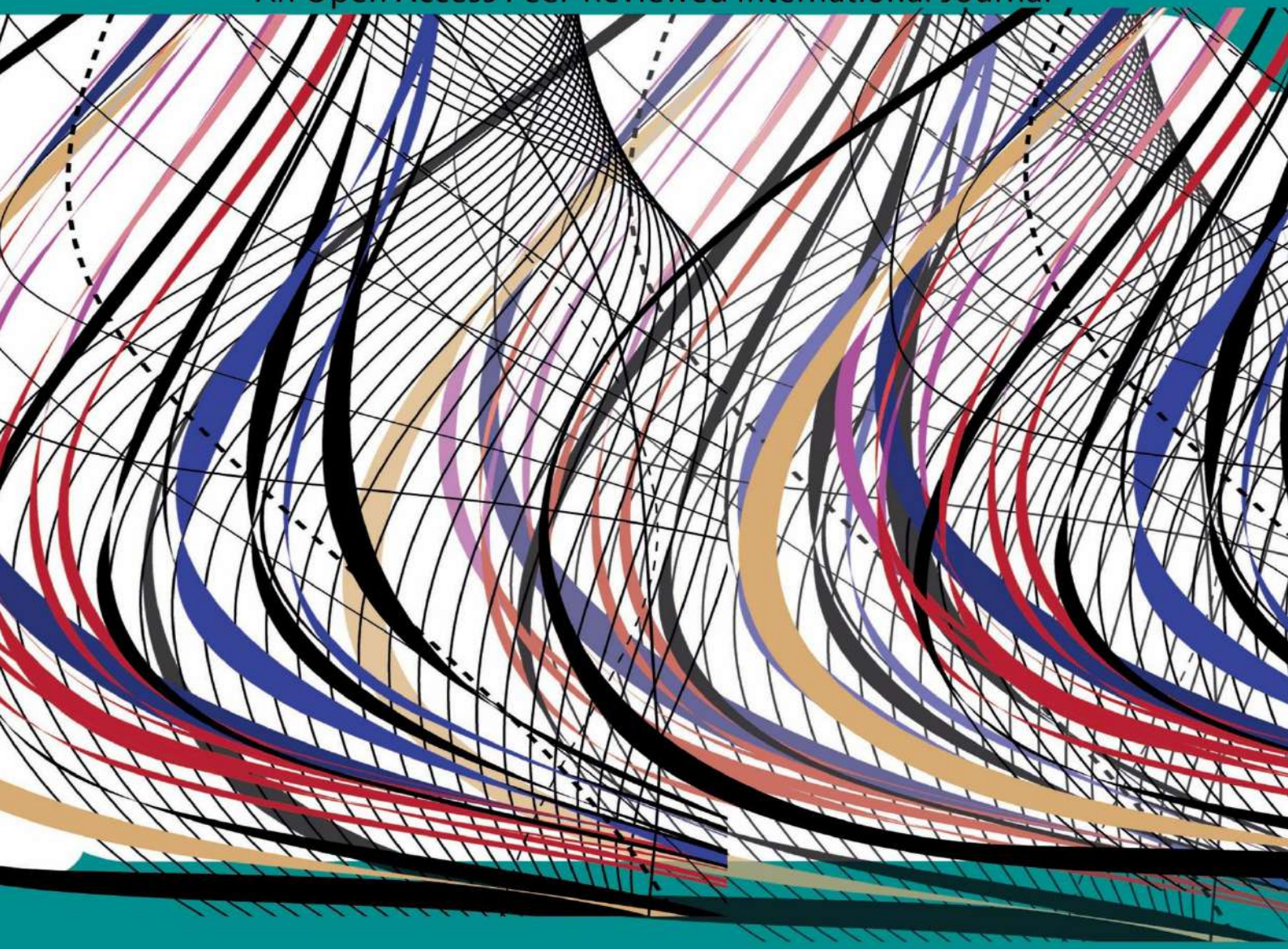

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Beyond Profits: India's Journey in Social Accounting and Responsibility

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Abstract *— Social Cost-Benefit Analysis (SCBA) is a key evaluative tool used to determine the economic and social feasibility of proposed projects from a societal perspective. It supports national planning by guiding resource allocation across sectors. Institutions such as UNIDO and OECD have developed methodologies for quantifying social costs and benefits. This paper explores the emergence and application of social accounting in India, particularly in the aftermath of the Bhopal Gas Tragedy, which acted as a catalyst for institutional reforms. The Government of India, along with leading corporates – such as Tata Group, Infosys, ITC, Bharti Enterprises, and Indian Oil – have taken significant strides in integrating Corporate Social Responsibility (CSR) into business practices. The Companies Act, 2013, mandates eligible companies to invest 2% of their average net profits in CSR, reinforcing social accountability. This paper analyzes current trends, frameworks, and corporate initiatives contributing to social accounting practices in India.*

Keywords *— **Feasibility, Viability, Corporate Social Responsibility (CSR), Social Accounting***

I. INTRODUCTION

Social Cost-Benefit Analysis (SCBA) is a comprehensive appraisal method used to evaluate a project's overall impact on society. It involves assessing the potential costs and benefits that a community may incur or gain from a proposed initiative. SCBA serves as a structured economic framework, often applied to urban development projects, to capture a broad spectrum of social implications.

In parallel, **social accounting** provides a mechanism for organizations to assess and communicate their performance in achieving stated social or ethical objectives. While the process may be independently verified, it remains organization-driven—built on internal indicators formulated in collaboration with stakeholders, rather than externally imposed standards.

Broadly speaking, SCBA is most relevant in projects with significant societal reach, typically implemented or regulated by the government. These initiatives often affect society directly or indirectly, necessitating a thorough evaluation of their societal value. The critical benchmark for such assessments is the **Benefit-Cost Ratio (BCR)**, which must be equal to or greater than one to justify project implementation:

Benefit ≥ Cost

Social accounting, on the other hand, involves the systematic evaluation and reporting of business activities that produce social consequences. It aims to measure both the positive and negative impacts of these activities—not only on the organization itself but also on its broader community of stakeholders.

II. ORIGIN OF THE CONCEPT OF SOCIAL ACCOUNTING

The concept of social accounting has gained significant recognition and maturity in recent decades. It is increasingly regarded as a core element of effective Corporate Social Responsibility (CSR)

practices. This growing importance is reflected in the attention it receives from large corporations, consultancy firms, and voluntary organizations that are committed to ethical governance and social accountability.

The intellectual roots of social accounting can be traced back to classical economists. Adam Smith, often regarded as the father of modern economics, emphasized the social responsibilities of business as early as 1776. Similarly, Karl Marx addressed the notion of social cost in his seminal 1876 work *Das Kapital*.

The contemporary framework of social accounting began to attract serious attention in the 1970s. During this period, professional and academic accounting bodies, including the predecessor of the Accounting Standards Board, the American Accounting Association, and the American Institute of Certified Public Accountants (AICPA), initiated discussions on integrating social considerations into accounting practices.

ORIGIN OF THE CONCEPT OF SOCIAL ACCOUNTING IN INDIA

In India, the concept of social accounting began to gain prominence following the catastrophic Bhopal Gas Tragedy, which served as a wake-up call for corporate accountability and environmental governance.

THE BHOPAL DISASTER

Often cited as the world's worst industrial disaster, the Bhopal Gas Tragedy occurred between the night of December 2 and 3, 1984, in Bhopal, Madhya Pradesh. The incident involved a massive leak of **methyl isocyanate (MIC)** gas from a storage tank at the Union Carbide India Limited (UCIL) pesticide plant. This deadly gas spread rapidly across densely populated areas surrounding the facility.

- **Date:** December 2–3, 1984
- **Location:** Bhopal, Madhya Pradesh, India
- **Cause:** Methyl Isocyanate gas leak from a UCIL storage tank
- **Non-fatal Injuries:** Over 558,000 individuals affected

More than half a million people were exposed to toxic chemicals, resulting in extensive human suffering and long-term environmental degradation. The gas infiltrated nearby shanty settlements, leading to immediate deaths, widespread injuries, and profound health consequences that continue to affect survivors decades later.

Investigations suggest that **poor maintenance**, **inadequate safety protocols**, and **management negligence** led to a backflow of water into the MIC storage tank, triggering the fatal chemical reaction. Both government officials and civil society organizations have long criticized the disaster response and the lack of corporate responsibility.

LONG-TERM HEALTH IMPACTS OF THE BHOPAL TRAGEDY

The lingering health effects of the disaster are numerous and include:

- **Ocular Damage:** Chronic irritation, vision impairment
- **Respiratory Disorders:** Tuberculosis, pulmonary fibrosis
- **Neurological Conditions:** Memory loss, numbness, cognitive dysfunction
- **Psychological Disorders:** Post-Traumatic Stress Disorder (PTSD)
- **Child Health Issues:** Stunted growth, developmental and intellectual delays

The Bhopal tragedy highlighted the urgent need for institutionalizing **social and environmental accountability**, paving the way for the development of social accounting practices in India.

Corporate Contributions to Social Responsibility

1. Reliance Group

Founded by Dhirubhai H. Ambani, Reliance Group is India's largest private sector enterprise, operating across energy, petrochemicals, textiles, and retail. Reliance Industries Limited, a Fortune Global 500 company, has implemented significant CSR initiatives.

In education, the company launched the Reliance Dhirubhai Ambani Protsahan Scheme to support academically meritorious students from underprivileged backgrounds and established the Dhirubhai Ambani International School in Mumbai, a leading institution in India.

In healthcare, the Dhirubhai Ambani Hospital at Lodhivali provides free emergency medical care to road traffic accident victims. The company also

undertakes extensive awareness and treatment programs for HIV/AIDS and organizes regular blood donation camps.

For its workforce, Reliance focuses on safe and quality working conditions through training and awareness initiatives. It also supports women entrepreneurs by offering resources and assistance. The company reported CSR spending of ₹760.58 crore.

2. Procter & Gamble (P&G)

With a global presence in over 180 countries, Procter & Gamble (P&G) impacts the lives of billions through its brands like Pampers, Tide, Ariel, Oral-B, and Gillette. In India, P&G has launched impactful CSR programs.

The 'Shiksha' initiative, launched in 2005, has helped over 280,000 underprivileged children gain access to education, supporting more than 140 schools nationwide. P&G has donated over ₹22 crore to this cause.

Under its healthcare program 'Drishti,' P&G funded corneal transplants to restore vision for 250 blind girls, contributing ₹1 per pack of Whisper sold. The company also invests in understanding consumer needs and trains employees to ensure high service quality.

3. Google

Founded by Larry Page and Sergey Brin in 1998, Google's CSR focus revolves around users, employees, and communities. Guided by its philosophy 'Focus on the user and all else will follow,' Google integrates CSR into its corporate culture.

Employee well-being is promoted through generous compensation, engaging workspaces, and collaborative environments. Google Grants provides free AdWords advertising to select nonprofits, while the company also supports global relief efforts such as earthquake recovery programs.

4. Mahindra & Mahindra

Established in 1945, Mahindra & Mahindra (M&M) is a leading Indian automobile manufacturer. The company is deeply committed to CSR, particularly in education and community health.

The 'Project Nanhi Kali' initiative has supported over 1.1 million underprivileged girls in ten states by providing both academic and material assistance. M&M also operates Mahindra Pride Schools for skill development and the Lifeline Express for mobile healthcare.

Headquartered in Mumbai, M&M reported a CSR expenditure of ₹85.57 crore in 2016–17, surpassing the mandatory requirement of ₹83 crore based on net profits from the previous three years. In 2015–16, the company invested ₹185.11 crore in CSR projects.

5. ITC Group

ITC is committed to creating shared value by integrating economic growth with social and environmental development. The company's CSR initiatives reflect this holistic approach.

The ITC e-Choupal network spans 6,100 internet kiosks, reaching over 35,000 villages and enabling small farmers to access market and weather information. Its forestry program has created over 120 million person-days of employment and supports agroforestry for rural communities.

The initiative is aligned with ITC's philosophy of 'Sab Saath Badhein,' symbolizing inclusive and sustainable growth for rural India.

Top 10 Indian Companies Leading in Corporate Social Responsibility (CSR)

1. Tata Steel

Tata Steel manages its CSR initiatives through three key organizations—Tata Steel Rural Development Society (TSRDS), Tata Steel Family Initiatives Foundation (TSFIF), and the Tribal Culture Society (TCS). These bodies focus on community development, using the Human Development Index (HDI) as a tool to monitor progress in villages.

2. Tata Chemicals

Tata Chemicals prioritizes environmental conservation, notably the protection of endangered species like the whale shark. The company allocates ₹12 crore annually to CSR, with wildlife preservation as a core focus.

3. Mahindra Group

Mahindra's 'Nanhi Kali' program is dedicated to the education of underprivileged girls. The company's CSR philosophy blends strategic philanthropy with sustainability and shared value creation.

4. Maruti Suzuki

Through its 'Making it Matter' initiative, Maruti Suzuki invests in community development and road safety. Efforts include building household toilets, upgrading government schools, and ensuring separate sanitation facilities for girls.

5. Tata Motors

Tata Motors shows strong environmental commitment by implementing green projects that focus on conserving and regenerating local ecosystems.

6. Siemens

To promote public health awareness, Siemens India launched the 'Fit4Life' program. This initiative aims to instill fitness consciousness among employees and the wider community.

7. Larsen & Toubro (L&T)

L&T contributes to public health through various CSR activities, particularly emphasizing maternal and child healthcare and HIV/AIDS awareness programs.

8. Coca-Cola India

Coca-Cola India supports diverse community welfare programs, emphasizing education, health, and water sustainability. Their initiatives include 400 rainwater harvesting systems, clean drinking water for over 100 schools, and contributions to disaster relief and eco-friendly packaging reforms.

9. Steel Authority of India (SAIL)

SAIL actively promotes cultural preservation and education. It supports maintenance of historic sites like Lodhi Gardens and celebrates regional heritage through events like the Chhattisgarh Lok Kala Mahotsav, involving over 600 artists annually. Additionally, it hosts rural sports festivals and has established numerous school libraries and sanitation facilities.

10. Infosys

Infosys has made significant contributions to educational infrastructure by supplying computers to schools and helping establish 60,000 libraries and numerous hygiene facilities such as Nirmala Shouchalayas.

III. CONCLUSION

Corporate Social Responsibility (CSR) and adherence to high ethical standards are no longer discretionary — they are essential duties for modern businesses. The principle that "what cannot be measured cannot be improved" underscores the importance of structured evaluation mechanisms like CSR and social accounting. CSR encourages organizations to take accountability for their actions and to generate meaningful, positive outcomes for a broad range of stakeholders, including consumers, employees, investors, and the larger community.

In this context, social accounting serves as a vital tool for assessing the broader societal impact of projects. It enables decision-makers to evaluate whether a given initiative is likely to produce net benefits or impose undue costs on society. Institutions such as the United Nations Industrial Development Organization (UNIDO) and the Organisation for Economic Co-operation and Development (OECD) have contributed significantly to this field by developing frameworks for the measurement and reporting of social costs and benefits. As India continues to integrate these practices, social accounting will play a key role in advancing sustainable and responsible business conduct.

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Impact and Challenges of the Cashew Nut Processing System: An Analysis of Users' Experiences

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Abstract *— This study explores the impact, challenges, and adoption of the Cashew Nut Processing System (CNPS) generated by the Philippine Center for Postharvest Development and Mechanization (PHilMech). The research utilized a descriptive design, incorporating interviews and secondary data to analyze user experiences within Alion Kapit-Bisig Sea-K Association and Samahang Kababaihan ng Conversion. Findings revealed that CNPS significantly enhanced productivity, product quality, and revenue generation, as users reported streamlined operations and higher-grade products. However, transitioning from traditional methods posed challenges, including technical skill requirements, maintenance efforts, and spare part availability. Despite these constraints, the system's user-friendliness, cost-effectiveness, and positive influence on collaboration and efficiency facilitated its adoption among small-scale processors. To address identified challenges, recommendations include expanded training programs, ongoing technical support, and exploration of automation to reduce manual labor. These measures aim to enhance CNPS utilization, promote sustainable practices, and empower small-scale processors to thrive in competitive markets.*

Keywords *— **Adopters, Challenges, Cashew Nut Processing System, Productivity, Technology***

I. INTRODUCTION

In the Philippines, cashew (Anacardium occidentale L.) is called kasoy or balubad in Tagalog or Balogo in Ilokano. It originated from north-eastern Brazil and was brought to the Philippines in the 17th Century. In 2022, the top cashew nut-producing countries were Ivory Coast (970,000 mt), India (752,000 mt), Vietnam, (341,680 mt), and Philippines (217,582 mt). The Philippines maintains its place among the top four cashew producers in the world. Cashew nut production and processing is considered an important sector for many developing countries in the aspect of improving local economy and sustainable environmental development.

Being a drought-tolerant crop, it has been widely used in reforestation activities even where topography and soil are generally poor for other fruit trees to survive and/or be productive.

According to the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2023), cashew nut production reached 217,583 tonnes in 2022 in the Philippines. This is 15.0% less than in the previous year. Historically, cashew nut production in the Philippines reached 255,931 tonnes in 2021 and 3,468 tonnes in 1983.

Processing of cashews into value-added products such as roasted whole and split nuts, wine, and prunes, to name a few, can significantly increase the income of cashew processors. For cashew nuts alone, kernel processing can increase the income by more than thrice. The largest local market of dried or roasted cashew kernel, whether whole or broken, is Metro Manila wherein it is consumed as an ingredient in the preparation of ice cream, cakes, pastries, confectioneries, and other food preparations, as well as snack items. (PCARRD, 1999).

The usual product obtained from shelled cashews is split nuts. This is done by the use of a simple cracking tool locally called 'kalukati". The split nut has an acrid taste because cashew nut shell liquid (CNSL) that contaminates the kernel. The traditional way of extracting the kernel from the shell is inefficient resulting in low shelling recovery and high split nut or broken kernels. A study by PHilMech revealed that the primary hindrance preventing cashew growers and processors from realizing the full value of cashew nuts is the lack of suitable technology to yield CNSL-free and whole cashew kernels (Dela Cruz, Lanuza, and Rapusas, 2000).

To enhance the cashew kernel quality and elevate the profitability of processors, the Philippine Center for Postharvest Development and Mechanization (PHilMech) has designed and generated a processing system that is capable of producing high-quality nuts that consider the technical and financial capacities of small-scale processors. This involves cleaning, drying, shelling using the PHilMech's Cashew Nut Sheller, picking, sorting, roasting using the Charcoal-Fired Cabinet Oven, labeling, and packaging. Each of these stages must be carried out to produce high-quality kernels with desirable grades. Two associations adopted the technology: the Alion Kapit-Bisig Sea-K Association in Mariveles, Bataan, and Samahang Kababaihan ng Conversion in Pantabangan, Nueva Ecija.

Initially, users found the technology challenging to use, as they were accustomed to traditional processing. The CNPS required manual effort and technical know-how, which presented significant challenges. In relation to this, this study shall analyze the impact and challenges of the user's experiences using the Cashew Nut Processing System. Generally, this study aims to explore how users managed the shift to the new processing system and strategies for overcoming initial difficulties. Specifically, the study seeks to:

1. Identify the impact of the technology in terms of aspects such as productivity, product quality, and sales.
2. Enumerate the constraints and understand the challenges faced by small-scale cashew nut processors in using the technology.
3. Evaluate the impact of the technology on its adoptability, and propose strategies to enhance the cashew nut processing system.

II. METHODOLOGY

This study utilized a descriptive research design (Subia, Mangiduyos & Turgano, 2020) to describe the impact and challenges of the user's experiences in using the Cashew Nut Processing System.

Descriptive research is suitable for such studies, as it provides general information without influencing the data collected, which makes it appropriate for exploring these phenomena. This is done through an interview using a questionnaire to gather the necessary data. A review and secondary data gathering, such as data from association records and the PHilMech monitoring report, will also be reviewed to validate findings.

The researchers gathered the necessary data and information from five of the association members in each of the assisted enterprises, namely the Alion Kapit-Bisig Sea-K Association in Mariveles, Bataan, and Samahang Kababaihan ng Conversion in Pantabangan, in the province of Nueva Ecija (Fronda, 2024). They were the direct adopters and users of CNPS. The study used descriptive statistics, including frequency count, weighted mean, and percentage, to analyze the impact and challenges of the Cashew Nut Processing System among the users, particularly focusing on the users' experience. Frequency count determined how often each variable occurred, while central tendency measures, such as the mean, summarized the data.

This approach helped in assessing the different aspects of the technology impact among users and generating possible recommendations for addressing

any encountered challenges related to the experience of the users.

III. RESULTS AND DISCUSSION

1. Impact of Cashew Nut Processing System on Productivity, Product Quality, and Sales

Table 1 presents the impact of CNPS on productivity, product quality, and sales. It determines the factors that influence these variables. The results presented in Table 1 show the impact of the Cashew Nut Processing System on the Productivity, Product Quality, and Sales. Respondents strongly agreed that CNPS had increased productivity, as demonstrated by a weighted score of 3.8. This indicated its effectiveness in enhancing production efficiency and output. Similarly, the system had improved the quality of processed cashew kernels, also scoring 3.8, which indicated that the technology contributed to producing higher-grade products that aligned with market and consumer standards. The CNPS has also established its ability to streamline operations by reducing the processing time, with a weighted score of 3.6. Furthermore, respondents agreed that the adoption of CNPS has led to an increase in product sales and revenue, another area where it scored 3.6, showing its impact on market performance and profitability. Additionally, the system enabled the production of a wider variety of value-added cashew products, as highlighted by a 3.6 score. This emphasized that the technology provided additional value to the product. Overall, the average weighted mean was 3.7, with a rating of Strongly Agree.

Table 1. Impact of Cashew Nut Processing System on Productivity, Product Quality, and Sales

STATEMENT	WEIGHTED MEAN	VERBAL DESCRIPTION
a. The CNPS has significantly increased the productivity of our cashew nut processing.	3.8	Strongly Agree
b. The CNPS has improved the quality of processed cashew kernels.	3.8	Strongly Agree
c. The technology has contributed to a reduction in processing time.	3.6	Strongly Agree
d. The adoption of CNPS has led to an increase in product sales and revenue.	3.6	Strongly Agree
e. The CNPS allows for the production of a wider variety of value-added cashew products.	3.6	Strongly Agree
Average Weighted Mean	3.7	**Strongly Agree**

2. Challenges and Constraints in Using Cashew

Table 2 presents the challenges and constraints faced in using the Cashew Nut Processing System (CNPS). The findings highlight areas that may affect the full potential of the system.

According to Table 2, some factors restrict the activities of users of the Cashew Nut Processing System (CNPS). The corresponding mean rating of 2.9 which falls under the "Agree" level indicates that users consider the system to be fairly easy to use, but some features of the system can be improved. The evaluation for start-ups and learning activities was 2.6, this means that users encounter problems when transitioning to the new system. Likewise, considering the technical skills needed to operate and take care of CNPS, the score recorded was 2.4, this position is quite challenging to users and would require better training and maintenance organization for this system.

Table 2. Challenges and Constraints in Using the Cashew Nut Processing System

STATEMENT		WEIGHTED MEAN	VERBAL DESCRIPTION
a.	The initial setup and learning process for using the CNPS was challenging.	2.6	Agree
b.	The manual effort required for operating the CNPS is manageable.	3.8	Strongly Agree
c.	The technical knowledge needed to operate the CNPS was difficult to acquire.	2.4	Agree
d.	The maintenance of the CNPS requires effort.	2.4	Agree
e.	The availability of replacement parts and technical support is sufficient.	2.6	Agree
f.	The cost of adopting and operating the CNPS is affordable for our association.	3.8	Strongly Agree
Average Weighted Mean		2.9	**Agree**

On the other hand, users strongly agreed that the manual effort required to operate the system was manageable, placing a high score of 3.8 on all the system's operations. This indicated the simplicity of the system regarding day-to-day activities. The cost involved in acquiring and running the CNPS also rated

3.8, indicating that the reasonable cost was one of the factors that encouraged users to adopt the technology, especially in small-scale enterprises. However the presence of spare parts and the technical assistance obtained, even though ranked at 2.6, makes it possible to see further improvements in the experience and even satisfaction of users of the system. The CNPS is used for its affordability and its operation mostly by hand, there are problems related to its technical training, maintenance and spare parts provision, and support. Overall, the average weighted mean was 2.9, with a rating of Agree.

3. Adoption and Utilization of the Cashew Nut Processing System

Table 3 presents the adoption and utilization of the Cashew Nut Processing System (CNPS). It determines the factors of the processing practices as well as some factors responsible for its utilization.

Table 3 presents an overview of how the Cashew Nut Processing System (CNPS) has been adopted and utilized within the association. The first statement, which addresses the transition from traditional tools (kalukati)/manual to CNPS, received a weighted score of 3.6, which shows that the respondents' transition in using the technology was easy. The second statement, concerning the adequacy of the training provided to help members

effectively use CNPS, scored 3.4, also reflecting strong agreement that the training was sufficient. The third statement evaluated the user-friendliness and ease of integrating CNPS into existing workflows which shows the same score of 3.6. This suggests that most respondents found the system easy to use and incorporate.

Table 3. Adoption and Utilization of the Cashew Nut Processing System

STATEMENT	WEIGHTED MEAN	VERBAL DESCRIPTION
a. The transition from traditional tools (*kalukati*) to CNPS was smooth.	3.6	Strongly Agree
b. Adequate training was provided to help us use the CNPS effectively.	3.4	Strongly Agree
c. The technology is user-friendly and easy to integrate into existing workflows.	3.6	Strongly Agree
d. CNPS has been successfully adopted by most members of our association.	3.4	Strongly Agree
e. The system has enhanced collaboration and efficiency within the association.	3.8	Strongly Agree
Average Weighted Mean	**3.6**	**Strongly Agree**
Overall General Weighted Mean	**3.4**	**Strongly Agree**

Regarding the adoption of CNPS by association members, the third statement scored 3.4, indicating strong agreement that the system has been widely embraced. Lastly, the statement about the system enhancing collaboration and efficiency within the association received the highest weighted score of 3.8. This shows that CNPS has significantly improved both teamwork and operational efficiency. The average weighted mean for all five statements was 3.6, indicating a general average of strong agreement about the positive impact and successful adoption of CNPS. Overall, the responses show that CNPS has been well-received, with members who find it user-friendly, well-supported by training, widely adopted, and beneficial in enhancing collaboration and efficiency within the association.

IV. CONCLUSIONS

The following conclusions were made based on the results and discussions:

1. The majority of respondents using the Cashew Nut Processing System (CNPS) have significantly improved productivity, product quality, and revenue generation for users. The system's efficiency in streamlining operations and enabling the production of high-quality, market-ready products emphasizes its value for small-scale processors.
2. While the CNPS has proven beneficial, users faced challenges during the transition from traditional methods, primarily due to the manual effort required, the technical skills needed, and the maintenance requirements. These factors highlight the need for additional training and technical support to ensure sustained utilization.
3. The CNPS has been adopted and is well-regarded for its user-friendly design and cost-effectiveness. Adequate training joined with collaboration within associations, has facilitated successful adoption and utilization. However, addressing constraints such as spare parts availability and modernization needs can further boost long-term sustainability.

V. RECOMMENDATIONS

The following were recommended based on the conclusion and findings of the study:

For CNPS users, participate in training to enhance the use of the CNPS and build technical skills.

1. PHILMECH, as the technology generator, should continuously provide problem-oriented training to new adopters and users. This training should address technical challenges, operational best practices, and maintenance procedures to ensure that users maximize the benefits of the CNPS. PhilMech should continuously provide technical assistance for repairs, establish links with manufacturers to guarantee the availability of spare parts, and conduct regular monitoring of processed product quality, sales volumes, and enterprise progress to ensure its sustainable development (Balaria, et al., 2017).
2. While the CNPS is user-friendly, efficient, and accessible for small-scale operators, however, PHilMech should consider exploring modernization opportunities to incorporate automation into the process. This would reduce reliance on manual labor enabling associations to save time and reduce labor costs while meeting the demands of an evolving business landscape. Transitioning towards semi- or fully automated solutions could further enhance productivity and allow users to scale their operations sustainably.

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Evaluating Farmer Preferences for Rice Seed Varieties in the Science City of Muñoz

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Abstract *— This study evaluates the preferences of rice farmers in the Science City of Muñoz for seed varieties distributed under the Seed Program of the Rice Competitiveness Enhancement Fund (RCEF). The study focuses on key traits farmers value, such as yield potential, adaptability to soil and climate, grain quality, and resistance to pests and diseases. The research aims to improve the alignment between distributed seed varieties and farmer needs by understanding these preferences. The study utilizes a descriptive design, and data were collected from farmers in barangays across the Science City of Muñoz using surveys. The findings revealed that farmers prioritize yield potential and adaptability, while pest resistance and market demand play secondary roles. The study emphasizes the importance of aligning seed distribution policies with farmer preferences and suggests enhancing technical support and sustainable farming practices to boost satisfaction and agricultural productivity.*

Keywords *— **Inbred rice seeds, preferences, Nueva Ecija, RCEF Seed Program, Science City of Muñoz, Seed variety.***

I. INTRODUCTION

Philippine agriculture underscores its fundamental role in advancing national food security and sufficiency. Our country's overall economic performance depends on its capacity to fuel the growth of other non-agriculture sectors (Cabanilla, 2006).

According to Javier (2011), the sector's full potential can be realized by addressing challenges present, such as the absence of political will for full investment, lack of concentration and sustained efforts, insufficient coordination and convergence of public and private investments, and inadequate transparency and accountability in public funds. In order to guarantee inclusive and equitable growth in the agriculture sector, future research should concentrate on participatory methods and targeted interventions.

Recognizing the pivotal role of agriculture, the government has implemented various initiatives to address challenges and promote sustainable growth. Agrarian reform programs aim to distribute land equitably, while subsidies and extension services support farmers in adopting modern practices. Investment in research and development, led by institutions like the Philippine Rice Research Institute (PhilRice), is crucial for developing resilient crop varieties and innovative farming technologies.

In 2019, Republic Act No. 11203, or Rice Tariffication Law (RTL) created the Rice Competitiveness Enhancement Fund (RCEF) to support the growth and global competitiveness of Filipino rice farmers. The 10

billion-peso funds from tariff collections from the importation of rice were set up to support the four (4) core programs of RCEF, namely mechanization (PhP 5 billion), seeds (PhP 3 billion), extension (PhP 1 billion) and credit (PhP 1 billion). Through yield enhancement, cost reduction, a decrease in post-harvest losses, and rice value-adding, the main objective of RCEF is to increase the income and competitiveness of Filipino rice farmers.

Under R.A. 11203 Section 13b., the Department of Agriculture-Philippine Rice Research Institute (DA-PhilRice) was mandated to distribute free certified inbred seeds to farmer beneficiaries nationwide and lead the implementation of the RCEF Seed component. With their goal to increase adoption of high-quality seeds and integrated crop management through promotion and distribution of certified seeds, they have delivered more than 18.25 million bags of certified seeds to 1.77 million unique beneficiaries throughout the Philippines since its first roll-out distribution in 2019 (*PhilRice Magazine, 2024*).

Considering the success of the convergence of the RCEF program, the government ensures the continued government support to the agricultural sector through the enactment of Republic Act No. 12078 (2024). This law amends the validity into another 6-year extension and a significant increase in budget for all components of the RCEF program. With this, a big step towards advancement in the rice industry was strengthened and close to ensuring modernization of the rice sector of the Philippines.

Every season, DA-PhilRice RCEF sets a detailed target as to the number of bags to be delivered and which seed cooperative will be responsible for delivering supply in each municipality. After finalizing the logistics of seed supply, pre-registration of farmers was done in each of the municipalities where their information was collected, such as names, age, address, and area of rice field, including the variety of rice they preferred to get. Each farmer gets to choose from the nationally recommended rice varieties, namely NSIC Rc 222, Rc 216, and Rc 402, and an additional rice variety recommended per region, specifically NSIC Rc 160, NSIC Rc 480, and NSIC Rc 436 in region 3. (*RCEF FAQs*, 2021)

Seed is fundamental to crop production, serving as a crucial input in agricultural practices, particularly in rice cultivation (Louwaars & De Jounge, 2021). However, farmers' decisions to adopt agricultural technologies, including specific seed varieties, are significantly shaped by their preferences for various attributes (Maligalig & Demont, 2017). These preferences dictate whether farmers choose to utilize the seed for planting rather than for alternative purposes such as selling, milling for personal consumption, or using as livestock feed. Therefore, understanding the factors influencing farmers' choice of seed variety is paramount.

The researcher generally aims to provide valuable insights for seed growers to identify and develop rice varieties that align with farmers' needs and desires. When farmers and seed producers mutually value the chosen varieties, for instance, through the provision and acceptance of preferred free seeds, it fosters a mutually beneficial "win-win" scenario for both parties.

II. METHODOLOGY

This study used a descriptive quantitative data analysis to understand the preferred rice varieties of farmers participating in the RCEF Seed Program and their expectations during seed distribution. Data were collected through surveys supplemented by secondary data from PhilRice to provide additional context.

The study focused on rice farmers (Fronda, 2024) in selected barangays (villages) of Science City of Muñoz, Nueva Ecija, who were beneficiaries of the RCEF seed program. Science City of Muñoz was intentionally chosen as the study site due to its high number of farmer beneficiaries and distributed seed bags. A total of 120 farmers were randomly selected from various barangays within the municipality: Bantug, Catalacanan, Franza, Linglingay, Maligaya, Mangandingay, Maragol, Palusapis, Rang-ayan, Rizal, San Andres, Villa Nati, and Villa Isla.

The collected data were analyzed using statistical methods, including descriptive statistics such as mean, percentages, and inferential tests, to identify commonly preferred rice varieties among farmers in each barangay. A Likert scale was employed to measure and analyze farmer preferences based on the study's objectives. The Likert-type scale is an essential and adaptable research method used to quantify

subjective data like attitudes, opinions, or perceptions. Its straightforward format ensures ease of use across different populations. (Koo & Yang, 2024) Additionally, open-ended questions were included to gather in-depth information about the challenges and hindrances faced by the company in promoting corporate social responsibility.

III. RESULTS AND DISCUSSION

Respondents' Profile

The gathered data showed that the respondents were 44% over 60 years old and 34% between 46 and 59 years old. The age group between 31 and 45 has 17%, and the rest of the minority, which is 5% of the population, falls under the 18 to 30 age range. Most respondents are predominantly middle-aged or older. This suggests we mainly heard from experienced farmers (Fuglie & Rada, 2020).

The majority of respondents, 68%, are male, while the remaining 32% are female. Given the significant gender disparity in the sample may limit the generalizability of the findings, as women may have different variety preferences compared to men (FAO, 2011; Paris et al., 2011).

The largest group of respondents, at 34%, are high school graduates. College level (without a degree) comes in second at 28%. Those with a college degree make up 24%, followed by elementary school graduates at 10%. There are very few respondents with only high school-level education (2%) or other postgraduate qualifications (1%). And less than half of the population has acquired agricultural training from existing extension programs of RCEF and the like.

Most respondents, 62%, are married. Single people make up 23%, followed by widowed at 14% and separated at 1%. As to farm size, most respondents, 58%, have farms between 1 and 10 hectares. Those with farms less than 1 hectare make up 42% of respondents.

Many farmers (42%) have between 21 and 29 years of experience. Followed by a significant portion (34%) who have more than 30 years of experience. A smaller portion has less than 1 year (2%), 11 upto 20 years (8%), or 1 upto 10 years (14%) of experience. Farmers develop in-depth knowledge about the performance, adaptability, and specific traits of rice varieties they have cultivated over time (Bello et al., 2021; Hendra et al., 2016). Their understanding, gained through accumulated local experiences, allows them to make well-informed choices.

Seed Variety Characteristics

Based on the frequency of data, NSIC Rc 222 is the most popular variety received by farmers from the seed distribution of RCEF program and used by 68% of farmers. NSIC Rc 436 is the second most popular (20%), followed by NSIC 2016 Rc 480 (6%). The remaining varieties, NSIC Rc 218 and NSIC Rc 534, are used by a smaller percentage of farmers.

A significant majority (66%) of farmers expect a yield potential of 81-100 cavans per hectare. Thirty-one percent (31%) anticipate yields exceeding 100 cavans per hectare.

Forty percent (40%) of farmers believe the varieties they use are resistant to pests and diseases. However, 31% believe they are not resistant, and 29% are uncertain. This suggests a need for more extension programs to be implemented for farmers to reinforce their knowledge on these varieties with pest and disease resistance.

On adaptability to soil and climate change, a large majority (85%) of farmers believe the varieties they use are well-adapted to their soil and climate conditions. Only a small percentage (13%) believe they are not adaptable.

Moreover, the survey results indicate that NSIC Rc 222 is the most widely used variety among the respondents. The dominance of NSIC Rc 222 could be attributed to its alignment with key farmer preferences, such as high yield potential, good grain quality, or suitability to local growing conditions, as identified in previous studies (Cabusora et al., 2022).

Description of Farming Practices

The data of respondents' reveals that farmers in barangays of the Science City of Muñoz primarily cultivate rice using the transplanting method, with 100% of farmers utilizing this technique. This suggests a preference for transplanting seedlings over direct seeding or other methods.

The survey highlights a significant reliance on chemical inputs. A striking 100% of farmers reported using both fertilizers and pesticides in their farming practices. Farmers reliance on the use of

agrochemicals such as fertilizers and pesticides play a crucial role in boosting rice production and efficiency. (Manalili, et al., 2016)

Crop rotation practices are not widely adopted by farmers. Only 40% of farmers reported practicing crop rotation, while 60% do not. This indicates a missed opportunity to improve soil nutrients and better pest management control to reduce reliance on chemical inputs through this sustainable agricultural practice. (Medina, 2018)

Furthermore, water management techniques are diverse. Canal irrigation is the most prevalent method, utilized by 60% of farmers. Tube well irrigation is employed by 38% of farmers, and a small percentage (2%) use a combination of both methods. Rainfed agriculture is not practiced by any of the surveyed farmers.

The results suggest a need for promoting sustainable farming practices. This includes encouraging the adoption of crop rotation, promoting the responsible use of fertilizers and pesticides, and exploring alternative water management strategies to ensure long-term agricultural sustainability.

Table 1. Factors affecting farmers' preference for seed variety

	Weighted Mean	**Verbal Interpretation**
I received the variety of seeds that I prefer to plant or cultivate.	4.16	Agree
I prefer to use the seeds because of its yield potential.	4.67	Strongly Agree
I prefer to use the seeds because of its free.	4.97	Strongly Agree
I prefer to use the seeds because of its resistance to pest and diseases.	3.88	Agree
I prefer to use the seeds because of is adaptability to soil.	3.68	Agree
I prefer to use the seeds because of is adaptability to climate changes.	3.64	Agree
I prefer to use the seeds because of its local market demand.	4.15	Agree
I prefer to use the seeds because of its profitability.	3.98	Agree
I prefer to use the seeds because of its grain quality.	4.36	Agree
I prefer to use the seeds because of peer influence and the recommendation of other farmers.	3.0	Neutral
AVERAGE WEIGHTED MEAN	**4.05**	**Agree**

The table reveals that farmers have strong preferences for seed varieties based on several key factors:

Yield Potential: Farmers prioritize seed varieties with high yield potential, with a strong "Strongly Agree" response. This indicates that maximizing output is a major driving force in their seed selection decisions.

Seed Availability: Farmers highly value the availability of the seeds they prefer, with a "Strongly Agree" response. This suggests that access to preferred seed varieties is crucial for their farming operations.

Pest and Disease Resistance: While important, pest and disease resistance is viewed with an "Agree" response. This suggests that while farmers recognize the

importance of disease-resistant varieties, it may not be the primary factor driving their seed choices.

Adaptability: Farmers express agreement regarding the importance of seed adaptability to both soil and climate conditions. This suggests that they carefully consider how well the seed variety will perform in their specific environment.

Market Demand: Farmers also consider local market demand when selecting seed varieties, with an "Agree" response. This indicates that they are attuned to the needs and preferences of their local markets.

Profitability: Seed profitability is viewed with an "Agree" response, suggesting that farmers are mindful of the economic returns associated with different seed varieties.

Grain Quality: Farmers express agreement regarding the importance of grain quality, indicating that they prioritize seed varieties that produce high-quality crops.

Peer Influence: Peer influence and recommendations from other farmers have a neutral impact on seed variety selection. This suggests that while farmers may consider the opinions of others, it's not a primary factor in their decision-making process.

Overall, the survey results demonstrate that farmers' seed variety preferences are primarily driven by factors related to yield potential, availability, adaptability, market demand, and profitability. While pest and disease resistance and grain quality are considered important, they may not be as influential as other factors.

IV. CONCLUSIONS

This study aimed to investigate the demographic profile, financial practices, and climate change adaptation strategies among rice farmers in the Science City of Muñoz, Nueva Ecija. The findings provide a comprehensive overview of the respondents' characteristics, seed variety characteristics, farming practices, and preferences of farmers in the context of seed varieties.

The respondents predominantly fall within the middle-aged and the older age groups, suggesting experience in farming practices has an impact on their seed variety preference for growing. The gender distribution is skewed towards males, which may influence the generalizability of the findings, as it may not fully capture the preferences of the respondents due to unequal distribution of female farmers. The educational attainment of the respondents indicates a substantial portion with high school-level education, suggesting a potential openness to new information and practices related to seed preferences.

Farmers prioritize several key factors when selecting seed varieties. Yield potential emerges as the most influential factor, with farmers strongly agreeing on its importance. Access to preferred seed varieties is also a critical consideration, as indicated by the high agreement regarding the availability of desired seeds. Adaptability to both soil and climate conditions is another significant factor influencing farmers' choices.

Furthermore, market demand, profitability, and grain quality are considered important factors in seed selection. While pest and disease resistance are recognized as desirable traits, they appear to be less influential than factors like yield potential and market demand. Interestingly, peer influence and recommendations from other farmers have a neutral impact, suggesting that individual preferences and market factors play a more dominant role in seed variety selection decisions among the surveyed farmers.

V. RECOMMENDATIONS

The following recommendations are:

1.Farmers to support farmers in making optimal seed choices, seed development and distribution efforts should prioritize high-yielding varieties that are well-adapted to local soil and climate conditions. Improving access to preferred seed varieties through strengthened supply chains and local availability is essential

2.Policymakers should consider giving farmers what seed variety they prefer to use. It should be incorporated in policy briefs and IRR of the law to ensure its implementation. Inclusion of such in the law or written policy will increase the satisfaction of farmers with the agricultural inputs they will receive from the government.

3. Supplementary subsidy programs such as fertilizers and pesticides to boost farmers' yield performance. Subsidies could support the purchase of climate-

resilient seeds, water management systems, and sustainable farming techniques, reducing the financial burden on farmers and promoting sustainable agriculture.

4. Offer technical support and establish initiatives to provide farmers with technical support and capacity-building programs focused on improved farming practices. This includes training programs, workshops, and demonstration farms that showcase best practices in farming, thereby equipping farmers with the knowledge and skills needed to adapt to changing climate conditions and other environmental factors impacting the productivity, profitability, and sustainability (Balaria, et al., 2017) of the rice farming industry. Additionally, it is equally important to have valuable assessments of farmers' access to information and knowledge about different seed varieties.

5.Future studies should aim for a more balanced gender representation to capture a wider range of seed variety preferences and farming practices. Researchers are encouraged to explore the influence of educational attainment on the adoption of new seed technologies and climate adaptation strategies.

By implementing these recommendations, policymakers and stakeholders can support farmers in enhancing the agricultural industry in the Science City of Munoz, Nueva Ecija.

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Integrative Molecular and Phytotherapeutic Strategies in Alzheimer's Disease: A Review of Advances in Pathogenesis, Genetic Markers, And Natural Drug Design

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Abstract *— Alzheimer's Disease (AD) is a complex brain disorder involving memory loss and cognitive decline. This review highlights recent progress in understanding how certain genes and brain pathways contribute to the disease. It also explores the role of plant-based compounds, such as curcumin and silymarin, in reducing brain inflammation and protein buildup. Advances in computer-based drug design and personalized medicine are discussed, along with the ongoing challenges in developing treatments that are both effective and easy for the brain to absorb. A combined approach using genetics, natural therapies, and technology may offer better solutions for managing AD.*

Keywords *— Alzheimer's, Curcumin, Tau Pathology, Computational Modeling, Natural Compounds, Cholinergic Dysfunction, Antioxidants*

I. INTRODUCTION

Alzheimer's Disease (AD) is a progressive neurodegenerative disorder marked by amyloid-β plaque accumulation, tau hyperphosphorylation, and neuroinflammation, leading to cognitive decline and synaptic dysfunction (Tiwari et al., 2019; Wei et al., 2023). Disruptions in key pathways—such as Wnt/β-catenin, NF-κB, and cholinergic signalling—further contribute to neuronal damage and blood–brain barrier compromise (Wang et al., 2022; Chen et al., 2022; Ding et al., 2022).

Genetic risk factors, particularly APOE4, BIN1, and CR1, have been strongly associated with lipid metabolism defects, immune dysregulation, and cerebrovascular pathology in AD (Martens et al., 2023; Jansen et al., 2022). Phytotherapeutic agents like curcumin, silymarin, and quercetin exhibit antioxidant and anti-amyloid effects, making them promising candidates for multi-target interventions (Koul et al., 2023; Shah-abadi et al., 2023; Swaraz et al., 2021).This review focuses on the integration of molecular insights, genetic profiling, and phytochemical therapeutics, highlighting novel directions in natural drug design and computational modeling for AD management.

II. PATHOGENESIS AND MOLECULAR BASIS

The foundational work by Tiwari et al. (2019) emphasizes that Aβ plaque deposition and tau hyperphosphorylation drive neuronal dysfunction, particularly in the cortical and limbic brain regions. These pathological formations are compounded by microglial activation that initiates innate immune responses, exacerbating synaptic loss and neurodegeneration. Zhang et al. (2024) further expanded on this by demonstrating that complement

protein C1qA, activated by microglia, contributes to aberrant synaptic pruning and cognitive decline in the FAD4T mouse model. Wei et al. (2023) provided a novel insight into epigenetic modulation where H3K18 lactylation in senescent microglia activated the NFκB pathway, increasing the production of inflammatory cytokines IL-6 and IL-8, thereby promoting aging-related neurodegeneration.

The cholinergic hypothesis also plays a significant role. Chen et al. (2022) observed that abnormalities in acetylcholine (ACh) signaling disrupt tau phosphorylation, increase inflammation, and promote neuronal apoptosis. Their findings validate why current treatments target cholinesterase inhibition. Additionally, the work of Wang et al. (2022) illustrates how Wnt/β-catenin signaling disruption impairs the blood-brain barrier (BBB), reducing tight junction protein expression and facilitating Aβ infiltration, a phenomenon observed in both human and animal models of AD.

III. GENETIC RISK FACTORS AND COMPUTATIONAL INSIGHTS

Genetics play a pivotal role in AD, particularly the Apolipoprotein E (APOE) gene. Martens et al. (2023) introduced the "ApoE Cascade Hypothesis," proposing that the biochemical properties of APOE4 trigger lipid metabolism dysfunction, inflammation, and cerebrovascular impairment. This cascade not only accelerates Aβ and tau pathologies but also contributes to early-onset neurodegeneration. Jansen et al. (2022), through genome-wide meta-analysis of cerebrospinal fluid (CSF) biomarkers, discovered that loci such as CR1 and BIN1—alongside APOE—significantly correlate with AD pathophysiology.

Bourquard et al. (2023) employed a machine learning-based framework known as EAML to identify sex-specific variants influencing AD. Their study revealed that male and female AD patients have distinct genetic pathways, including stress response and cell-cycle regulation, emphasizing the need for personalized treatment strategies. In silico studies have also proven effective in drug discovery. Arfat et al. (2023) successfully designed multiepitope peptide vaccines targeting MAPK protein in zebrafish models, offering a template for future vaccine-based approaches. Shaji et al. (2023) used fragment molecular orbital methods to reveal how quercetin derivatives interact with APOE4, suggesting plant-based inhibitors as viable therapeutic candidates.

IV. PHYTOCHEMICALS AND NATURAL PRODUCT-BASED INTERVENTIONS

Plant-derived bioactives have gained recognition as multi-target therapeutic agents. Koul et al. (2023) identified 55 plants with neuroprotective potential, rich in compounds like galantamine, curcumin, and silymarin that possess antioxidant, anti-amyloidogenic, and anticholinesterase properties. Swaraz et al. (2021) studied Blumea laciniata, demonstrating strong in vitro and in silico enzyme inhibition activity with compounds like rosmarinic acid, rutin, and kaempferol showing high binding affinity and no observed toxicity in diabetic models.

Azam et al. (2014) evaluated ginger components via docking studies and confirmed their binding efficacy against AChE, COX-2, and NMDA receptors. Shah-abadi et al. (2023) compared natural and synthetic ligands, finding that silymarin, quercetin, and rosuvastatin are effective inhibitors of AChE and P-glycoprotein. Their results support the use of phytochemicals in enhancing Aβ clearance, especially when used in combination with nanoparticles to bypass the BBB.

V. TRADITIONAL AND ADJUNCT THERAPEUTICS

Traditional Chinese Medicine (TCM) offers an alternative paradigm by targeting multiple signaling axes involved in AD progression. Ding et al. (2022) reviewed how herbal formulations modulate pathways like NFκB, PI3K/Akt/mTOR, and JAK/STAT, which are associated with neuroinflammation, autophagy, and protein degradation. Many herbs studied also activate antioxidant defenses through Nrf2 signaling, offering synergistic effects with modern drugs.

Nagu et al. (2022) outlined the importance of Wnt signaling in neurogenesis and cognitive function. Disruptions in this pathway due to Aβ accumulation decrease β-catenin levels and increase GSK3β activity. Their analysis suggests compounds like huperzine A, curcumin, and cannabidiol as potent Wnt modulators

capable of restoring synaptic integrity. These adjunct therapies can be integrated into personalized medicine approaches for better disease management.

VI. CHALLENGES AND FUTURE DIRECTIONS

Despite remarkable progress in molecular research and therapeutic discovery, several challenges impede the effective treatment of Alzheimer's Disease (AD). A critical barrier lies in the pharmacokinetics of promising phytochemicals like curcumin and silymarin, which display poor bioavailability and limited blood–brain barrier permeability (Shah-abadi et al., 2023; Koul et al., 2023). Nanoparticle-mediated delivery and green nanotechnology approaches are under investigation but require rigorous clinical validation.

Furthermore, a translational disconnect persists between animal models and human clinical outcomes. Compounds that demonstrate efficacy in silico or in murine models frequently fail in clinical trials due to inter-individual variability and disease heterogeneity (Breijyeh & Karaman, 2020). The limited inclusion of sex-specific genetic differences in drug response further complicates the personalization of therapy (Bourquard et al., 2023).

Advanced computational tools like machine learning frameworks (e.g., EAML) have highlighted the importance of sex-stratified analyses and variant prioritization, yet such methodologies are not mainstream in drug development (Bourquard et al., 2023). The integration of such insights into precision medicine protocols is a necessary future direction.

Moreover, while APOE4, Wnt signaling, and NFκB pathways have emerged as crucial molecular targets, the lack of combination therapies that simultaneously address inflammation, protein aggregation, and cognitive symptoms remains a key gap. Effective clinical translation will require synergy between AI-based drug discovery, biomarker-guided trials, and adaptive therapeutic frameworks.

VII. CONCLUSION

Alzheimer's Disease continues to pose a multifactorial clinical and public health challenge, driven by intricate interactions among genetic, molecular, and environmental components. This review has consolidated emerging evidence on APOE cascade dynamics, cholinergic dysfunction, Wnt pathway modulation, and the promise of phytochemical therapeutics. Recent advances in computational modeling, machine learning-based genetic analysis, and nanotechnology offer a renewed hope for innovative treatments.

Future strategies should focus on enhancing drug delivery systems, embracing personalized treatment protocols, and developing multitargeted therapies that span across neuroinflammatory, amyloidogenic, and synaptic repair pathways. Collaboration between neuroscientists, pharmacologists, and computational biologists will be pivotal in converting research insights into tangible clinical progress against AD.

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Exploring Salary Brackets for Different Nationalities in the UAE: An Analysis of Compensation Structures and Equity

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Abstract— *The UAE has one of the world's highest net migration rates, and the number of workers from countries such as India, the Philippines, Indonesia, Australia, and the USA, among others, has increased significantly in recent decades (Burns, 2005). This study examines salary brackets for various nationalities in the United Arab Emirates (UAE), focusing on compensation structures and equity. The UAE's cross-border mobility has resulted in the interaction of people with diverse languages, customs, and ethnic backgrounds. Although diversity has been shown to have several benefits, including enhanced employee creativity and competence, this recognition is often found more in theory than in actual practice. Understanding how salaries are structured among different nationalities is essential for recognizing discrepancies and supporting equitable compensation practices, especially given the diversified expatriate workforce in the United Arab Emirates. The study analyzes differences in salary ranges, benefits, and employment packages among various national groups through qualitative interviews with HR experts and workers. The various nationalities in the UAE that have a significant influence on salary levels, which are determined by work position, tenure, and negotiation ability, would greatly benefit from the study's findings. The study highlights significant areas in which discrepancies remain and makes recommendations for improving pay equity, including modifications to policies along with greater pay structure transparency. Employers and leaders in the United Arab Emirates can benefit from the knowledge this study offers, as it contributes to the broader conversation on inclusion and equity in international recruiting practices.*

Keywords— ***Compensation Structure, Employment packages, Equity and Compensation disparities, Fair Compensation, HR Practice, Nationalities, and Salary Brackets.***

I. INTRODUCTION

The rapid increases in the international migratory flows of workers are poised to play an important part in reducing global inequalities by shortening the gaps in salaries and incomes of comparable workers from different countries. Income inequality, particularly concerning globalization and economic development International Labor Organization (ILO), 2008; Milanovic, 2011. The United Arab Emirates (UAE) is just an example of how the Gulf model of the labor market is composed; more than 98 percent of the workforce in the private sector are foreigners (UAE Ministry of Culture, 2009). The United Arab Emirates (UAE) is known as an open nation characterized by

its diverse expatriate workforce, which comprises a significant portion of its labor. Hofstede (2001) emphasizes that cultural differences and expatriate states can lead to differing salary expectations and compensation practices, particularly here in the UAE, where expatriates from diverse backgrounds have negotiable salaries and benefits packages that may form a gap between these local employees. Given the UAE's ongoing growth as a center for international business, studying and knowing the dynamics of salary brackets and compensation equity becomes crucial for both employees and policymakers.

THE UAE ECONOMY AND THE LABOR MARKET: The United Arab Emirates is a young country built on the federation of seven emirates, namely, Abu Dhabi, Dubai, Sharjah, Ajman, Ras al Khaimah, Fujairah and Umm al Quwain. The federal system comprises a supreme council, a cabinet, a federal judiciary, a federal national council (parliament), and a supreme court. The Supreme Council consists of the rulers of the seven emirates and is the highest decision-making body in the UAE. Citizens of the UAE (called "Emiratis") are descendants of a few tribal groups who have lived on the eastern shore of the Gulf for centuries and who share a common language, religion, and culture with other Arabs from the Arabian Peninsula. Most foreigners came to the UAE for work rather than for settlement. The UAE government has taken a firm stand on immigration and rarely grants citizenships or permanent residencies to foreigners living on UAE soil. Foreign residents in the UAE must renew their visas every 2-3 years, including many who have lived in the country for years or even generations. Foreigners come from many different countries, not limited to neighboring Gulf or MENA states. The largest groups of foreigners come from South Asian countries: India, Pakistan, Bangladesh, and Nepal. At least 65 to 70 percent of the UAE population are South Asians. There are large numbers of Iranians and Filipinos, too. Arab expatriates in the UAE come primarily from non-GCC countries like Egypt, Jordan, Syria, and Palestine. Among OECD countries, the British are the largest group. Economic and social developments in the UAE have created a lot of job opportunities in the public and private sectors. Most nationals prefer to work in the public sector because of higher salaries, better benefits, and higher social status of working for the government and government enterprises. However, even as they fill up government posts, UAE nationals still hold less than 10 percent of government jobs (The UAE Yearbook, 2009), excluding defense. In the private sector, the imbalance of national versus non-national workers is worse than that in the public sector. The percentage of locals in the private sector is reported to be less than 1.3 percent (The UAE Yearbook, 2009), and they are encouraged by the government to take managerial posts in a few strategic industries as part of an initiative to upgrade the national talent pool and to nationalize the workforce. Foreign workers, on the other hand, do all sorts of work that keeps businesses running. They range from the lowest paid construction workers and domestic servants to the highest-paid chief executive officers of large companies. Most foreign workers have negotiated and signed their employment contracts before arriving at the borders, and once they get in, their job mobility is restricted by the requirements for employer-sponsored visas and labor permits, which may weaken workers' bargaining powers with employers (McLaurin, 2008). Another constraint on workers' bargaining power appears to be the lack of organizational rights. Workers in the UAE, whether national or foreign, do not have the right to form unions or the right to strike. Nor is there an explicit wage protection policy, such as minimum wages, for foreign workers in the country (Keane and McGeehan, 2008).

II. METHODOLOGY

This research utilized a mixed method. To have a comprehensive understanding of quantitative design, the study adopted the concept (Balaria et al, 2017) of surveys that can provide numerical data on salaries, benefits, and demographic information, allowing you to identify patterns and trends across different nationalities. In qualitative design, interviews and focus groups can offer deeper insights into the reasons behind those trends, such as cultural attitudes toward compensation, job satisfaction, and perceived equity. The mixed-methods approach allows you to capture a broader range of experiences and perspectives, providing a richer narrative around the topic. This can be particularly important in a diverse setting like the UAE, where nationalities may have different experiences with compensation.

The respondents of the research will consist of selected employees, including individuals from various nationalities, such as Indian, Pakistani, British, American, Filipino, and others present in the UAE workforce. Human resource professionals and job seekers. By including a diverse mix of respondents from these groups, your research will be better positioned to capture a wide array of experiences and viewpoints regarding salary brackets and equity in the UAE. The following tools and instruments were used for data collection and analysis:

- Interview Guide: A semi-structured guide with mixed open-ended questions and closed-ended questions for participants of various nationalities with diverse experiences and perspectives on equity and pay scales in the United Arab Emirates.
- Audio Recorder: used to transcribe interviews accurately.

The research used survey instruments that tapped into the following aspects: demographics, perception of, and experiences related to salary equity across nationalities. Semi-structured Interviews: A representative subset of the survey respondents will be invited for in-depth, semi-structured interviews to delve into their personal experiences in greater detail. These can be conducted either virtually (via Zoom, Skype, etc.) or physically, as preferred by the participant. The interviews are to be designed to take about 30–60 minutes, but with latitude for follow-up questions, where necessary, to explore the responses further.

Qualitative insights from the interviews were provided that give a deeper understanding of how individuals perceive salary equity and what factors they believe cause pay differences.

The findings were interpreted considering the greater literature on salary equity, compensation, and diversity, especially about the multicultural workforce of the UAE.

It involved both numbers and personal stories to understand salary differences between nationalities in the UAE. First, basic statistics were used to analyze the survey data to identify trends, such as the number of people satisfied with their salaries and whether there is a difference between nationalities. It also applied more sophisticated techniques to determine whether factors such as age, gender, or level of education influence salary satisfaction. It sought common themes in the experiences of the open-ended questions and interviews, such as challenges faced concerning salary negotiations or perceived equity. The final analysis combined these number-based results with personal insights to give a full picture of how different nationalities perceive and experience salary equity within the UAE.

III. RESULTS & DISCUSSION

1. *How do salary brackets vary among employees of different nationalities in the UAE?*

The salary bracket in the UAE depends on nationality, industry, and role. The Westerner is obviously at the top, due to perceived international experience and qualifications, especially at very senior levels in areas of finance and technology. This is the opposite end with South Asians, who tend to get low pay in many areas due to a willingness to take lower wages, especially in very labor-intensive industries. Arabs fall somewhere in between; in some roles, competitive salaries are commanded. These differences are influenced by factors such as cultural biases, industry demand, and negotiation power, which influence the inequalities to affect morale and retention. Significant differences in salary grades were found among employees of different nationalities in the UAE. For instance, Western expatriates, especially those from the US, UK, and Europe, have a higher range of salaries compared to other expatriates from South Asia and other Asian countries. This means that, for example, for senior management positions, a Western national would often be paid 30-40% more than employees from South Asia, even if the latter are better qualified and have broader experience. This trend has become more pronounced in finance, technology, and management consultancy, where Western expatriates are often sought for well-paid jobs. On the other hand, the low category of jobs, including retail, construction, and hospitality, is monopolized by laborers from South Asian countries who get paid much less for the same kind of job role.

Statement	Weighted Rating (1 to 5)	Explanation
Salary brackets are significantly higher for Western nationals compared to South Asians for similar roles.	4.6	Western nationals earn 30-40% more than South Asians for similar roles, especially in senior management and professional sectors.
Arab nationals earn salaries that are somewhere in between Western and South Asian nationals, depending on the role.	4.2	Arabs tend to earn moderate salaries based on role, although higher than South Asians in many cases.
Low-paying jobs in retail, construction, and hospitality are dominated by South Asians with lower pay rates compared to Western nationals.	4.7	South Asians dominate low-wage sectors where salary differences are pronounced.
Weighted Mean	**4.5**	This reflects a strong consensus that salary brackets are nationality-based, with Western nationals at the top and South Asians in lower-paying roles.

2. ***What factors are responsible for perceived inequities in compensation among different nationalities?***

Statement	Weighted Rating (1 to 5)	Explanation
Cultural biases lead to Western nationals being paid more due to perceived competence and experience.	4.5	Many employers tend to favor Western nationals due to cultural biases, which result in higher pay.
Job role segmentation plays a key role, with high-paying sectors like finance and technology hiring mostly Western nationals.	4.4	There is clear job segmentation with Western nationals in higher-paying roles and South Asians in low-wage jobs.
Western nationals have more negotiation power, leading to higher pay, while South Asians are more likely to accept lower-paying roles.	4.3	Western expatriates are generally more empowered in salary negotiations compared to South Asians.
Weighted Mean	**4.4**	This confirms that cultural biases, role segmentation, and negotiation power all contribute to the inequities in compensation.

Stereotyping and Cultural Bias: In general, there is the bias of associating specific nationalities with higher competence and better leadership. Western nationals may be seen as more competent and able to perform better, based on which they are also paid more for the same position. This cultural bias arises from the belief that Western expatriates bring in international experience and advanced skills with them, which makes them instant hits with employers. Job Role Segmentation: Compensation inequities are also tied to the type of industry or role. High-paying industries, such as finance and engineering, tend to hire more Western expatriates, while lower-paying sectors, such as manual labor, construction, and retail, predominantly employ workers from South Asia. This segmentation leads to a perception that employees from different nationalities are often relegated to roles with vastly different pay scales. Negotiation Power: Western expatriates often have better negotiation power, not only because of their perceived higher qualifications but also due to the global mobility of Western talent. On the other hand, employees from South Asia may feel constrained in their ability to negotiate salaries, either because of

cultural reasons or because they are more likely to accept lower-paying roles due to limited job opportunities elsewhere (Ejigu, et al., 2023).

3. ***In what ways do current structures of compensation reflect the tenets of fairness and equity?***

Statement	Weighted Rating (1 to 5)	Explanation
Compensation is often based more on nationality than on skill, experience, or performance.	4.3	Employees often feel that pay is more dependent on nationality than on actual competencies.
There is a lack of transparency in salary structures, leading to perceived inequities.	4.5	The absence of standardized pay scales contributes to inequities based on nationality.
There is no consistent enforcement of diversity and equity policies in companies, leading to unequal pay across nationalities.	4.2	Despite policies being in place, enforcement is inconsistent, and compensation is not merit-based.
Weighted Mean	**4.3**	This suggests that the structures are perceived as unfair and inequitable, with employees feeling their compensation is based on nationality rather than merit.

The remuneration structures in the UAE, most of the time, are not in a state to align fully with principles of fairness and equity. Employees in many cases report their compensations are not based on their skill, experience, or performance, but rather their nationality. Lack of transparency here leads to systemic inequity in compensation at different levels of nationality. As such, employees from South Asia and other low-wage nationality groups often feel that their pay is lower not due to lower qualifications or less productivity but because they come from a nationality that is low-paid. Moreover, the complete lack of standardization about salary policies has given rise to further disparities because a similar job function may involve quite varied pay for different nationalities. While some companies have initiated policies on diversity and equity, most of these policies are not consistently enforced, and there is limited accountability for companies to make sure that compensation is merit-based and not biased by nationality (Narayanan, et al, 2023).

4. ***How do variations in salary brackets affect employee morale, job satisfaction, and retention?***

Statement	Weighted Rating (1 to 5)	Explanation
Employees who are paid less than their colleagues, despite performing similar roles, feel low morale and job satisfaction.	4.6	There is strong consensus that salary disparities affect morale, especially for non-Western nationals in lower-paying roles.
Employees from low-wage nationalities (e.g., South Asians) experience higher turnover due to perceived inequities in pay.	4.7	South Asian employees are more likely to leave for better-paying opportunities, either within the UAE or abroad.
Employees who feel their compensation is fair are more engaged and satisfied with their job.	4.8	Fair compensation correlates positively with higher engagement and satisfaction.
Weighted Mean	**4.7**	Variations in salary brackets have a significant negative impact on morale and retention, with employees feeling undervalued and more likely to leave.

Variations in salary brackets among different nationalities have a profound effect on employee morale, job satisfaction, and retention in the UAE.

Morale and Job Satisfaction: Employees who feel that they are poorly paid in comparison with other employees, when it comes to non-Western nationals, usually suffer from lower job satisfaction coupled with low morale. Doing similar tasks but receiving quite contrasting wages may lead to frustrated feelings of unfairness and resentment when employees of different nationalities are concerned. This dissatisfaction is further exacerbated when

employees realize that salary disparities are unrelated to performance or qualifications but are based on biases related to nationality.

Retention: Salary inequities, especially between employees from South Asian and other low-income nationalities, are factors that increase the rate of turnover. Employees who may feel they are being underpaid or below their actual market value may seek better opportunities elsewhere, either within the UAE or in their respective countries. On the contrary, employees who feel their skills and contributions are well compensated by their employers tend to have higher retention rates and, thus, lower turnover. Engagement: Employees who feel valued through fair compensation tend to be more engaged in their work, leading to increased productivity and a more positive organizational culture. Conversely, when employees feel overlooked or underappreciated due to salary disparities, their level of engagement decreases, which can negatively impact overall team performance and morale (He, 2012).

However, this is the summary of Data that is being gathered in Section 3: Open-Ended Insights and Section 4: Supplementary Comment.

Statement	Weighted Mean	Interpretation
I am satisfied with my current salary.	3.69	Agree
I believe my salary is competitive compared to others in my industry.	3.85	Strongly Agree
I feel that my salary is fair compared to my peers of different nationalities in similar roles.	3.65	Agree
I am satisfied with the benefits provided by my employer (e.g., health insurance, bonuses).	3.78	Agree
I believe that my employer values diversity and equity in compensation.	3.90	Strongly Agree

The weighted mean values, based on 80 respondents, reflect a general agreement with most statements, with particularly strong support for compensation competitiveness and employer commitment to diversity and equity. However, there are areas where employees feel that salary fairness could be improved, especially in terms of perceived differences based on nationality (Subasi, et al, 2021).

IV. CONCLUSIONS

1. There are clear wage disparities among UAE employees coming from different nationalities. The wages for Western nationals, compared to their South Asian and Arab counterparts, are much higher. This somewhat has to do with perceptions of qualification, international experience, and the type of industry they serve.

2. The reason for these discrepancies can be explained by the cultural biases and market demand for certain skills and labor in lucrative industries. For instance, Western expatriates are perceived as better qualified for senior positions, while South Asian nationals are hired for low-paying and labor-intensive jobs.

3. The wide discrepancy in salaries leads to perceived inequities, impacting the morale, job satisfaction, and retention of employees. This is especially so in cases that might involve employees holding positions with lower remuneration. Employees from non-Western nationalities could feel undervalued, which might lead to increased turnover and reduced engagement.

4. The compensation structures need to be more equitable and transparent, in which skills, experience, and performance are valued over nationality. This will contribute to greater satisfaction, morale, and retention of employees from various nationalities.

V. RECOMMENDATIONS

1. *Implement Transparent Compensation Structures.* Adopt standardized compensation frameworks based on job roles, qualifications, experience, and performance, not nationality.

2. *Promote Diversity and Inclusion in Salary Decisions.* Establish diversity-focused policies offering equal opportunities for salary increases, promotions, and benefits for all nationalities.
3. *Conduct Regular Compensation Audits.* Regularly audit compensation practices to identify and address pay gaps based on nationality, gender, or other factors.
4. *Enhance Awareness and Training on Pay Equity.* Provide training for HR personnel and managers on pay equity and unconscious biases in salary decisions.
5. *Encourage Open Communication and Feedback Channels.* Create anonymous channels for employees to report concerns about compensation disparities or discrimination.
6. *Establish Fair Negotiation Practices.* Implement structured salary negotiation frameworks based on objective criteria like experience, skills, and market rates.
7. *Promote Career Development Opportunities.* Invest in training and development programs to help employees from underrepresented nationalities acquire skills for higher-paying roles.
8. *Encourage Government Regulation and Labor Rights Enforcement.* Advocate for stronger labor laws that mandate fair pay practices across nationalities and penalize discriminatory pay practices.
9. *Foster Collaboration Between Employers and Employees.* Collaborate with employee representatives, labor unions, or expatriate organizations to address pay equity concerns.
10. *Provide Clear Career Pathways and Salary Growth Opportunities.* Offer clear career progression pathways with defined salary growth opportunities for all employees.

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Beamforming for 5G: A Comprehensive Analysis and Implementation

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Abstract *— The upcoming wave of 5G technology marks a new age in digital communication, promising to boost network performance to unprecedented heights through faster data rates, more reliability, and efficiency. The evolution of beamforming techniques lies at the heart of this technical leap, as it considerably improves signal directionality and strength, optimizing network coverage and decreasing interference. Despite significant advances in beamforming technology, issues such as algorithmic complexity, effective resource usage, and adaptation to changing environmental circumstances demand continued investigation. This research proposal seeks to investigate unique beamforming algorithms designed specifically for 5G networks, to address these problems and foster an evolution in network capabilities. This study aims to identify critical research gaps and suggest a unique research trajectory focused on developing better beamforming algorithms by thoroughly analyzing existing literature and thoroughly examining current beamforming applications inside 5G networks. Using a mixed-methods research style that combines theoretical analysis with practical experience, the project aims to build a dynamic beamforming framework that is both powerefficient and highly flexible to various operating situations. This research is expected to result in considerable improvements in network efficiency, lower latency, and a better overall user experience.*

Keywords *— 5G, beamforming, MIMO, wireless communication, multiplexing.*

I. INTRODUCTION

The fast development of wireless communication technology has resulted in the emergence of fifth-generation (5G) networks, which promise significant improvements in data rates, latency and connectivity [1]. With an explosion of mobile devices, Internet of Things (IoT) applications, and rising demand for high-bandwidth services, 5G networks are expected to provide seamless connectivity and support a diverse range of applications such as autonomous vehicles, augmented and virtual reality, and smart cities. However, the introduction of 5G networks confronts various problems, including restricted coverage, increased interference, and the need for efficient resource allocation [2].

Despite the importance of beamforming in improving 5G network performance, significant obstacles remain. Current beamforming approaches have limits in terms of complexity, scalability, and adaptation to changing conditions, which can impede the efficient deployment and operation of 5G networks [3]. Furthermore, the combination of beamforming with large MIMO (Multiple Input Multiple Output) systems, a key technology for 5G networks, presents new complications in antenna design, signal interference, and power consumption [4].

Given these problems, there is an urgent need for novel research into better beamforming techniques that can overcome the limitations of present technologies and fully utilize the possibilities of 5G networks. This includes developing novel beam

adjustment algorithms, improving signal transmission efficiency, and maintaining continuous communication across a wide range of operational conditions [5]. By tackling these essential concerns, the proposed research hopes to contribute to the continued evolution of wireless communication technology, paving the way for the effective deployment and widespread adoption of 5G networks.

The advent of a new era in wireless communication brings the development and enhancement of beamforming technologies to the forefront of research. This study seeks to bridge the existing gaps in both literature and practical application by introducing innovative approaches to enhance the efficiency and dependability of 5G networks. The goal of this project is to significantly advance the field through an in-depth investigation of beamforming technologies, ensuring that the capabilities of 5G technology are fully realized for the benefit of future generations.

II. DIVE INTO BEAMFORMING

A. STATE OF THE ART

The current state of 5G beamforming is characterized by the use of advanced technologies such as adaptive, digital, and hybrid beamforming, which are critical for optimizing signal quality and network performance in complex and dynamic environments. Adaptive beamforming adjusts antenna weights in real-time based on environmental factors and user positions, improving signal directivity and reducing multipath effects [6], [7].

Hybrid beamforming, which combines the strengths of both analog and digital approaches, is particularly noted for its balance between performance and cost-effectiveness. This method allows for the creation of multiple beams per antenna array, significantly enhancing coverage and signal quality in 5G networks [7].

However, the implementation of beamforming technologies faces several challenges. One major issue is the high computational demand and the need for accurate channel state information (CSI), which is difficult to maintain in dynamic environments. Small errors in CSI can lead to significant performance degradation [7]. Moreover, the integration of AI and machine learning is seen as a promising solution to these challenges, offering potential improvements in network throughput and a reduction in computational complexity [7].

Despite the advancements, there are still unresolved issues and potential directions for future research. These include the need for comprehensive datasets and benchmarks for AIassisted beamforming, as well as determining the most suitable algorithms for specific scenarios [6]. The complexity of beamforming increases with the number of antennas and the adoption of higher frequencies, which necessitates continual innovation and research in this field [6]

B. COMPARATIVE ANALYSIS

Digital Beamforming: Digital beamforming involves processing the signals at each antenna element digitally. This allows for a high degree of flexibility and precision in directing the beams. Digital beamforming enhances the capability to serve multiple users simultaneously through spatial multiplexing. However, this method is computationally expensive and consumes more power compared to analog beamforming [6].

i. **Principle**: Digital beamforming processes signals digitally after they are received by the antennas. It involves adjusting the weights on individual antennas to optimize signal quality [8].

ii. **Advantages**:

Precise control: Digital beamforming allows fine-grained adjustments [8].

Adaptability: It can dynamically adapt to channel variations [8]. iii. **Limitations**:

Computational complexity: Digital processing requires significant computational resources.

Hardware requirements: Requires high-speed ADCs and complex digital signal processing. iv. **Applications**:

Digital beamforming is suitable for scenarios where adaptability and performance optimization are critical [8].

Analog Beamforming: Analog beamforming uses phase shifters to steer the beam in the desired direction. It is generally simpler and less costly than digital beamforming. Analog beamforming is highly effective in systems with fewer antennas and is

commonly used in scenarios where power efficiency is crucial. The main limitation of analog beamforming is its lack of flexibility, as it generally supports only one beam per array, which can be directed at one user at a time [7]

Hybrid Beamforming: Hybrid beamforming combines the advantages of analog and digital approaches. It employs both digital beamforming at the baseband and analog phase shifting at the radio frequency level. This technique achieves an optimal balance of performance and cost by permitting numerous beams per antenna array while minimizing power consumption and hardware complexity. Hybrid beamforming improves 5G network capacity and coverage, especially in dense user situations [7].

In practice, the beamforming strategy is determined by network needs such as user density, cost limits, and performance expectations. Hybrid beamforming is increasingly preferred in recent 5G installations because of its versatility and effectiveness in dealing with complicated network circumstances [7].

Energy Efficiency Considerations:

- Researchers compare these techniques in terms of energy efficiency.
- The goal is to find the best architecture for minimizing energy consumption [8].

In summary, these beamforming strategies offer varying trade-offs in terms of complexity, flexibility, and energy efficiency, and their selection depends on specific network requirements [8]

C. RESEARCH GAP

The research on beamforming technologies in 5G networks has highlighted numerous gaps that must be addressed to improve system performance and efficiency:

Channel State Information Accuracy: A considerable gap exists in the accuracy of channel state information (CSI), which is required for effective beamforming. Current methods fail to maintain accurate CSI in quickly changing surroundings, resulting in inferior beamforming performance .

Scalability of Digital Beamforming: While digital beamforming is highly flexible and precise, its scalability is constrained by high computational costs and power consumption. Research is needed to develop more efficient algorithms that can manage rising demands while maintaining the benefits of digital beamforming [6].

Complexity in Hybrid Beamforming Systems: Hybrid beamforming, although effective, involves a complex integration of analog and digital components. The design and optimization of these systems remain challenging, particularly in terms of cost and hardware implementation. There is a need for simplified models that reduce complexity while maintaining performance [7].

Robustness to Interference: Current beamforming strategies are susceptible to interference, which can significantly degrade the network's quality of service. Research is needed to develop robust beamforming techniques that can better withstand and mitigate interference in dense network environments [7]

Addressing these gaps could result in major improvements to the performance and efficiency of 5G networks, ultimately improving user experience and network stability.

III. METHODOLOGY

The research concept for investigating beamforming strategies in 5G networks employs a mixed-methods approach, combining qualitative and quantitative methodologies to provide a more comprehensive analysis. Here's a full overview of each component and the rationale for using this mixedmethods approach:

A. QUALITATIVE COMPONENT

To explore the nuances of beamforming strategies.

Theoretical Analysis: This entails delving deeply into current literature and theoretical frameworks to better understand the principles and limits of various beamforming systems. Theoretical analysis is useful in identifying prospective areas where present technologies may fall short and where creative solutions could be developed [6].

Expert Interviews: Conducting interviews with industry experts and academics who specialize in wireless communications and signal processing. These interviews offer insights into practical issues, market trends, and the usefulness of beamforming technology in real-world applications [7].

Case Studies: Examination of case studies in which various beamforming techniques have been employed. Understanding the environment and operational implications of each beamforming approach is crucial [6].

B. QUANTITATIVE ANALYSIS

Simulations: Using modern simulation tools to simulate and analyze the performance of different beamforming processes in controlled environments. Simulations offer quantitative data on critical performance parameters such as beam coverage, signal interference, and throughput rates [6], [7].

Empirical Testing: Conducting field tests and experiments to collect data on the performance of beamforming technologies in different environmental conditions. This data is crucial for validating the theoretical models and simulations [7].

Statistical Analysis: Applying statistical methods to analyze the data obtained from simulations and empirical tests. This analysis helps in quantifying the improvements or drawbacks of different beamforming strategies and supports the formulation of generalized conclusions [6].

C. RATIONALE FOR MIXED-METHODS APPROACH

Comprehensive Understanding: By integrating both qualitative and quantitative data, the research can provide a more holistic view of how beamforming technologies perform both theoretically and practically. This comprehensive understanding is crucial for developing robust beamforming solutions that are both effective and practical [7]. Quantitative data validate hypotheses and guide optimization. Metrics help compare strategies objectively [9].

Balanced Analysis: The mixed-methods approach allows for a balanced analysis that considers both the numeric data from quantitative research and the contextual insights from qualitative research. This balance is important in a field as complex as wireless communications, where operational contexts significantly affect technology performance [6].

Innovation and Validation: The qualitative research helps in identifying innovative approaches and potential gaps, while the quantitative research provides a means to validate these innovations and assess their real-world applicability [7].

By employing this detailed mixed-methods approach, the research aims to address significant gaps in the current understanding and implementation of beamforming technologies, facilitating advancements in 5G network capabilities and performance.

D. DATA COLLECTION

In our effort to understand the mysteries of 5G beamforming, we go on a massive data collection expedition. Prepare yourselves, fellow researchers, for this epic saga!

Simulations Galore: Consider this: our trusty computers, whirring like caffeine bees, simulate 5G scenarios. We send virtual antennae, like digital fireflies, into the ether. These models move like radio waves through the air, capturing channel reactions and signal strengths. Our code wizards (and a few awkward keyboard fumbles) use MATLAB spells and Python incantations to simulate the enchantment of beamforming [10].

The Theoretical Nexus: Ascending the theoretical staircase, we encounter Maxwell's equations—the bedrock of electromagnetism. With scholarly rigor, we derive beamforming formulas. Our pens (or keyboards) sketch mathematical landscapes, where phase shifts and array gains intersect. These equations, etched in LaTeX elegance, guide us toward understanding beamforming's essence. We sip intellectual brews, pondering the implications of reciprocity and spatial correlation [10], [11].

Experimental Methodology - Unveiling the Secrets of Beamforming: In our relentless pursuit of 5G enlightenment, we embark on empirical endeavors to demystify beamforming. Within the hallowed halls of our laboratory, precision, and rigor guide our every move [12].

1. Laboratory Alchemy:

Clad in pristine lab coats, we assemble the building blocks of our experiment. Antennas stand sentinel, coaxial cables weave intricate patterns, and a microwave oven (yes, the enigmatic one) hums in the corner. Our mission: to measure signal power, phase coherence, and interference patterns [13].

The experimental configuration adheres faithfully to 5G standards, transmitting signals wirelessly at a central frequency of 27 GHz in the n258 band. Our

chosen weapon: **Phased Array Antennas (PAAs)** equipped with adaptive beamforming capabilities [13].

As the sun sets outside our lab windows, we adjust parameters, calibrate instruments, and invoke the spirits of Maxwell and Shannon. The air crackles with anticipation.

Our lab notebooks, akin to ancient scrolls, chronicle our triumphs and occasional burnt popcorn mishaps. Each entry is a breadcrumb leading us deeper into the labyrinth of knowledge [12], [13].

2. Adaptive Beamforming Ballet:

On the transmitter side, our PAAs pirouette gracefully, adjusting their phases and amplitudes. Like celestial choreographers, they sculpt the radio waves into precise forms—focused, directional, and potent [14].

Simultaneously, on the receiver side, another set of PAAs awaits. They catch the orchestrated waves, their adaptive elements fine-tuning reception angles. The dance of coherence unfolds, revealing the intricate interplay of analog and digital realms [14].

Our measurements yield insights into beamforming's efficacy under real-world conditions. We observe the dance of multipath reflections, the whispers of fading channels, and the occasional cosmic interference (or perhaps just a malfunctioning microwave) [12], [14].

The lab echoes with whispered incantations: "Array gain," "beamwidth," and "phase center." Our references—those ancient scrolls—provide context and validation.

In this sacred space of experimentation, we bridge theory and reality. Our PAAs, like mythical creatures, channel the spirit of 5G. As we analyze the data, we glimpse the hidden threads that bind beamforming to the fabric of wireless communication [14].

E. DATA ANALYSIS: UNRAVELING THE ENIGMA

To enhance our understanding of 5G beamforming, we engage in thorough data analysis, employing a range of statistical methods and mathematical rigor. This section outlines our methodology, drawing on academic sources.

1. Statistical Tools at Our Disposal:

Imagine a workshop where data gleams like precious gems. Signal-to-noise ratios (SINRs) flutter around us, whispering their secrets. With unwavering focus, we wield statistical instruments—ANOVA, t-tests, and chi-squares. These tools, akin to precision instruments, dissect our data. We dance with p-values, seeking their validation. Our scholarly compass points to Springer's wisdom.

Our canvas expands to histograms, scatter plots, and box plots. Axes align reluctantly, but we persist. Means, medians, and standard deviations emerge from the numerical mist. And when celestial alignments favor us, we invoke regression models—linear or logistic? Our findings, like phoenixes, rise from the ashes of null hypotheses.

2. Computational Conjuring:

In the digital sanctum, our processors hum. We summon Python, R, and MATLAB—our trusty familiars. With incantations of "for loops" and "if statements," we traverse arrays and matrices. We simulate beamforming scenarios, tweaking parameters like alchemists adjusting elixirs. Our code snippets harbor typos, like hidden runes [15].

3. Hybrid Musings:

Within the intricate tapestry of 5G beamforming, we weave a hybrid approach! Part analog, part digital—a chimera of elegance. We blend real-world measurements with simulated dreams. Our antennas bow to both theory and practice. We calculate array gains, phase shifts, and beam widths [14], [16].

Simultaneously, in the digital ether, simulations unfold. Multi-user mMIMO scenarios dance with configurable geometries. We explore the impact of variables—the user count, antenna configurations, and modulation schemes. Our laptops glow, revealing the spectral efficiency of the waltz and channel capacity of the channel [14].

In conclusion, our data analysis rituals—statistical, computational, and hybrid—endorse the path towards 5G enlightenment.

IV. EXPECTED RESULTS

A. THEORETICAL CONTRIBUTIONS 1. Advancements in Beamforming Theory:

Precise Channel Modeling: Our theoretical work refines channel models, accounting for real-world

complexities like non-line-of-sight scenarios and dynamic environments. By capturing multipath propagation and fading effects, we enhance our predictions of signal strength and spatial characteristics [6].

Optimal Beamforming Algorithms: We anticipate novel algorithms—whether based on singular value decomposition (SVD), maximum likelihood estimation (MLE), or convex optimization. These algorithms adapt antenna weights to maximize signal quality while minimizing interference [6].

Massive MIMO and Hybrid Beamforming: Our contributions extend to massive multiple-input, multiple-output (MIMO) systems. We explore spatial multiplexing limits, array size considerations, and energy efficiency. Hybrid beamforming, harmonizing analog, and digital domains, remains a focal point [17].

B. PRACTICAL IMPLICATIONS 1. Transforming 5G Network Performance:

Speed and Capacity Boost: Beamforming enhances data rates by focusing energy on users. Dynamic beam tracking ensures seamless handoffs, reducing latency. Expect faster downloads, smoother video streaming, and responsive applications [7].

Coverage Enhancement: Directional beams extend coverage to challenging areas—urban canyons, indoor spaces, and rural expanses. Reduced interference translates to broader network reach, bridging digital divides [7].

Reliability and Energy Efficiency: Precise beamforming minimizes interference, enhancing reliability. Massive MIMO arrays improve link robustness. Reduced power consumption benefits both users and the environment [7].

Network Slicing and QoS Customization: Beamforming facilitates network slicing—customized virtual networks for diverse services. Each slice receives tailored quality of service (QoS), optimizing resource allocation [7].

In conclusion, theoretical strides empower practical leaps in 5G network performance. As we unravel beamforming's intricacies, may our references guide us toward a connected future.

V. CONCLUSION: ILLUMINATING THE PATH AHEAD

In the vast expanse of wireless communication, where signals traverse invisible highways, beamforming emerges as a guiding star. Our research proposal, like a compass needle, points toward uncharted territories—5G networks and their transformative potential.

A. THE IMPORTANCE OF BEAMFORMING

Precision in Signal Delivery: Beamforming transcends mere signal transmission. It is an art—a symphony of phased arrays and adaptive weights. By directing energy toward users, we unlock faster data rates, reduced interference, and seamless handoffs.

Coverage Beyond Boundaries: Directional beams pierce through urban canyons, penetrate indoor spaces, and stretch across rural landscapes. They bridge gaps, connecting the disconnected.

Reliability and Efficiency: Beamforming ensures robust connections, critical for emergency services and IoT devices. Simultaneously, it treads lightly on the planet, minimizing energy consumption.

B. THE POTENTIAL IMPACT

Speeding Toward Tomorrow: Imagine 5G networks where downloads happen in the blink of an eye, video streams flow seamlessly, and applications respond instantly. Beamforming accelerates this reality.

Coverage as a Universal Right: Beamforming extends its embrace to every corner—urban high-rises, remote villages, and underground tunnels. It democratizes connectivity.

A Greener Horizon: Reduced interference means efficient spectrum utilization. Beamforming contributes to energy savings, aligning with our environmental aspirations.

Customized Networks: Network slicing, guided by beamforming, tailors virtual networks for diverse services. Autonomous vehicles, smart factories, telemedicine—they all find their niche.

As we embark on this journey, our references—those scholarly companions—illuminate our path. Springer, IEEE, and the collective wisdom of researchers guide us. Let us unravel the enigma, one beam at a time.

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Applications and Challenges of Artificial Neural Networks in Autonomous Vehicle Technology

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Abstract *—This report explores the application of Artificial Neural Networks (ANN) in autonomous vehicles, focusing on their role in perception, decision-making, and control systems. The analysis is based on recent research and developments, highlighting the advantages and challenges of integrating ANN in autonomous driving technology.*

Keywords *—**ANN, AV, Perception, decision making, CNN***

I. INTRODUCTION

Autonomous vehicles (AVs) represent one of the most transformative advancements in modern transportation technology. These vehicles, capable of navigating and operating without human intervention, promise to revolutionize the way we travel, offering significant benefits in terms of safety, efficiency, and convenience. At the heart of this technological revolution are Artificial Neural Networks (ANNs), which play a crucial role in enabling AVs to perceive their environment, make informed decisions, and execute precise control actions.

ANNs are particularly well-suited for the perception tasks required in AVs. Perception involves the ability to interpret data from various sensors, such as cameras, radar, and LiDAR, to create a comprehensive understanding of the vehicle's surroundings. Convolutional Neural Networks (CNNs), a type of ANN, have proven to be highly effective in processing visual data, allowing AVs to detect and recognize objects such as other vehicles, pedestrians, and traffic signs with high accuracy. This capability is essential for safe navigation and collision avoidance.

In addition to perception, ANNs are integral to the decision- making processes of AVs. Decision-making involves determining the optimal path for the vehicle to follow, predicting the behavior of other road users, and making real- time adjustments to the vehicle's trajectory. Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks are commonly used in these applications due to their ability to handle sequential data and predict future states based on past information. These networks enable AVs to anticipate potential hazards and make proactive decisions to ensure safe and efficient travel.

Control systems in AVs also benefit significantly from the application of ANNs. Control involves the execution of actions such as steering, acceleration, and braking to follow the planned path and respond to dynamic changes in the environment. Deep Reinforcement Learning (DRL), a subset of ANN techniques, is used to optimize control strategies by learning from interactions with the environment. This approach allows AVs to improve their performance over time, adapting to new scenarios and enhancing overall driving efficiency.

Despite the significant advancements in ANN technology, several challenges remain in the deployment of ANNs in AVs. One of the primary

concerns is the lack of explainability and transparency in ANN-based systems. Understanding how these networks arrive at their decisions is crucial for building trust and ensuring safety. Additionally, the computational demands of ANNs pose a challenge for real-time applications, necessitating the development of more efficient architectures and hardware accelerators. Ensuring the robustness and safety of ANN-based systems is also critical, requiring rigorous testing and validation to prevent failures in diverse and unpredictable driving scenarios.

Therefore, Artificial Neural Networks are a cornerstone of autonomous vehicle technology, enabling advanced perception, decision-making, and control capabilities. While challenges remain, ongoing research and technological advancements continue to enhance the performance and reliability of ANN- based systems in AVs, bringing us closer to a future where autonomous vehicles are a common sight on our roads.

II. PERCEPTION SYSTEMS

Perception systems are fundamental to the operation of autonomous vehicles, enabling them to interpret and understand their surroundings. These systems utilize a variety of sensors, including cameras, radar, and LiDAR, to gather data about the environment. Artificial Neural Networks (ANNs) play a crucial role in processing this sensor data, allowing the vehicle to detect and recognize objects, understand the road layout, and identify potential hazards. By integrating information from multiple sensors, perception systems create a comprehensive and accurate representation of the vehicle's surroundings, which is essential for safe and efficient navigation.

A. Object Detection and Recognition

Object detection and recognition are critical components of the perception systems in autonomous vehicles (AVs). These tasks involve identifying and classifying objects within the vehicle's environment, such as other vehicles, pedestrians, traffic signs, and obstacles. The ability to accurately detect and recognize these objects is essential for safe and efficient navigation [1].

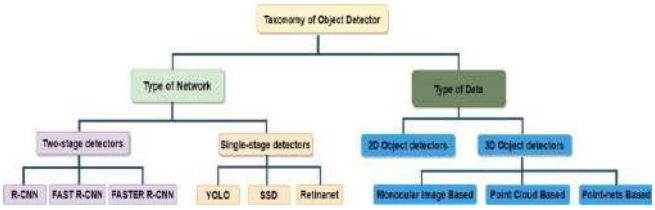

Fig 1. Taxonomy of object detectors [6]

1) Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) are the backbone of modern object detection systems in AVs. CNNs are particularly effective in processing visual data from cameras and LiDAR sensors. They consist of multiple layers that automatically learn to extract features from raw input data. These features are then used to identify and classify objects. The hierarchical structure of CNNs allows them to detect complex patterns and shapes, making them ideal for object detection tasks [1].

2) Two-Stage and Single-Stage Detectors

There are two main approaches to object detection: two- stage detectors and single-stage detectors. Two-stage detectors, such as Faster R-CNN, first generate region proposals and then classify these regions. This approach is highly accurate but computationally intensive. Single-stage detectors, such as YOLO (You Only Look Once) and SSD (Single Shot MultiBox Detector), perform detection and classification in a single step, making them faster but slightly less accurate. Both approaches have their advantages and are used depending on the specific requirements of the AV system [1], [2].

3) Real-Time Object Detection

Real-time object detection is crucial for AVs, as they need to process and respond to their environment instantaneously. Techniques such as MobileNets and EfficientDet have been developed to optimize CNNs for real-time performance without significantly compromising accuracy. These models use lightweight architectures and efficient operations to reduce computational load, enabling real-time object detection on embedded systems [2]. Significant challenge. Researchers are continuously working on improving the robustness of object detection algorithms to handle these challenges.

5) Integration with Other Sensors

Object detection systems in AVs often integrate data from multiple sensors to improve accuracy and reliability. For example, combining data from cameras and LiDAR sensors can provide both visual and depth information, enhancing the detection and classification of objects. Sensor fusion techniques, which will be discussed in the next section, play a crucial role in this integration [2].

6) Applications in Autonomous Driving

Object detection and recognition are applied in various aspects of autonomous driving. For instance, detecting and recognizing traffic signs and signals is essential for obeying traffic rules. Identifying pedestrians and other vehicles is crucial for collision avoidance and safe navigation. Additionally, object detection is used in advanced driver assistance systems (ADAS) to provide features such as automatic emergency braking and lane-keeping assistance.

In summary, object detection and recognition are vital for the perception systems of autonomous vehicles. Convolutional Neural Networks (CNNs) form the foundation of these systems, enabling accurate and real-time detection of objects. Despite challenges such as varying lighting conditions and occlusion, continuous advancements in object detection algorithms and integration with other sensors are enhancing the capabilities of AVs.

B. Sensor Fusion

Sensor fusion is a critical technology in autonomous vehicles, enabling the integration of data from multiple sensors to create a comprehensive and accurate representation of the vehicle's environment. By combining information from various sensors, such as cameras, radar, and LiDAR, sensor fusion enhances the reliability and robustness of perception systems [3].

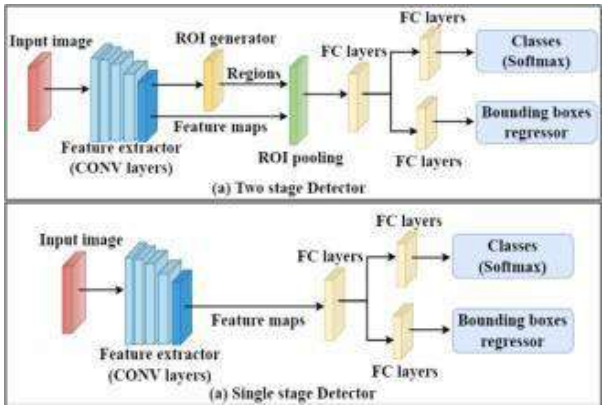

Fig 2. Two-stage vs Single stage object detector diagram [6]

4) Challenges in Object Detection

Despite significant advancements, object detection in AVs faces several challenges. One major challenge is dealing with varying lighting conditions, such as low light or glare from the sun. Another challenge is detecting objects in adverse weather conditions, such as rain, fog, or snow. Additionally, occlusion, where objects are partially obscured by other objects, poses a

1) Types of Sensors

Autonomous vehicles use a variety of sensors to perceive their surroundings. Cameras provide high-resolution visual information, which is essential for tasks such as object detection and lane recognition. Radar sensors measure the distance and speed of objects, making them useful for detecting moving objects and estimating their velocity. LiDAR sensors generate detailed 3D maps of the environment by measuring the time it takes for laser pulses to reflect off objects. Each sensor has its strengths and weaknesses, and sensor fusion leverages the complementary capabilities of these sensors.

2) Sensor Fusion Techniques

There are several techniques for sensor fusion, each with its advantages and applications. One common approach is Kalman filtering, which combines sensor measurements to estimate the state of the vehicle and its environment. Kalman filters are particularly effective for fusing data from sensors with different update rates and noise characteristics. Another approach is particle filtering, which uses a set of particles to represent the probability distribution of the vehicle's state. Particle filters are well-suited for handling non-linear and non-

Gaussian processes.

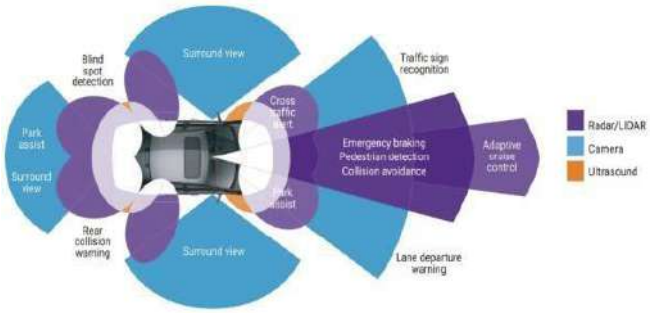

Fig.3. Car radar system

3) Deep Learning for Sensor Fusion

Deep learning techniques are increasingly being used for sensor fusion in autonomous vehicles. Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) can be trained to fuse data from multiple sensors and generate a unified representation of the environment. These networks can learn complex relationships between sensor inputs and improve the accuracy of perception systems. For example, a deep learning model can combine visual data from cameras with depth information from LiDAR to enhance object detection and classification.

4) Challenges in Sensor Fusion

Sensor fusion in autonomous vehicles faces several challenges. One major challenge is sensor calibration, which involves aligning the data from different sensors to a common reference frame. Accurate calibration is essential for ensuring that the fused data is reliable and consistent. Another challenge is dealing with sensor failures or malfunctions. Robust sensor fusion algorithms must be able to detect and compensate for faulty sensor data to maintain the reliability of the perception system.

5) Applications of Sensor Fusion

Sensor fusion is applied in various aspects of autonomous driving. For instance, it is used in simultaneous localization and mapping (SLAM) to create accurate maps of the environment and track the vehicle's position. Sensor fusion also enhances object detection and tracking by combining data from multiple sensors to improve accuracy and reduce false positives. Additionally, sensor fusion is used in advanced driver assistance systems (ADAS) to provide features such as adaptive cruise control and collision avoidance.

6) Future Directions

The future of sensor fusion in autonomous vehicles lies in the development of more advanced algorithms and the integration of new sensor technologies. Researchers are exploring the use of machine learning techniques to improve sensor fusion and develop more robust perception systems. Additionally, the integration of new sensors, such as thermal cameras and ultrasonic sensors, can provide additional information and enhance the capabilities of autonomous vehicles. Continuous advancements in sensor fusion technology will play a crucial role in the development of safe and reliable autonomous driving systems [2].

III. DECISION-MAKING SYSTEMS

Decision-making systems are a crucial component of autonomous vehicles, enabling them to navigate complex environments and make real-time decisions. These systems process information from perception systems and use it to determine the optimal path, predict the behavior of other road users, and execute safe and efficient maneuvers. Artificial Neural Networks (ANNs) play a significant role in enhancing the decision-making capabilities of autonomous vehicles by learning from vast amounts of data and adapting to dynamic driving conditions[4].

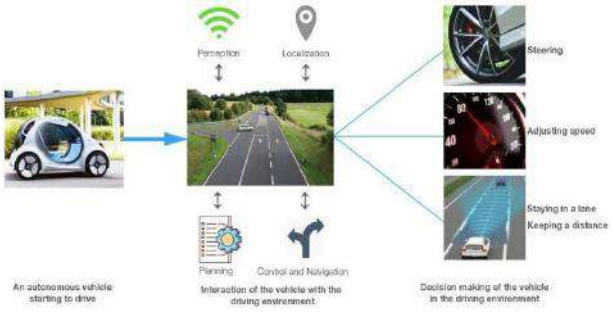

Fig 4. A general structure of AI-driven decision making of an autonomous vehicle in its driving environment. [7]

A. Path Planning

Path planning is a critical component of the

decision-making systems in autonomous vehicles (AVs). It involves determining the optimal route for the vehicle to follow, considering various factors such as road conditions, traffic, and safety. The goal of path planning is to ensure that the vehicle navigates efficiently and safely from its current position to its destination. Artificial Neural Networks (ANNs) play a significant role in enhancing the path planning capabilities of AVs by leveraging their ability to learn from data and adapt to dynamic environments [4].

ANNs are used in path planning to process complex and high-dimensional data, enabling the vehicle to make informed decisions in real-time. They can learn from vast amounts of driving data, capturing patterns and behaviors that are essential for effective navigation. By training on diverse datasets, ANNs can generalize to new and unseen scenarios, making them robust and adaptable to various driving conditions [2], [4].

Types of Neural Networks Used

Different types of neural networks are employed in path planning, each suited to specific tasks. Convolutional Neural Networks (CNNs) are used for processing visual data from cameras, helping the vehicle understand the road layout and detect obstacles. Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks are particularly useful for modeling temporal dependencies, allowing the vehicle to predict future states based on past information. These networks can anticipate the movement of other vehicles and pedestrians, enabling the AV to plan its path accordingly.

One of the strengths of ANNs in path planning is their ability to adapt in real-time. Autonomous vehicles operate in dynamic environments where conditions can change rapidly. ANNs continuously process sensor data, such as camera feeds, radar, and LiDAR, to update their understanding of the surroundings. This real-time adaptation is crucial for handling unexpected events, such as sudden lane changes by other vehicles or obstacles appearing on the road.

In complex traffic scenarios, AVs must interact with multiple agents simultaneously. ANNs can model these interactions and predict the behavior of each agent. This capability allows the vehicle to navigate safely and efficiently, even in dense traffic. For instance, the network can predict the intentions of nearby vehicles and adjust the path to avoid potential conflicts.

B. Behavior Prediction

Behavior prediction is an essential component of the decision-making systems in autonomous vehicles (AVs). It involves forecasting the actions of other road users, such as vehicles, pedestrians, and cyclists, to ensure safe and efficient navigation. Accurate behavior prediction allows AVs to make informed decisions and avoid potential collisions. Artificial Neural Networks (ANNs) play a pivotal role in enhancing the behavior prediction capabilities of AVs by learning from extensive datasets and adapting to dynamic environments [1].

ANNs are used in behavior prediction to process complex and high-dimensional data, enabling the vehicle to anticipate the actions of other road users. By training on diverse datasets, ANNs can learn patterns and behaviors that are essential for accurate prediction. This capability allows AVs to make proactive decisions and navigate safely in various driving conditions. Different types of neural networks are employed in behavior prediction, each suited to specific tasks. Convolutional Neural Networks (CNNs) are used for processing visual data from cameras, helping the vehicle understand the behavior of other road users. Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks are particularly useful for modeling temporal dependencies, allowing the vehicle to predict future actions based on past information. These networks can anticipate the movement of other vehicles and pedestrians, enabling the AV to make informed decisions [1].

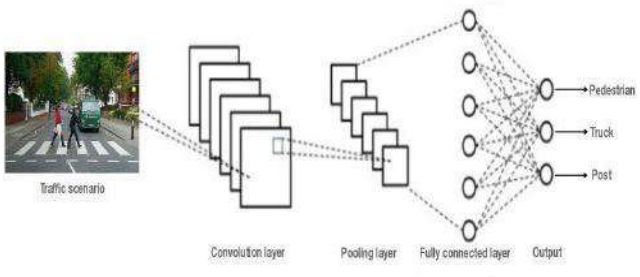

Fig.5. CNN for object classification in a real-time traffic scenario.

IV. CONTROL SYSTEMS

Control systems in autonomous vehicles (AVs) are responsible for executing the decisions made by the perception and decision-making systems. These systems manage the vehicle's acceleration, braking, and steering to ensure safe and efficient navigation. Control systems rely on a combination of sensor data, algorithms, and actuators to maintain vehicle stability and respond to dynamic driving conditions. Advanced control strategies, such as Model Predictive Control (MPC) and Deep Reinforcement Learning (DRL), are employed to optimize vehicle performance. These strategies enable AVs to handle complex maneuvers, such as lane changes, obstacle avoidance,

and emergency braking. The integration of control systems with perception and decision-making systems is crucial for achieving high levels of autonomy and ensuring the safety and reliability of AVs.

A. Vehicle Dynamics Control

Vehicle dynamics control is a critical aspect of autonomous vehicle operation, focusing on maintaining vehicle stability and handling. This involves managing the forces acting on the vehicle, such as traction, braking, and steering, to ensure smooth and safe driving. Advanced control algorithms, such as Model Predictive Control (MPC), are used to predict the vehicle's future states and optimize control actions accordingly. MPC considers various constraints, such as vehicle dynamics, road conditions, and safety margins, to generate optimal control inputs. By continuously adjusting the vehicle's speed and direction, MPC helps maintain stability and improve handling, especially in challenging driving conditions.

Deep Reinforcement Learning (DRL) is another technique used in vehicle dynamics control. DRL algorithms learn from interactions with the environment to optimize control strategies. These algorithms can adapt to different driving scenarios and improve performance over time. For example, DRL can be used to optimize the vehicle's braking and steering responses during emergency maneuvers, ensuring that the vehicle remains stable and avoids collisions. The integration of DRL with traditional control algorithms enhances the robustness and adaptability of vehicle dynamics control systems [4].

Sensor fusion plays a crucial role in vehicle dynamics control by providing accurate and reliable data about the vehicle's state and surroundings. By combining data from multiple sensors, such as cameras, radar, and LiDAR, sensor fusion algorithms create a comprehensive understanding of the environment. This information is used to inform control decisions and ensure that the vehicle responds appropriately to changing conditions. For instance, sensor fusion can help detect slippery road surfaces and adjust the vehicle's speed and braking accordingly to maintain stability [4].

Vehicle dynamics control is essential for maintaining stability and handling in autonomous vehicles. Advanced control algorithms, such as Model Predictive Control and Deep Reinforcement Learning, optimize control actions and improve performance in various driving conditions. Sensor fusion enhances the accuracy and reliability of vehicle dynamics control systems, ensuring safe and efficient navigation).

B. Energy Efficiency and Trajectory Tracking

1) Energy Efficiency

Enhancing energy efficiency is a crucial objective for autonomous vehicles (AVs). Artificial Neural Networks (ANNs) significantly contribute to this goal by optimizing the vehicle's power usage. These networks manage energy resources by analyzing real-time data from various sensors, such as speed, acceleration, and road conditions. By processing this information, ANNs can predict the vehicle's energy requirements under different driving scenarios [3].

ANNs employ predictive modeling to forecast future driving conditions, allowing the vehicle to adjust its energy

consumption proactively. For instance, if the network anticipates heavy traffic or steep inclines, it can modify the vehicle's speed and power distribution to conserve energy. This adaptability ensures that the vehicle operates efficiently, regardless of the driving environment.

Moreover, ANNs implement adaptive control strategies that dynamically allocate power between the engine, battery, and other components. This real-time adjustment helps maintain optimal energy usage during various driving phases, such as acceleration, cruising, and braking. By continuously

learning from diverse driving conditions, ANNs refine their energy management techniques, leading to more sustainable and eco- friendly transportation solutions. This continuous improvement not only extends the vehicle's range but also reduces overall energy consumption, contributing to a greener future [3].

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

2) Trajectory tracking:

Is a fundamental function of control systems in autonomous vehicles, ensuring that the vehicle follows a planned path accurately. This involves continuously adjusting the vehicle's steering, acceleration, and braking to stay on the desired trajectory. Accurate trajectory tracking is crucial for safe navigation, especially in complex environments with tight curves, intersections, and obstacles.

Trajectory tracking is therefore a critical function of control systems in autonomous vehicles, ensuring accurate and safe navigation. Advanced control algorithms, such as Model Predictive Control and Deep Reinforcement Learning, optimize control actions and improve performance in various driving conditions. Sensor fusion enhances the accuracy and reliability of trajectory tracking systems, ensuring that the vehicle follows the planned path accurately and safely [3], [4], [5].

V. CONCLUSION

The deployment of Artificial Neural Networks (ANNs) in autonomous vehicles (AVs) presents several challenges that need to be addressed to ensure safe and reliable operation. These challenges include explainability and transparency, computational efficiency, robustness and safety, and the integration of new technologies. Addressing these challenges is crucial for advancing the capabilities of AVs and achieving widespread adoption [1], [3], [4].

The integration of new technologies, such as 5G communication and edge computing, presents opportunities and challenges for AVs. 5G communication can provide high-speed, low-latency connectivity, enabling AVs to exchange data with other vehicles and infrastructure in real-time. This can enhance the situational awareness and decision-making capabilities of AVs. Edge computing, on the other hand, allows data processing to be performed closer to the source, reducing latency and improving response times. Integrating these technologies with ANN-based systems requires addressing challenges related to data security, privacy, and interoperability.

Artificial Neural Networks are a cornerstone of autonomous vehicle technology, enabling advanced perception, decision- making, and control capabilities. While challenges remain, ongoing research and technological advancements continue to enhance the performance and reliability of ANN-based systems in AVs. Addressing these challenges is crucial for achieving widespread adoption of AVs and realizing the potential benefits of autonomous driving technology. As the field continues to evolve, the integration of ANNs with new technologies and the development of robust and explainable AI techniques will play a key role in shaping the future of autonomous vehicles.

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Perceptions of Undergraduate Nursing Students Towards Simulation-Based Learning: A Cross-Sectional Study

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Abstract *— This study aimed to assess the perception levels of undergraduate nursing students toward Simulation-Based Learning in Nursing and to examine the association between perception levels and demographic characteristics. A non-experimental, cross-sectional quantitative design was employed, involving 171 undergraduate nursing students from selected institutions in Vellore and Dharmapuri Districts of Tamil Nadu. Participants were selected using a purposive sampling technique, and data were collected using a structured self-report instrument based on the Simulation Perception Scale. The data analysis included descriptive statistics and chi-square tests for association at a 0.05 significance level. Results indicated that students demonstrated a favourable perception toward SBL, with 75.22% of participants reporting a positive view. The highest mean score was noted in the domain of Use and Effectiveness of Simulation (Mean % = 84.4), followed by Technological Integration (76.2%). Institutional Support scored moderately (68.0%), while Perceived Barriers scored the lowest (48.2%). No statistically significant association was found between perception levels and demographic variables such as age, gender, year of study, or prior exposure to simulation ($p > 0.05$). Overall, students exhibited a generally positive perception towards Simulation-Based Learning in Nursing. The findings emphasize the importance of integrating simulation into nursing education to enhance learning outcomes. Continued efforts are required to address perceived barriers and improve institutional support for effective implementation of simulation-based strategies in nursing education.*

Keywords *— **Simulation-Based Learning, Nursing Education, Student Perception, Technological Integration, Perceived Barriers***

I. BACKGROUND

The increasing complexity of healthcare delivery demands that nursing education equips students with not only theoretical knowledge but also practical skills and clinical judgment applicable to diverse, real-world environments. Simulation-Based Learning (SBL) has become an essential instructional strategy in nursing curricula worldwide, offering experiential learning through realistic scenarios that enhance students' competence, confidence, and critical thinking without risking patient safety [(1)]. Particularly in Nursing, where nurses play vital roles in health promotion, disease prevention, and managing public health challenges, simulation allows

learners to engage with complex situations such as home visits, health screenings, and culturally sensitive care provision.

Recent studies highlight the positive impact of simulation on nursing students' skill development and preparedness for clinical practice in community settings demonstrated improved readiness among nursing students to handle Maternal and neonatal emergencies in primary care through simulation-based training [2]. Similarly, it was found that immersive community health simulations fostered better communication skills and decision-making abilities (3). These findings align with global trends emphasizing simulation as a bridge between classroom learning and practical application, especially where direct community exposure may be limited due to logistical or public health constraints.

Despite its recognized benefits, students' perceptions of SBL vary, influenced by factors such as faculty support, technological access, and anxiety related to performance in simulated environments. Moreover, limited research has specifically addressed undergraduate nursing students' attitudes toward SBL which requires holistic and context-sensitive approaches. [4]

Understanding students' perceptions is critical, as positive attitudes toward simulation correlate with greater engagement, motivation, and improved learning outcomes. Therefore, this study aims to assess the perceptions of undergraduate nursing students regarding Simulation-Based Learning in Nursing, exploring their perceptions including facilitators and barriers, and examining whether their background variables influence these perceptions. The findings are expected to inform curriculum development and optimize simulation strategies for Nursing education. [5]

Simulation-Based Learning (SBL) has emerged as a pivotal pedagogical tool in nursing education, offering safe, controlled, and realistic environments for students to practice clinical skills and decision-making without endangering patients. With the evolving demands of healthcare and the increasing complexity of nursing curriculum scenarios, there is a growing emphasis on preparing nursing students for diverse, population-centered roles beyond hospital settings. SBL is particularly relevant in Nursing, where students must assess, intervene, and educate within dynamic, resource-limited, and culturally varied environments [1].

Recent literature underscores the effectiveness of SBL in improving clinical competence, communication, and critical thinking among nursing students. For instance, reported that simulation enhanced students' readiness to manage maternal and neonatal emergencies within primary care settings, particularly in rural contexts [2]. In South Korea found that community-based simulations strengthened students' confidence in conducting health assessments and providing education in non-hospital environments [3].

Incorporating simulation in nursing curricula also supports students' development of public health competencies, including teamwork, cultural sensitivity, and health promotion strategies. The use of immersive technologies and virtual simulations in community scenarios improved student engagement and adaptability, especially during the COVID-19 pandemic, when clinical placements were restricted [6].

Despite these benefits, perceptions toward SBL can vary based on exposure, institutional support, and technological infrastructure. While many students view simulation positively, others may experience challenges such as technical barriers, anxiety, or inadequate debriefing [4]. Furthermore, limited research has focused specifically on students' perceptions of SBL in the context of Nursing, where patient interactions, health promotion, and systems thinking differ markedly from acute care settings.

Understanding students' perceptions is crucial to refining simulation practices and ensuring their effectiveness. Positive attitudes often correlate with increased engagement and learning outcomes [5]. Hence, this study aimed to explore undergraduate nursing students' perceptions of SBL in Nursing, identify perceived benefits and barriers, and assess the influence of demographic factors on their views.

II. METHODOLOGY

This study adopted a non-experimental, cross-sectional design with a quantitative research approach. The research was conducted in selected nursing colleges located in Vellore and Dharmapuri

District of Tamil Nadu. The target population for this study consisted of undergraduate nursing students enrolled in selected nursing colleges in Vellore and Dharmapuri Districts of Tamil Nadu. These students, from various year of the nursing program, were included to capture diverse perceptions of Simulation-Based Learning (SBL) as a learning tool within their academic curriculum. A purposive sampling technique was used to select students.

The inclusion criteria

- Enrolment in the second, third or fourth year of the B.Sc. Nursing program.
- Willingness to participate and provide informed consent.

This included 58 students from the 2rd year and 57 from 3rd year, 56 students from 4th year B.Sc., Nursing Programme total 171 students participated in the study. This approach facilitated a appropriate representation of perceptions across the different groups while minimizing potential biases.

III. TOOL DEVELOPMENT

The two parts of the tool are:

Tool I: Background data, including: Age, gender, year of study, prior exposure to Simulation-Based Learning (SBL) in Nursing and the type of simulation used.

Tool II: **Simulation Perception Scale for Nursing Students** is a structured, self-report assessment tool designed to evaluate undergraduate nursing students' perceptions regarding the use, effectiveness, barriers, technological integration, and institutional support related to simulation-based learning in Community Health Nursing, which was slightly modified to use in this study. The scale consists of 25 items divided into four key domains: Use and Effectiveness of Simulation (6items), Perceived Barriers (6 items), Technological Integration and Trends (5 items), and Institutional/Pedagogical Support (8 items). Each item is rated on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), with negatively phrased items (Items 7–12) reverse scored to ensure accurate interpretation of attitudes. Obtainable score is 25-125. Reliability of the tool achieved a Cronbach's Alpha of 0.8**,** indicating good internal consistency.

3.1 Subscale Score Ranges:

- Use & Effectiveness (Items 1–6): min 6, max 30
- Perceived Barriers (Items 7–12, reverse-scored): min 6, max 30
- Technology Integration (Items 13–17): min 5, max 25
- Institutional Support (Items 18–25): min 8, max 40

IV. DATA COLLECTION

Data is collected through self-administration method using Google forms through WhatsApp and E mails.

V. ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Institutional Ethics Committee of the lead investigator's college. Written informed consent was secured from all participants, ensuring confidentiality, anonymity, and voluntary participation. Participants were informed that they could withdraw from the study at any time without penalty.

VI. DATA ANALYSIS

Data were entered and analyzed using IBM SPSS version 26.0. Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarize responses. Inferential statistics including the Chi-square test was applied to examine associations between demographic variables and students' perceptions of SBL. A significance level of $p < 0.05$ was considered statistically significant.

VII. RESULTS

Background Profile of Participants

Table 1: Frequency and Percentage Distribution of Background Variables of Nursing Students. (N = 171)

Background Variables	Category	Frequency (f)	Percentage (%)
Age (in Years)	20-22	118	69.01
	> 22	53	30.99
Gender	Male	14	8.19
	Female	157	91.81
Year of Study	II year	58	33.92
	III Year	57	33.33
	IV Year	56	32.75
Prior Exposure to Simulation	Yes	122	71.35
	No	49	28.65

Table 1, reveals that the background profile of the 171 nursing students. Results shows that the majority (69.01%) are between 20 and 22 years old, with the remaining 30.99% being older than 22 years. Females overwhelmingly represent the sample, comprising 91.81%, while males account for only 8.19%. The students are fairly evenly distributed across the years of study, with approximately one-third in each of the second (33.92%), third (33.33%), and fourth years (32.75%). Most of the students (71.35%) reported prior exposure to simulation-based learning, indicating its prevalent use in their curriculum.

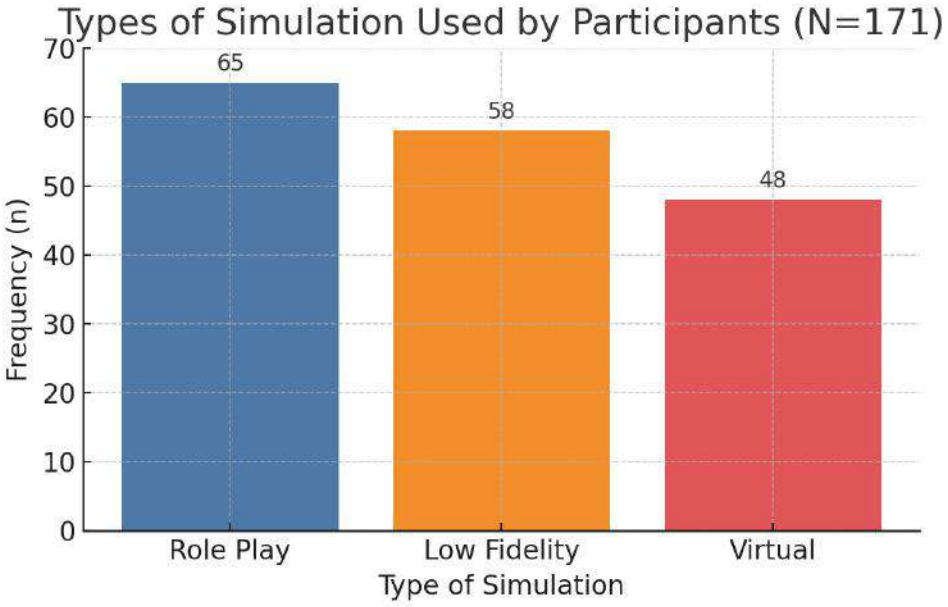

Fig.1.Types of Simulation Used by Participants.

Table 2: The Perception Levels on Simulation-Based Learning in Nursing Among Nursing Students.

(N=171)

Domain	Obtainable score	Min Score	Max score	Mean	Mean %	SD
Use & Effectiveness of Simulation	6-30	16	26	25.32	84.4	0.51
Perceived Barriers	6-30	10	20	14.46	48.2	0.67
Technological Integration	5-25	13	23	19.05	76.2	0.58
Institutional Support	8-40	20	30	27.20	68.0	0.62
Global score	**25-125**	**59**	**99**	**86.03**	**68.8**	**2.21**

The findings presented in Table 2 indicate that undergraduate nursing students hold an overall moderately positive perception towards Simulation-Based Learning (SBL) in Nursing. The highest mean percentage (84.4%) was observed in the domain of *Use and Effectiveness of Simulation*, suggesting that students strongly value the role of simulation in enhancing their understanding and application of community health concepts. The domain of *Technological Integration* also received a favourable response (76.2%), highlighting students' appreciation for the integration of digital tools and platforms in simulation learning. The domain of *Institutional Support* showed a comparatively lower mean percentage (68.0%), indicating a need for improved infrastructural and administrative backing to optimize the simulation experience. The domain of *Perceived Barriers* recorded the lowest mean percentage (48.2%), suggesting that students encounter several challenges, such as limited access to resources, time constraints, or insufficient faculty support, which may hinder the effectiveness of simulation-based learning. The global mean score of 86.03 (68.8%) reflects a generally encouraging perception and underscores the importance of addressing existing barriers and strengthening institutional support to fully realize the benefits of simulation in Nursing education.

Table 3: Frequency and percentage distribution of the perception levels on simulation-based learning in Nursing among nursing students.

(N= 171)

Category	Range	Frequency	Percentage
Unfavourable Perception	1 – 41	0	0
Neutral Perception	42 – 83	43	24.78
Favourable Perception	84 – 125	128	75.22

Table 3 shows the frequency and percentage distribution of overall perception levels towards Simulation-Based Learning (SBL) in Nursing among 171 students. The results indicate that a majority of students (128 out of 171, or 75.22%) demonstrated a favourable perception (scores between 84–125), suggesting that most participants viewed simulation as a beneficial and effective learning method. A smaller proportion of students (43 or 24.78%) had a neutral perception (scores between 42-83), indicating moderate or mixed views about the value or impact of simulation. Importantly, none of the students fell into the unfavourable perception category (scores 1–41), reflecting the absence of strong negative attitudes toward simulation-based learning. Overall, these findings highlight a predominantly positive student response to the integration of simulation in Nursing education.

Table.4. Association Between the Background Variables and the Perception Levels on Simulation-Based Learning Among Nursing Students.

(N=171)

Demographic variables	Category	Favourable perception	Neutral perception	df	Chi-square	P value/ significance
Age (in Years)	20-22	59	59	1	0.32	P >0.05
	>22	24	29			NS
Gender	Female	76	81	1	0.01	P >0.05
	Male	7	7			NS
Year of study	II	29	29	2	0.51	P >0.05
	III	29	28			NS
	IV	25	31			
Previous exposure to simulation	Yes	60	62	1	0.07	P >0.05
	No	23	26			NS

*NS..No significance P<0.05 level

Table. 4 reveals that there was no statistically significant association found between students' levels of perceptions on simulation-based learning in Nursing and their demographic variables, including age, gender, year of study, and previous exposure to simulation ($p > 0.05$ for all comparisons). Students across different age groups (20–22 years and above 22), genders (male and female), academic years (II, III, and IV), and levels of prior simulation experience reported similar levels of favourable or neutral perception. These findings suggest that students' attitudes toward simulation-based learning are generally consistent, regardless of their background characteristics, indicating broad acceptance and perceived value of simulation as a teaching strategy in Nursing education.

VIII. DISCUSSION

The findings of the present study reveals that a significant majority of nursing students (75.22%) exhibited a favourable perception toward Simulation-Based Learning (SBL) in Nursing. This aligns with a growing body of recent evidence supporting simulation as a dynamic, experiential learning method. In particular, the "Use and Effectiveness of Simulation" domain was rated the highest (Mean = 4.22), highlighting the value students place on simulation in enhancing clinical judgment, decision-making, and the application of theoretical knowledge to community health settings. These findings are consistent with those of, who reported that simulation-based training significantly improved students' preparedness and clinical reasoning in public health scenarios among undergraduate nursing students in the Middle East (1). Similarly, a study in Chile confirmed that students perceived simulation as instrumental in boosting competence, especially in managing community and home-based care [7]. High scores in the "Institutional Support" domain (Mean = 4.03) reflect student appreciation for effective debriefing, skilled instructors, and respectful, inclusive simulation environments. This aligns with (3), who found that supportive faculty facilitation and structured debriefing enhanced reflective learning and critical thinking in Korean nursing students engaged in community-based simulations. In a 2024 qualitative study in Tanzania, emphasized the importance of skilled facilitators and safe learning spaces in enabling confidence and practical skill acquisition during neonatal simulation sessions [2].

Interestingly, this study found no statistically significant association between perception levels and

demographic variables such as age, gender, year of study, or prior simulation experience. These findings suggest that the benefits of simulation transcend student background, confirming the universal appeal and applicability of SBL. Similarly, a study reported consistent positive feedback among nursing students across different age groups and academic years during community health simulation programs in Latin America [8]. A study conducted in India also revealed uniform satisfaction across various student demographics, indicating that simulation is broadly accepted as an effective educational tool [5].

The lowest mean score was observed in the "Perceived Barriers" domain (14.46), which, after reverse scoring, indicates that students faced relatively few challenges. This supports the notion that improvements in simulation design have successfully mitigated common issues like performance anxiety, equipment failure, and time constraints. A recent study in Nigeria found a marked reduction in anxiety and discomfort when structured pre-briefing and psychological support were integrated into the simulation process. Additionally, emphasized that student-centered simulation environments significantly reduce emotional barriers and foster psychological safety [9].

Moderate scores in the "Technological Integration" domain (Mean = 19.05) suggest a general acceptance of tools such as virtual simulation, VR, and high-fidelity manikins, although some usability or accessibility issues remain. confirmed that while students appreciated the realism of virtual platforms, barriers such as unfamiliarity with devices or limited access to hardware affected full engagement. More recently, a study emphasized the need for better digital infrastructure and training to maximize the benefits of immersive technologies in Nursing education [6].

Overall, the results affirm the effectiveness of simulation-based learning in fostering essential competencies in Nursing. The consistently favourable perceptions across different student groups highlight simulation's universal value and its potential for broader integration into nursing curricula. Ongoing efforts to refine technological tools and reduce residual barriers will further strengthen the role of SBL as a cornerstone of nursing education.

Previous researches of the Author also has emphasized the importance and demonstrated the effectiveness of SBL[10,11] These findings underscore significant implications for both nursing practice and education. To enhance practice readiness, institutions must strengthen simulation infrastructure by investing in high-fidelity simulators and well-equipped labs that foster realism and preparedness. Faculty competence should be continually developed through training in simulation facilitation and debriefing, while the integration of virtual simulations, especially in resource-limited settings can expand access and engagement. Curricula should be revised to ensure adequate time and focus on simulation in Nursing, fostering essential public health competencies. In nursing education, structured simulation activities can bridge the theory-practice gap, and incorporating both virtual and high-fidelity technologies can offer scalable, realistic learning alternatives where clinical placements are scarce.

In the current era of technological advancement, where patients can access information from multiple sources, there is a growing need for alternative and integrated methods and blended to improve student learning. Consequently, keeping these in mind researchers from the same institution have previously examined a range of teaching-learning strategies (based on the current needs and circumstances), such as OSCE - Objective Structured Clinical Examination [12,13], Problem-Based Learning [14], Virtual Reality training [15], Bibliotherapy [16], and Neuro-Linguistic Programming. [17]

Previous studies also emphasized the importance of building strategies to empower the students that foster Self Esteem, [18] Emotional intelligence, [19] Self Confidence, [20] Creativity, [21] Mindfulness practice [22] and motivation [23] among students to maximize the learning outcome and achieve the goal. SBL when combined with diverse and need based motivational teaching learning strategies can positively influence and facilitate the overall learning outcome.

Therefore, Faculty development and students training on SBL and other innovative approaches remain crucial for effective strategies design and learner engagement, while a student-cantered learning approach promotes critical thinking, communication, and decision-making skills which

are relevant in Nursing. Finally, institutions must prioritize sustained investment in students learning including simulation resources and support systems to ensure the long-term quality and impact of nursing education.

IX. CONCLUSION

In conclusion, simulation-based learning is perceived as a valuable tool for enhancing undergraduate nursing education, particularly in Nursing. While students appreciate the effectiveness of simulations in improving their clinical skills and preparedness for community practice, barriers such as inadequate infrastructure, faculty training, and realism in scenarios must be addressed. This study had few limitations that may affect the interpretation and generalizability of findings. It was limited to selected institutions in two districts, with purposive sampling potentially introducing bias. Investing in simulation resources, faculty development, and virtual simulation technologies will help overcome these barriers and improve the overall quality of nursing education.

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Impact of Perceived Service Quality (PSQ) Elements on Client Satisfaction in Telecommunication Industry with Perceived Corporate Image as Mediator

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Abstract *— The main objective of this study is to determine the relationship between various PSQ (Perceived Service Quality) elements and customer satisfaction levels in the telecom business. In terms of customer satisfaction, the Corporate Image factor serves as a mediator between PSQ and CS. The conceptual model and the hypotheses that were drawn from the literature are put forth. Members of the target population telecom businesses were used, and questionnaires were used to collect data. The relationships between PSQ (Perceived Service Quality) and CS (Customer Satisfaction) are mediated by CI (Corporate Image), according to the data analysis results. There was a significant correlation found between customer satisfaction and the PSQ aspects of Tangibles, Reliability, Responsiveness, Assurance, and Empathy. The findings of this study recommend that telecom companies enhance the aspects of their service quality to raise customer satisfaction. Customers will become more loyal as a result, and businesses will be able to hold onto them for longer. A larger sample size may yield a more thorough analysis of this crucial issue.*

Keywords *— **Perceived service quality PSQ, Corporate Image (CI), Telecom, SERVPERF***

I. INTRODUCTION

QOS has attracted consideration of specialists past numerous many years. Due to its significance in CS, it has become an important subject. Quality characterized as essential portion of client insight about the help. By satisfying clients' necessities through top notch administration, business firms can hold their clients, as well as augmentation their market share [1]. Telecom industry has been under enormous strain to give quality offers and increment efficiencies. For a really long time, the public area specialist organization has ruled Pakistani telecom industry. However, the market is now highly competitive due to privatization and the emergence of new service providers.

Among other factors QOS has Proven as one of the important factor in increasing customer satisfaction level. Providing high quality service is important as it can contribute to positive image building of the company (Song, Ruan, and Park 2019).The main purpose of providing quality is to meet customer requirements.it also helps company to retain its customers and attract other potential customers .Previous study results also shown that better QOS helps building positive image of the company(Setiadi, Setiadi, and Rahayu 2016).

Although QOS is one of the factor to improve corporate image, it take time to build image of the company. Positive image of the company also helps customer to understand the product and it also reduce uncertainty in customers mind(Adeniji et al. 2014). According to Herbig and Mileicz corporate image is built on company's action and gestures towards customers. corporate image also effects customers

trust towards the company. The main aim of this research is to determine the influence of Perceive QOS element on corporate image by using SERVPERF tool(Setiadi, Setiadi, and Rahayu 2016).

II. LITERATURE REVIEW

PSQ

PSQ refers to the difference between Promised QOS and Actual QOS. It is also know as degree of difference between expectation and Perception. PSQ is one of the perfect driver for customer satisfaction. Customer satisfaction is one of the key strategic issue in service industry and is mostly customer driven or customer centered industry. The better they understand the customer needs, the more they can satisfy their customers and a satisfied customer can become a loyal customer(Izogo and Ogba 2015). Empirical literature review shows that QOS is reliant on purchasers' needs and desires, it represents whether the dimension of service addresses these desires or needs. As indicated by research, satisfaction is subject to numerous components including responsiveness, quality of tangible facilities, and empathy of staff to customer needs and requests. The accuracy of QOS and consistency to provide information plays an important role in building customer perception (Presbury et al. 2006) .

Majority of researchers believe that quality of service does not depend on a single attribute, it must have different dimensions on which overall quality can be measured. In this context, results of qualitative research (focus group) shows that customer pay little attention to the type of service while comparing QOS of different companies, for example customer does not care about how he gets his TV service but he is more concern about his favorite channel. After decades of work, Researchers developed SERQUAL model which states the five dimensions as tangibles, reliability, responsiveness, assurance, and empathy. It's unique and one of the most efficient tool to measure QOS (Alhaddad 2015). GAPQOS demonstrates discoveries based on exploratory research and it contains in-depth focus group interviews. Parasuraman analyzed the QOS model and proposed a gap model based on the findings of Gronross. According to Parasuraman, PSQ attributes are Tangibles, Reliability, Responsiveness, Assurance and Empathy (Journal and Gr 2016).

Due to its soundness and remarkable success, researchers prefer to use the SERVPERF scale for surveying QOS. The SERVPERF tool is also a useful research instrument when one is interested in QOS comparisons across service industries (Babic-Hodovic, Arslanagic-Kalajdzic, and Imsirpasic 2017). The SERVPERF technique uses factorial investigation to gauge service performance. A comparison study conducted in 2017 by Beyza Aydin to test difference in outcome using SERQUAL and SERPERF tool. Although results were as at dimensions level, the difference between them was that SERVPERF tool provides detail information about the dimensions and explain which part of dimension is important for customer satisfaction (Aydin(Beyza and Dokuz Eylul University, İzmir 2017) .

Tangibles are defined as physical equipment that are provided by the service provider and they can vary from service to service (D. A. G. A. Anantha Raj A. Arokiasamy 2015). Reliability is service provider 's ability to deliver the guaranteed service flawlessly and within a predefined period. Responsiveness is defined as service provider's ability to respond quickly and promptly. Regardless of whether clients are modest in returning to service provider, responsiveness is one important part of QOS assessment(Brady, Cronin, and Brand 2002). Assurance represents service provider's specialty; Service provider is supposed to be an expert in service they are providing. Sometimes service provider is providing service to its complete specifications, yet customer may not be satisfied and may not feel that service provider cares about it(Abkar 2017). Customer thinks service provider does not give due importance to it. disinterested (Pantouvakis and Chlomoudis n.d.).

CI(Corporate image)

CI is the customer's perception of the service provider and is usually known as buyer's view of service organization. Service provider image relies upon its specialization of quality, cost, interaction with customer, facility, competence and behavior of service provider's employees (Abd-Elrahman AEH (2018) 2018).Researchers defined corporate image repeatedly and used different methods to analyze its concept. Kaller defined corporate image as impression of

company that customer has in its mind and it reflects customer's interaction with company. A brand is said to have positive or negative client-based brand value. Corporate image is based on, company's attributes and it is defined as descriptive features that characterize a service or product (Keller 2013). The meaning of corporate image according to various concepts are different, for example, Fombrun defines CI as the image customer has of an organization through the collection of received messages. Intensive literature review show Kaller's definition more is relatable to corporate image and researchers like Dowling, Kazoleaz, and Kim also agree with Kaller's version of corporate image (Valaei and Rezaei 2016).Many Researchers defined corporate image difficult to measure as most of the parameters are intangible in nature. corporate image usually represents overall experience and reputation of the company(Adeniji et al. 2014). Customer asses his or her experience and nature of interaction with the company. Customer combine interaction, Product used , reputation and marketing values while building an image of the company(Tang 2007). Result of research shows that corporate image enhances customer loyalty and create trust between Customer and company(Hart and Rosenberger 2004). It is also important that management of the company always consider impact of their decision on corporate image(Moon 2007).

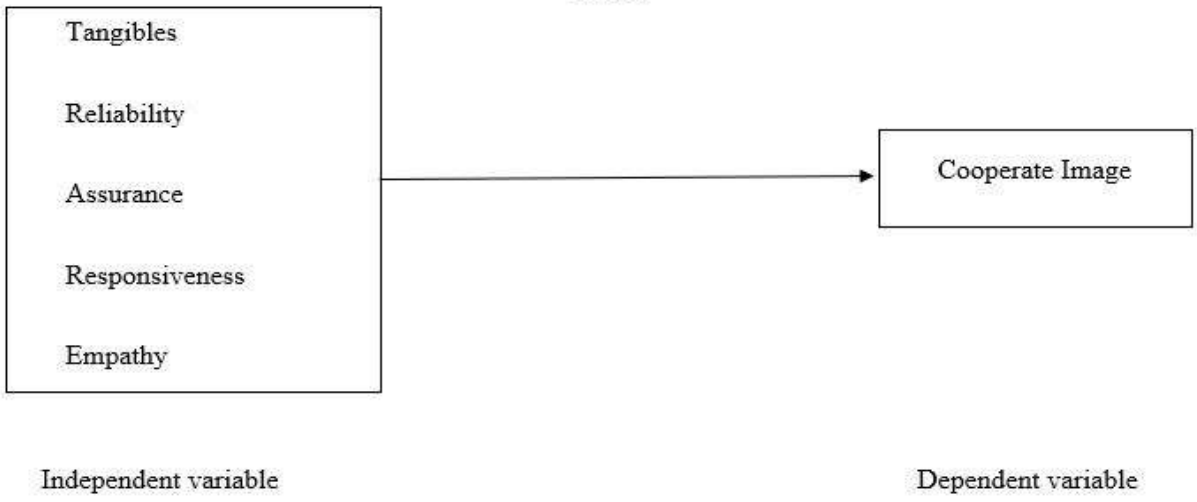
According to intensive research review, PSQ and corporate image are the factors on which service industry depends. Important dimensions of PSQ that work as independent variables are:

- Tangible(Ta).
- Reliability(RI).
- Assurance(AS).
- Responsiveness(RS).
- Empathy(EP).

Dependable variable:

- Cooperate Image(CI).

Model



Hypotheses

Tangibles (Ta) has significant impact on Corporate image (CI)

Reliability(RI) has significantly affects Corporate image (CI)

Responsiveness(Rs) has significant impact on Corporate image (CI)

Assurance (As) has significant affects on Corporate image (CI)

Empathy(EP) has significant impact on Corporate image (CI)

III. METHODOLOGY

This is a descriptive study based on quantitative data. The main aim is this study is to explore the factors of

PSQ effecting corporate image. The target population for telecom subscribers residing in Islamabad and Rawalpindi. To collect data customers of telecommunication companies were approached and questioners were distributed to collect data for analysis. convenient sampling technique was used to for sampling as adopted in (Journal, Sciences, and Al 2012), (Negi 2009), (Brady, Cronin, and Brand 2002).SPSS software was used for data analysis. Independent variables are measured using the SERVPERF scale adopted from the study(Taylor and Cronin 2015). Its 5 items are rated on 6-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (6).and for dependent variable (CI) . items scale adopted from the study(Babic-Hodovic, Arslanagic-Kalajdzic, and Imsirpasic 2017). The items are rated on 6-point Likert scale. (1) represents Strongly Disagree and (6) represents Strongly Agree.

IV. ANALYSIS & RESULTS

DEMOGRAPHICS

Out of 385 questionnaires, 44 were filled online while 265 responses were collected on printed questionnaires. Total 290 questionnaires were considered valid for analysis. The response rate is calculated to be 75.8%.

Gender	Frequency	Percentage
Male	150	51.7%
Female	140	48.3%
Marital status	**Frequency**	**Percentage**
Single	202	69.7%
Married	88	30.3%
Age	**Frequency**	**Percentage**
21 or less	25	8.6%
21-30	201	69.3%
31-40	59	20.3%
41-50	3	1.0%
60 and above	2	0.7%

Factors loadings

Loading values are above 0.5 and all items were retained for analysis. Test result shows all items load perfectly when executed together.

Iems	Initial	Extraction	Items	Initial	Extraction
Ta1	1.000	0.760	**EP1**	1.000	0.72
Ta2	1.000	0.752	**EP3**	1.000	0.70
Ta3	1.000	0.692	**EP2**	1.000	0.83
Ta4	1.000	0.695	**EP4**	1.000	0.77
RI1	1.000	0.696	**EP5**	1.000	0.79
RI2	1.000	0.686	**CI1**	1.000	0.72
RI3	1.000	0.688	**CI2**	1.000	0.74
RI4	1.000	0.718	**CI3**	1.000	0.69
RS1	1.000	0.71	**CI4**	1.000	0.80
RS2	1.000	0.682	**CI5**	1.000	0.72
RS3	1.000	0.683			
RS4	1.000	0.720			
RS5	1.000	0.696			

Communalities : Tangibility Ta, Reliability RI, Responsiveness RS, Assurance AS, Empathy EP, Corporate image CI

Cronbach's Alpha:

Cronbach's Alpha is calculated to test the reliability of scale used. As it is evident from the test results that all the values are above 0.6 shows that scale used is reliable.

Scale	Reliability	Number of Items
Ta	**0.73**	**4**
RI	**0.72**	**5**
RS	**0.77**	**4**
AS	**0.71**	**4**
EP	**0.83**	**5**
CI	**0.79**	**5**

Cronbach's Alpha: Tangibility Ta, Reliability RI, Responsiveness RS, Assurance AS, Empathy EP, Corporate image CI.

Correlation Analysis :

Correlation analysis is done to describe the relationship between independent and dependent

variable .Test results shows that all the values are significantly related to each other.

	Ta	RI	Rs	As	EP	CI
Ta	1					
RI	.491**	1				
Rs	.281**	.217**	1			
As	.532**	.515**	.210**	1		
EP	.213**	.213**	.531**	.161**	1	
CI	.401**	.420**	.211**	.319**	.208**	1

Regression Analysis

Regression analysis was done using SPSS software. After establishing significant relationship between independent and dependent variable, Regression analysis was performed. Regression analysis represents the impact of independent and dependent variable Tests results are as follows

Hypothesis	Relationship	Beta	S.E (β)	Significance (P)	T value	Results
H1	Ta → CI	0.318	0.018	0.000	8.375	Supported
H2	RI → CI	0.356	0.102	0.000	11.99	Supported
H3	RS → CI	0.421	0.045	0.012	5.530	Supported
H4	AS → CI	0.124	0.041	0.000	9.976	Supported
H5	EP → CI	0.199	0.048	0.000	6.945	Supported

As the model summary shows, that 31.8% of variation is present in CI because of Tangibility(Ta) . that 35.6% of variations are present in CI because of Reliability (RI). 42.1% of variations are present in CI because of Responsiveness (Rs) . 12.4% of variation is present in CI because of Assurance (As). 19.9% of variations are present in Corporate image because of Empathy (EP).

V. CONCLUSION

The main aim of the study was to examine the impact of PSQ elements on CI. To validate the model proposed theory was consulted. After that scale were selected to measure the variables. Cronbach alpha test results shows that chosen scale are reliable to perform analysis on. Correlation test showed that items are strongly related to each other. Regression Analysis was done using SPSS and test results shows that Corporate image (CI) is related to all the elements of PSQ. Responsiveness (RS) of service provider have the most significant impact on CI(corporate image). Reliability(RI) of service also have significant impact on Corporate image while Assurance have the lowest impact on Corporate image (CI).

VI. RECOMMENDATIONS, LIMITATION AND FUTURE RESEARCH

As evident by the findings of test results , all five dimensions of PSQ have significant impact on CI(Corporate image).Telecom companies can improve their corporate image by shifting their focus on these dimensions .It will also contribute the overall and Image of the company .Collected Data and interpretation of findings should be taken with caution because this study used a convenient sampling technique and sample size can not represent the entire population of telecom users. In the same way, Study results cannot be generalized to the entire population because Customer views about PSQ might be different depending on their interaction and experience. The qualification, occupation and usage respondents may also have differential influence on the results. Future research can take an approach of filtering population on the basis of their qualification or occupation. This approach could provide more detailed and comprehensive results. The views of respondents may differ if the population is sorted on the basis of education level or income level.

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To what extent are SME decision-makers familiar with the most common strategy methods? Results of a survey among presidents, owners, CEOs and managing directors of industrial SMEs

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Abstract— *The objective of this article is to examine whether decision makers of small and medium enterprises (SMEs) are familiar with the most common strategy methods. To this end, a survey was conducted among decision-makers (presidents, owners, managing directors & CEOs) of SMEs to determine their knowledge of standard strategy methods which were identified for this investigation as SWOT-Match, Competitive Profile Matrix (CPM), Strategic Position & Action Evolution Matrix (SPACE-Matrix), Boston Consulting Group Matrix (BCG-Matrix), Internal & External Matrix (IE-Matrix), and the Grand Strategy Matrix (GSM). The results showed that approx. 50% do not know any strategy method at all and approx. 60% have never used strategy methods in their professional life. This confirms the assumption that SME decision-makers have limited knowledge of strategy methods, strategy development and planning. In addition, the standard methods were evaluated by 2 participants for their suitability, and they gave an assessment of whether formalized strategic planning is helpful for the long-term success of SMEs.*

Keywords— ***Strategy methods, SWOT-Match, Competitive Profile Matrix, Strategic Position & Action Evolution Matrix, Boston Consulting Group Matrix, Internal & External Matrix, Grand Strategy Matrix, Small and Medium Enterprises, SMEs.***

I. INTRODUCTION

In short, small and medium enterprises (SMEs) are described as independently operating companies with less than 250 employees and less than 50 Mio € revenues or a balance sum below 43 Mio € (European Commission 2017).

Although SMEs play such a significant role in the world-wide economy, they are rarely focus of investigation and theory building, especially in the field of strategic management, strategic positioning, and resilience (Belas et al. 2022, Dimson et al. 2020, Klausmann et al. 2020). SMEs are generally less resilient than large and public companies, which usually have more resources and reserves and have implemented an established strategic development process (Eggers, F. 2020, Gunasekaran et al. 2011, Herbane 2012, Hong et al. 2012, Kraus et al. 2013, Ozgulbas et al. 2012). It is generally recognized that industrial SMEs have fewer resources than larger or public companies (Conz et al. 2015, Juergensen et al. 2020). This applies in particular to financial resources, but also to management capacities and management

expertise (Adam et al. 2021, Bouncken et al. 2022, Mayr et al. 2016, Vargo et al. 2011).

The aim of this paper is to investigate the level of knowledge of (standard) strategy methods among CEOs, managing directors, owners, presidents, in the following the decision-makers, of industrial SMEs and the frequency of their use for strategy development and implementation. These decision-makers are the ones who decide about, start and drive strategy activities in SMEs. If they do not have or have only limited knowledge about strategy methods, it can be assumed that structured strategy planning and implementation will not or only happen in an unstructured intuitive way.

Kelly et al. (2014) for example, found that a strong entrepreneurial orientation (Lumpkin et al. 1996, Latham 2009) is not enough for SMEs to be successful, but that it would be helpful for SME decision-makers to acquire basic skills for formal strategic planning. They found out that the emergent approach (Mintzberg 1973) alone has a negative impact on business success because it reduces the positive effects of proactivity and innovation. In recent years, researchers have also investigated the necessity of ambidexterity (simultaneously successful in exploitation and exploration orientation) for the survival in crises of SMEs (Bouncken et al. 2022, Dolz et al. 2018, Kraus et al. 2020).

A comprehensive understanding of strategic methods and practical experience in their application is essential for the development of a structured and planned strategy development.

In order to investigate this, a survey was conducted in which around 250 decision-makers from industrial SMEs were contacted, 31 of whom responded.

II. METHODS

2.1 Online survey

The aim of this paper is to investigate:

(a) the level of knowledge of (standard) strategy methods among the decision-makers of industrial SMEs

(b) the frequency of the use of the named strategy methods for strategy development and implementation

(c) knowledge of other strategy methods than the mentioned and if they use them for their strategy development process

(d) would they see significant benefit for the long-term success of their firm if they have knowledge of the methods named in the survey?

For that purpose, six strategic methods were identified as standard methods for this work, as these methods are taught as standard methods in the textbook of Fred et al. (2017).

1. SWOT-Match method: based on the SWOT-Analysis (Strengths & Weaknesses = IFE-Matrix, Opportunities & Threats = EFE-Matrix) the SWOT-Match method develops possible strategies by linking internal strengths with external opportunities, internal strengths with external threats, internal weaknesses with external opportunities, and internal weaknesses with external threats. Initially, as many alternative strategies as possible are developed in a value-free manner and without any claim to feasibility. The SWOT-Analysis is a prerequisite for the SWOT-Match method and provides important insights into the company's situation in the market (industry) environment, but initially no possible strategies for the future.

2. Competitive Profile Matrix = CPM method: with this method, the most important competitors are identified and compared with the company's own company and its own strategic position based on internal and external success factors, whereby the individual success factors are weighted. This provides important information regarding the company's own competitive position, which in turn can be used to derive strategies for improving the competitive position.

3. Strategic Position & Action Evolution Matrix = SPACE-Matrix method: is a four-quadrant framework that assesses two internal dimensions (financial position and competitive position) and two external positions (stability position and industry

position). Depending on the outcome, it indicates whether aggressive, conservative, defensive, or competitive strategies are appropriate.

4. Boston Consulting Group Matrix = BCG-Matrix method: is also a four-quadrant framework method based on the two dimensions (1) relative market share position (RMSP) on the x-axis and (2) industry growth rate (IGR) on the y-axis. Depending on the quadrant in which the valued company / business unit is located appropriate standard strategies are proposed. This method is mainly used to analyze the strategic position of larger firms` divisions / business units to apply appropriate strategies for each unit but can also be used to develop strategies for SMEs.

5. Internal-External Matrix = IE-Matrix method: This method is based on the IFE- and EFE-Matrix of the SWOT-Analysis and a nine-cell framework. Similar to the BCG-Matrix method standard strategies are proposed depending on the cell in which the results are located.

6. The Grand Strategy Matrix = GSM method: is also a four-quadrant framework tool to formulate alternative strategies and is based on the evaluation the 2 dimensions (1) competitive position on the x-axis and (2) market (industry growth) on the y-axis.

While methods 1,3,4,5,6 focus on developing alternative strategies, method 2 (CPM) focuses on identifying the own competitive position relative to the key competitors.

Then the following questions for the survey were formulated:

1. Which of the following methods for strategy development do you know?
   a. Strength-Weakness-Opportunities-Threats (SWOT)-Match
   b. Competitive Profile Matrix (CPM)
   c. Strategic Position & Action Evolution Matrix (SPACE)
   d. Boston Consulting Group (BCG) Matrix
   e. Internal-External (IE) Matrix
   f. Grand Strategy Matrix (GSM)
2. Did you or use you one or more of these methods? If yes which ones? Do you use an alternative method?

Because knowledge of these issues is not publicly available the author contacted via his LinkedIn account (https://www.linkedin.com/in/juergen-klausmann-796a9456/) his LinkedIn contacts who seemed to be decision-makers of SMEs. Once a contact answered the two survey questions, the author asked the respondent for the number of employees and the annual revenues of their company to check whether the respondent's company met these two SME criteria. To make it easier for participants to respond, only these two criteria (number of employees and annual revenues) were used to define an SME for this study.

2.2 Number and location of participants generated

In the period of January 2023 to April 2025 around 250 decision-makers of SMEs were contacted and 31 responses received which corresponds to a participation rate of around 12 %. Thereof 22 are located in Germany, 2 in Austria and 9 in USA.

In total 26 companies of the participants fulfilled both criteria for SMEs (≤ 50 Mio € annual revenues and ≤ 250 employees).

A closer look at the companies that do not fulfill the 2 criteria for SMEs shows the following:

- two companies (one in Germany, one in the USA) with annual sales of €80 million and USD 105 million and employee numbers of 400 and 330 violate both criteria, but are typical SMEs in terms of their structure and business activities and are therefore included in the further analysis
- two US companies violated the sales criterion with USD 300 million and USD 80 million but did not violate the employee criterion with 150 and 115 employees, so that the company with annual sales of USD 80 million and 115 employees (very close to the 2 criteria) is included in the further analysis.
- one German company with annual sales of € 450 million and 4,500 employees clearly exceeds both criteria.

Therefore, the answers of 29 participants will be used for the following.

2.3 Meaningfulness of the generated number of participants

In 2018 alone in Germany 3,466,583 SMEs existed of which 20.3% equates to 703,716 were SMEs in the manufacturing sector (IfM 2017), meaning an extremely large population size exists with no knowledge about the standard deviation in the total population or about the proportion of the population with regards to the questions in the questionnaire. Based on that, the confidence level Z for the results of this questionnaire was calculated.

$$z = \sqrt{\frac{n \cdot E^2}{p(1-p)}} \quad (1)$$

n = 29, sample size

p = 0,5, proportion

Z = Z level for the desired confidence level

E = 10%, the maximum allowable error

Based on equation (1) the confidence level Z of the survey results of 29 participants is 86% at an allowable error rate of 10%.

2.4 Testing and evaluating the strategy methods in practice

After receiving the answers to the 2 survey questions and to the SME criteria the participants were asked if they were interested in learning and testing the strategy methods mentioned to evaluate and improve their existing strategy or to develop a corporate strategy if no formal strategy exists yet.

Of the 29 SME survey participants 5 agreed to take part in this process. But only 2 completed the process (no 8, no 10).

The process of evaluating the methods was as following:

The author designed one excel files per strategy method. Then he sent the 1. file to the participant and explained the task by a Teams meeting. After receiving the completed excel file, he evaluated the file, asked the participant to make corrections, if necessary, explained the results via Teams meeting and discussed the next excel file. At the end of the entire process which lasted appr. one year, a final interview took place.

III. RESULTS

3.1 Survey results

19 of the 29 participants indicated that they know the SWOT-Match method but when again contacted 14 of the 19 participants stated that in fact, they know the SWOT-Analysis and only 5 of 29 (17%) stated that they know indeed the SWOT-Match method (and have also used it).

However, the author posits that the SWOT-Analysis is not a strategy method in itself, but rather a preparatory tool for the subsequent application of a strategy method, namely the SWOT-Match method. The list of methods was therefore expanded for the results analysis and the SWOT-Analysis was placed above the SWOT-Match method. Furthermore, the following analysis in table 1 shows the survey results with and without the number of mentions of the SWOT-Analysis.

The CPM method is known by only 7 (24%) participants, the SPACE method by only 3 (10%) participants, the BCG-Matrix method which is the most known method by 10 (34%) participants, the IE-Matrix method by only 2 (7%) participants and the GSM method is known by no participant.

Table 1: Number of participants knowing / not knowing mentioned strategy method

Strategy method	No of participants familiar with method	Percentage	No of participants not familiar with method	Percentage
SWOT-Analysis	19	66%	10	34%
SWOT-Match	5	17%	24	83%
CPM	7	24%	22	76%
SPACE	3	10%	26	90%

BCG-Matrix	10	34%	19	66%
IE-Matrix	2	7%	27	93%
GS-Matrix	0	0%	29	100%

In table 2 it is shown how many strategy methods the individual participants actually know.

14 (48%) of the respondents do not know of a single method for strategic planning, 7 (24%) know only one method, whereas 5 (17%) know 2 methods, 2 (7%) know 3 and 1 (3%) know 5 methods (excluding SWOT-Analysis as a method).

Table 2: Number of strategy methods known to the individual participants

No of Strategy method known to participant	No of participants familiar with method incl. SWOT-Analysis	Percentage	**No of participants familiar with method excl. SWOT-Analysis**	**Percentage**
0	9	31%	**14**	**48%**
1	6	21%	**7**	**24%**
2	6	21%	**5**	**17%**
3	5	17%	**2**	**7%**
4	2	7%	**1**	**3%**
5	1	3%	**0**	**0%**
6	0	0%	**0**	**0%**
7	0	0%	**-**	**-**
Total	29		**29**	

Table 3 presents the frequency of strategy method utilization in SMEs.

Assuming that the SWOT-Analysis is not a strategy method then only 5 (17%) of the participants have used or use the SWOT-Match method, similar 5 (17%) use(d) the CPM method, 3 (10%) the SPACE method and 6 (21%) the BCG Method which is the most used method; IE-Matrix and GS-Matrix is not used by any participant.

Table 3: No of participants who have used or use mentioned strategy method

Strategy method	No of participants have used or use method	Percentage	No of participants did /do not use method	Percentage
SWOT-Analysis	18	62%	11	38%
SWOT-Match	5	17%	24	83%
CPM	5	17%	24	83%
SPACE	3	10%	26	90%
BCG-Matrix	6	21%	23	79%
IE-Matrix	0	0%	29	100%
GS -Matrix	0	0%	29	100%

Table 4 shows how many strategy methods the individual participants actually use or have used.

17 participants (59%) do not use or did not use a single strategy method, only 8 (28%) use(d) one method, whereas only 1 (3%) use(d) 2 methods and 3 (10%) use(d) 3 strategy method (excluding SWOT-Analysis as a method).

Table 4: Number of strategy methods applied or in use by the individual participants

No of Strategy methods applied or in use	No of participants who have used or use method incl. SWOT-Analysis	Percentage	**No of participants who have used or use methods excl. SWOT-Analysis**	**Percentage**
0	11	38%	**17**	**59%**
1	6	21%	**8**	**28%**
2	8	28%	**1**	**3%**
3	1	3%	**3**	**10%**
4	3	10%	**0**	**0%**
5	0	0%	**0**	**0%**
6	0	0%	**0**	**0%**
7	0	0%	**0**	**-**
Total	29		**29**	

US participant No 16 is using in addition to the BCG-Matrix method the Entrepreneurial Operating System method (Wickmann 2007) and US participant No 22 is using in addition to the SWOT-Match method the Rockefeller Habits method (Harnish 2024) and the Gazelles OPSP method (Harnish 2022).

3.2 Results of the testing and evaluating process

In order to investigate whether the strategy methods mentioned actually have added value for the development of corporate strategies of SMEs (and the longer-term success of the firm), the survey participants were asked whether they would be willing to develop a formalized strategy or revise their existing strategy under the guidance of the author with the help of the methods mentioned.

Of the 29 respondents, five agreed to participate in the strategy development process, but one (No 11) dropped out immediately after receiving detailed information about the process and the effort involved; the second decision maker (No 12) dropped out after six months and the third (No 28) stopped after 5 months, both because of overwhelming day to day challenges. They cited urgent tasks and day-to-day challenges as reasons for dropping out. 2 participants (No 8, No 10) completed the exercise over a period of approximately one year.

It is striking that the participants who completed the entire process had an MBA or economics degree, in contrast to the participants who cancelled the process, who had engineering degrees or no degree. In addition, the participants who completed the process were already familiar with several strategy methods and had experience in using them, while the participants who cancelled the process were not familiar with any strategy method.

At the end of the entire process, the 2 participants participated in an expert interview and evaluated the methods and the process.

In addition to the 6 strategy methods mentioned above, the Quantitative Strategic Planning Matrix (Fred et al. 2017) was used in this exercise to prioritize the identified company strategies.

Table 5 gives an overview about the 5 participants, their firms, and the results of the process.

It should be noted in advance that the results of the 2 participants are not representative of industrial SMEs for the reasons mentioned above.

Both participants used the process as an opportunity to question, prioritize and further develop their non-

formalized but already existing strategy and strategic goals. Both found the process helpful and supportive for their strategy development. Both participants already used the SWOT-Analysis and prefer the CPM method for determining the competitive situation and the BCG-Matrix method for the development of corporate strategies. Participant number 8 described in addition the SWOT-Match method and QSPM method as very helpful. In addition, participant number 10 will use the formalized strategy process to improve the communication with his employees.

Table 5: Participants of the strategy method testing, evaluation & development process

Information / Participant	No 8	No 10	No 11	No 12	No 28
Annual revenues	< €50 million	€12 million	€31 million	€16 million	€1 million
No employees	10	80	81	110	3,5
Company`s activity	Development of solar parks	Manufacturing of metallic high precision parts	Manufacturing of hot formed parts by hot forging	Manufacturing of electronics and PCB assembly	Trade with and installation of building locking technology
Company`s age	<10	>10	>10	>10	<5
Participant`s position	Shareholder, CEO	Owner, CEO	Owner, CEO	Owner, CEO	Owner, CEO
Participants education	M.A. Economics	MBA	Dipl. Ing. (Ph.D.)	Dipl. Ing.	Sales expert
Completion of the entire strategy exercise	Yes	Yes	No	No	No
Reason for termination of exercise			No time as busy with new organizational structure	Urgent tasks and day-to-day challenges	Urgent tasks and day-to-day challenges
Strategy methods were known & applied prior to the exercise	SWOT-Analysis, CPM	SWOT-Analysis, CPM, BCG-Matrix	SWOT-Analysis	No	No
Informal strategy in place before exercise	Yes	Yes	Yes	Yes	No
Was the effort worthwhile?	Yes	Yes	-	-	-
Achievements through exercise	Existing strategies were formulated with greater clarity and prioritized	Formalized strategies are used to communicate with employees	-	-	-
What are your favorite methods?	SWOT-Match, CPM, BCG, QSPM	SWOT-Analysis, CPM, BCG	-	-	-

Is a formalized strategy process helpful for the success of SMEs?	Yes	Yes	-	-	-

IV. DISCUSSION

The results of the survey confirm the general statements about the limited resources and management knowledge regarding strategy planning and development of SMEs. They provide detailed information about the strategic methods that decision-makers of industrial SMEs actually know. 48% of the participants do not know any standard strategy method and 59% do not or did not use any standard strategy method during their career. To the participants the best known (34%) and most used (21%) method is the BCG-Matrix method, which is surprising, as this method was developed more for large companies with several divisions. Furthermore, the participants were only aware of 2 other strategy methods beside of the 6 standard methods surveyed, i.e. it is indeed the case that approx. 60% of the participants did not and do not use any strategy method for strategy development, which leads to the conclusion that no formalized planned strategy development takes place in approx. 60% of industrial SMEs.

The final objective of this study - whether SME decision-makers see a significant benefit for the long-term success of their company if they have knowledge of strategy methods - could not be answered conclusively, as only 2 decision-makers - and these are not representative for decision-makers of industrial SMEs - could be recruited for the testing and evaluation process. There is therefore a need for further research on this topic, as the authors believe that in our highly competitive and global world, formal strategy development and planning for decision-makers of industrially active SMEs needs to be given more space compared to day-to-day challenges and tactical tasks.

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Implementation of Green Practices in Logistics Sector

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Abstract *— Green logistics has become a viable option as environmental concerns grow. Green logistics is the process of incorporating environmental concerns into supply chain management in order to enhance suppliers' and customers' environmental performance and, as a result, change the way the business operates. Green Logistics refers to as a strategy for providing services that improve the environment, economy, and social sustainability. Therefore, Green practices must be implemented from the very beginning in order to practice ecologically responsible logistics. This paper explores the concept of green logistics, green logistics practices or strategies that need to implement, and real world application of green techniques in the logistics industry in India.*

Keywords *— **Green Logistics, Sustainability, Green practices, Eco-friendly logistics strategies, Sustainable solutions***

I. INTRODUCTION

The green logistics industry in India is predicted to expand rapidly, making up 14.4% of the country's GDP and forecast to reach $380 billion by 2025. Green projects like the National Master Plan- Gati Shakti, National logistics policy 2022, tax reduction through GST, E-Way Bill, FASTag are being supported by the government.

The transport sector is at a critical juncture. Green logistics has become a viable option as environmental concerns grow. It may help address issues like waste management, rising carbon emissions, and other problems with traditional logistical operations. Technology advancement in logistics has opened the doors for efficient, effective, reliable and transparent freight and passenger transport systems. But, at the same time negative impacts of transportation on environment have gained attention that causes problems in sustainability. Environmental concern due to human activities created need for environment friendly transportation system. Logistics companies are facing new challenge these days, that is green logistics and sustainable development that aims to strike a balance between environmental approach and economic factors. It plays significant role in supply chain management as well as improvement in transportation. Green logistics operate through all stages of operation; first, middle and last mile logistics. Green logistics includes reduction of carbon emissions, waste management, reusable packaging, renewable materials, recycling, reducing energy consumption, optimum distribution of network, cross docking, sustainable transportation and so on.

Green logistics requires enterprises to reclaim, reuse, and recycle waste, establishing a cyclic logistics system for sustainable development. Staff training and educational initiatives are frequently more successful in fostering environmental consciousness, achievement, and an environmental culture in green logistics.

With regard to green manufacturing, marketing, and consumption, green logistics is essential to sustainable growth. Preventing pollution, damage to the ecosystem, and excessive resource usage is crucial. Sustainable development, a healthy momentum, and the preservation of the environment and resources

should be the top priorities of modern logistics (Ping, 2009).

DEFINE GREEN LOGISTICS

Green logistics, sometimes referred to as ecological logistics, seeks to minimise the negative effects of transportation on the environment by using less energy and materials **(Rogers and Tibben-Lembke, 1998).**

Nowakowska-Grunt, (2008) define green logistics in monetary terms that coordinates all the logistics activities of a firm including transportation, storage, packing, material handling and data collection to meet customer orders at minimum cost.

"Producing and distributing goods in a sustainable way, taking account of environment and social factors" is the definition of "green logistics" as it pertains to sustainable development **(Sibihi & Eglese, 2009).**

Green logistics, according to **Karia & Asaari (2016)**, is a tactic for offering services that enhance the economics, social sustainability, and environment; for instance, by reducing operating expenses, preserving energy, and raising living standards without posing a threat to the environment or society.

In **2021, Dzwigol, Trushkina, Kvilinskyi, & Kvilinskyi**, one of the most important requirements for putting the idea of corporate social responsibility into practice for businesses operating in a circular economy is to maintain the required degree of environmental safety while reducing the expenses associated with using green logistics mechanisms to manage the flow of logistics.

RESEARCH OBJECTIVES

1. To determine the green practices that the logistics industry needs to implement
2. To identify logistics businesses that have adopted green techniques in India

II. REVIEW OF LITERATURE

Companies are compelled to green their logistics services due to marketing demand and environmental concerns, as consumers increasingly prefer green products and are conscious of green activities.

Maurya, Padval, Kumar, & Pant (2023), Using environmentally friendly cars, cutting fuel use, and making use of recyclable materials are some of the tactics used in green transportation. Reusing resources, using recyclables, employing green packaging materials, and cutting down on waste, material consumption, and unpacking time are all examples of green packaging. Energy-efficient lighting, energy-efficient buildings, and minimising transportation are all part of green warehousing and distribution. Strategic planning, value inclusion and control, and the use of cutting-edge machinery and technology for green logistics are all part of green value-added services.

Qin, W.; Qi, X. (2022) Policies ought to direct the growth of green logistics, control consumer behaviour, and strengthen legal frameworks. The infrastructure for green logistics, storage, and transportation should be planned by provincial governments in order to lessen traffic and boost customer satisfaction.

Castillo-Manzano, Castro-Nuño, & Fageda, (2021), In European nations like Norway, Finland, and Sweden, the use of megatrucks has increased traffic accident prevention. The effect on the safety of cross-border travel is still uncertain, though. According to the report, mature nations with a track record of accomplishments in road safety should be the only ones where megatruck circulation is permitted. But launching this kind of car needs careful planning and investigation.

Mutie, Odock & Litondo (2020) recommends that in order to boost business performance and guarantee sustainability for future generations, Kenyan logistics companies should implement green logistics techniques. Since logistics activities have an adverse effect on the environment, these techniques include carbon emission measurement, green packaging, fuel efficiency, route optimisation, and reverse logistics.

Malá, et al. (2017), Sustainable development is supported by the forestry and wood-processing businesses, which rely on renewable resources. Green logistics enhances product value and fosters social and economic development by minimising ecological effect and emphasising ecological orientation.

Karia, & Asaari, (2016), Green Logistics refers to as a strategy for providing services that improve the environment, economy, and social sustainability; for example, by lowering operational costs, conserving energy, and improving living standards without endangering the environment or society. The business

has made some financial benefits such as increased fuel economy, optimised routes and warehouses, and preservation of the environment and society by eliminating any operations that result in needless carbon emissions (CO2).

Kumar (2015) recognised importance of eco-friendly logistics system. While technological developments improve transportation systems' dependability, cost, and efficiency, they also have an influence on the environment. Green logistics tackles urban sustainability challenges by emphasising eco-friendly applications.

Seroka-Stolka (2014), Businesses face ongoing pressure to create ecologically conscious and conscientious operations, and environmental commitment is a crucial factor in competitive settings. Corporate green logistics variables can come from both internal and external sources for an organisation.

Mesjasz-Lech (2011) In order to fulfil or surpass consumer demand, green logistics include the environmentally responsible management of product and information flows between point of origin and point of consumption.

Scott, Lundgren & Thompson (2011), The terms "green logistics" and "reverse logistics" are now frequently used interchangeably; nevertheless, green logistics "summarises logistics activities that are primarily motivated by environmental considerations," whereas reverse logistics does not.

Larbi, Alpan, Baptiste, & Penz, (2011), In a single receiving and shipping door cross dock, the study looks at transhipment scheduling under three different scheduling policies: complete information, partial information, and no information. For comprehensive information, a polynomial time algorithm and an ideal graph-based model are suggested, while heuristics are created for other situations.

Soto, Perales, & Thiell, (2011), Small order volumes and frequent deliveries present distribution issues for businesses. Cross-docking shortens lead times and lowers manipulation costs; reverse logistics aids in product recovery and resale, especially in the fashion industry. In order to enable product redirection without storage, this work presents a linear programming model for cross-docking in reverse logistics.

GREEN PRACTICES REQUIRED FOR LOGISTICS SECTOR

- **Use of energy saving vehicles:** Use of fuel efficient vehicles required lesser fuel and produce lesser amount of greenhouse gases, use of bikes to make delivery in local area for small orders. Electric vehicles such as hybrid, plug-in and all electric vehicles are also helpful in sustainable transportation development. Emerging plans of alternative fuel vehicles include; biodiesel, electricity, ethanol, hydrogen, natural gas and propane. Alan McKinnon's (2010) identify some ways to reduce carbon emission in logistics activities, such as reduction in transport intensity, use of green modes of transportation known as rail, barge, pipeline, and ship, optimum vehicle utilization, electric-transportation, use of energy saving vehicles, proper driving skills can also minimise carbon emission, decarbonising warehousing activities. Green initiatives and renewable energy can lessen the social and environmental challenges of global warming, climate change, carbon emissions problems without sacrificing economic expansion (Khan, 2019).
- **Route optimization:** Green Distribution Logistics include, but are not limited to, employing electronic invoicing, loading the cargo, streamlining the routes of transportation, selecting environmentally friendly modes of transportation, and cutting CO2 emissions (Malá et al. 2017). Cargo distribution optimisation, route optimisation, eco-driving, eco-friendly fuel, use of energy saving equipments defines green distribution logistics practices (Vienažindienė, et al. 2021).
- **Green warehousing:** Energy-efficient lighting, energy-efficient buildings, and minimising transportation are all part of green warehousing and distribution (Maurya et al., 2023).
- **Green packaging:** Seroka-Stolka, & Ociepa-Kubicka (2019), Green logistics work in putting businesses into the circular economy includes the application of green packaging that is good to the environment, as well as

green storage, processing, and transportation. Reusing resources, using recyclables, employing green packaging materials, and cutting down on waste, material consumption, and unpacking time are all examples of green packaging (Maurya et al., 2023).

- **Reverse logistics:** Sibihi & Eglese (2009) emphasize the importance of green logistics activities, which involve assessing environmental impacts, reducing energy usage, managing waste, and promoting sustainable practices. According to Pishvaee, Kianfar, and Karimi (2009), putting in place a good reverse logistics network can boost revenue, improve customer satisfaction, and foster a favourable public perception in addition to offering a competitive edge, cost savings, and increased profit.
- Using **cross-docking** systems, materials are moved as quickly as possible from the receiving dock to the shipping dock during the warehousing process (Apte, & Viswanathan, 2000).
- **Partial truck load service known as PTL service**: Use of PTL service is effective whenever a shipper does not have enough material to fill the vehicle, in such case, two or more shipper share same truck for transporting goods and make payment on volume basis, helps in energy saving. This is also known as **crowdshipping**.
- The potential of **autonomous vehicles and truck platooning** to improve public and private transportation, lower carbon emissions, and use less fuel and pollution is drawing interest from governments, businesses, and academic institutions; however, the real advantages will rely on operating conditions and technological advancements (Paddeu, & Denby 2021).
- **Drones for last mile delivery:** Logistics is starting to pay more attention to drones because of their agility, adaptability, and autonomy. Drones are used by businesses like Amazon to deliver packages while cutting expenses and improving customer happiness. They're environmentally beneficial as well, being electric cars. According to the study, a drone-based parcel delivery system uses more energy than an electric truck-based parcel delivery system, particularly in metropolitan regions with high customer density and short vehicle tours, as well as in rural areas with large distances (Kirschstein, 2020).
- **Crowdshipping**: Use of PTL service is effective whenever a shipper does not have enough material to fill the vehicle, in such case, two or more shippers share same truck for transporting goods and make payment on volume basis, helps in energy saving. This is also known as **crowdshipping**.
- **Longer and Heavier Vehicles:** The trucks with a length of 25 metres and a weight of 60 tonnes are referred to as "megatrucks" and are designated Longer and Heavier Vehicles (Castillo-Manzano, Castro-Nuño, & Fageda, 2021). First, a reduction in the cost of operation per tonne-kilometer moved is implied by increasing the trucks' weight and length. Reducing the quantity of automobiles also lessens externalities (Ortega et al. 2014).
- **Artificial Intelligence and Machine Learning:** AI and ML are revolutionising the logistics industry by assisting in decision-making, lowering human error, forecasting demand, and optimising routes.
- **Cloud Logistics:** Cloud logistics is the practice of performing all logistics tasks online.

INSTANCES OF LOGISTICS FIRMS USING GREEN PRACTICES IN INDIA

- **Ark India** offers temperature-controlled logistics services in India, ensuring the safe transportation of sensitive goods like perishable foods and pharmaceuticals, thereby preserving their integrity throughout their journey.
- As a test project, **Blue Dart** intends to install e-waste recycling bins at a few locations to encourage sustainable practices and responsible trash management.
- **Blue Dart**, a South Asian company, has teamed up with Skye Air, a leader in drone

technology, to deliver about 100 parcels in Gurugram in just 10 minutes instead of hours.

- In order to facilitate cooperative operations in Gurugram, Skye Air and **ECom Express** have teamed. Drones will be integrated into the last-mile delivery ecosystem.
- Training, renewable energy systems, natural daylighting, water conservation, recycling, and effective docking bay design are just a few of the ecologically friendly activities that **Varuna Group**, a logistics company, advocates.
- **Safexpress** is making a concerted effort to minimise waste, optimise product value, and move towards a circular economy. Safexpress is a logistics solutions company that prioritises sustainability and the environment. It uses green, emission-free vehicles for transportation.
- A Mumbai-based business called **Greenline Logistics** provides green logistics services with LNG-fueled vehicles. Utilizing automobile fuels like LNG, CNG, and EV to lower carbon emissions and boost gas stations for heavy-duty cars, Greenline, India's top green logistics company, is making its operations sustainable and green.
- The massive global transportation company **DHL** is dedicated to reducing greenhouse gas emissions and plans to use electric cars for 60% of last-mile and long-distance shipments by 2030. The company plans to deploy a variety of electric and alternative fuel vehicle types for intra-city delivery by 2025, with a goal of using 100% green fuel and electric vehicles.
- **Mahindra Logistics** has pledged to achieve carbon neutrality by 2040, employing more than 1,300 electric cars for environmentally friendly transport services. Mahindra Logistics possesses solar-powered warehouses and other LEED-certified buildings are examples of additional green logistics projects.

III. CONCLUSION

Innovation in logistics technology improves transparent, trustworthy and efficient methods for moving people and goods, but it also brings up difficulties with sustainability and the environment. According to Green logistics is the process of incorporating environmental concerns into supply chain management in order to enhance suppliers' and customers' environmental performance and, as a result, change the way the business operates. This paper has identified some examples of green practices in the logistics industry are energy-efficient trucks, route optimization, green warehousing, eco-friendly packaging, reverse logistics, PTL service, autonomous vehicles, drones, crowdshipping, longer and heavier vehicles, artificial intelligence, and cloud logistics. Ark India, Blue dart, Ecom express, Mahindra Logistics, DHL. Greenline Logistics, Varuna group, Safexpress are few examples of logistics companies that are taking initiative to make logistics sector more eco-friendly and sustainable.

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