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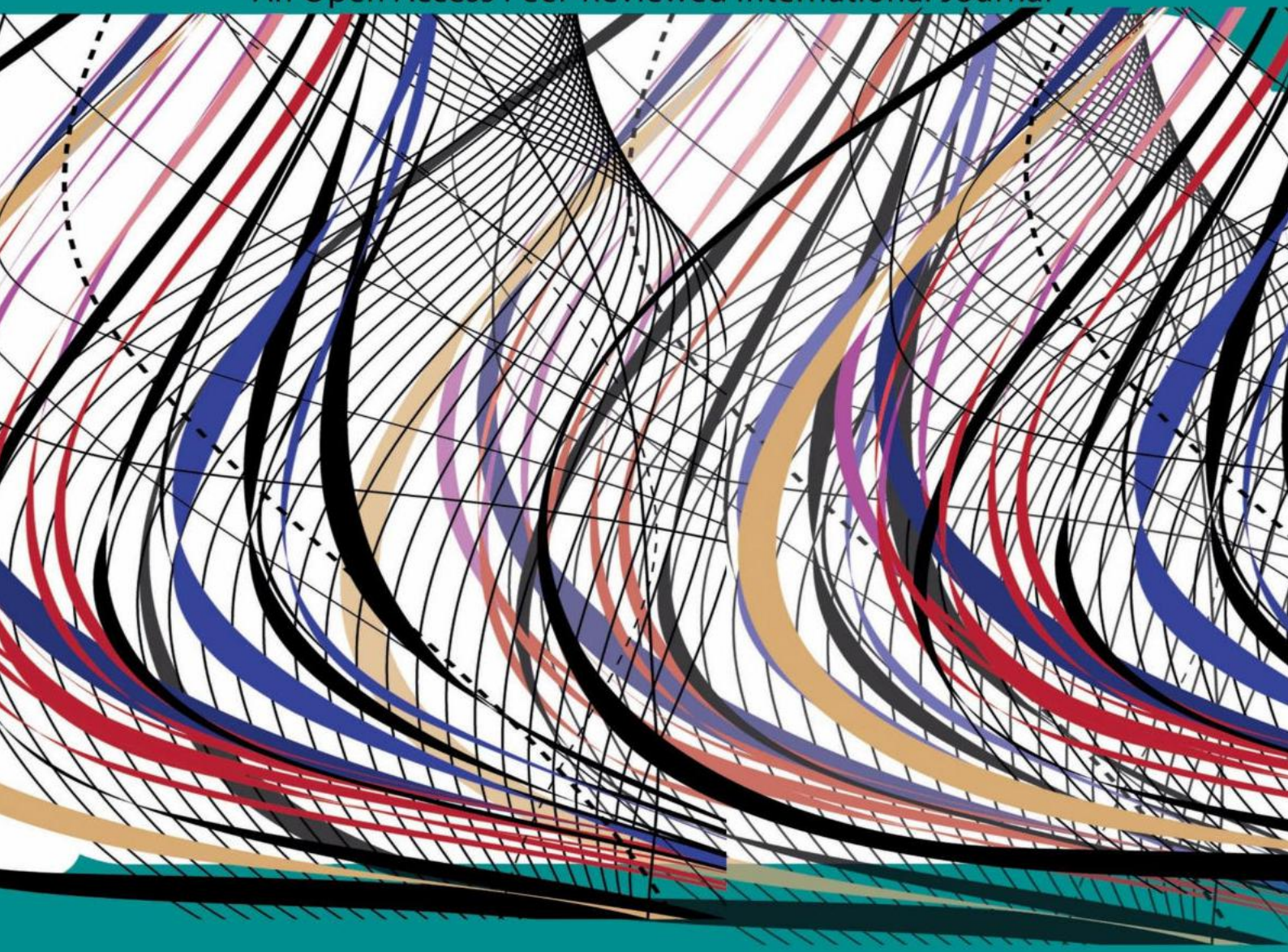

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Integrating AI-Driven Automated Code Review in Agile Development: Benefits, Challenges, and Best Practices

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Abstract *— The integration of AI-powered automated code review tools has significantly transformed Agile software development by improving efficiency, maintaining coding standards, and enhancing developer productivity. These tools streamline repetitive tasks, identify potential issues early, and enforce consistency in code quality. However, their adoption comes with challenges such as accuracy constraints, difficulties in integrating with legacy systems, and hesitation among developers. This research employs a mixed-methods approach, combining qualitative and quantitative techniques to examine the benefits, challenges, and best practices associated with AI-driven code reviews. To gather insights, surveys and interviews were conducted with software engineers, DevOps professionals, and Agile practitioners. Additionally, real-world case studies analyzed how organizations have implemented AI-based code reviews, while an experimental study measured performance indicators such as error detection rates, review efficiency, and developer workflow improvements. The findings suggest that AI tools significantly reduce code review time, enhance consistency, and allow developers to concentrate on complex problem-solving rather than manual review processes. However, AI's inability to fully grasp context-sensitive issues, challenges in analyzing complex code logic, and resistance from developers remain notable barriers. Concerns about job security and loss of control over decision-making further contribute to adoption challenges. To overcome these issues, this study emphasizes the importance of a balanced approach where AI tools assist rather than replace human reviewers. Regular training and updates are crucial to improving AI accuracy and keeping pace with evolving coding practices. Gradual integration with existing systems can mitigate compatibility challenges, while transparent communication can help alleviate developer concerns. Additionally, establishing a validation mechanism, where human reviewers verify AI-generated recommendations, can enhance reliability and trust in these tools. In conclusion, while AI-driven automated code reviews offer substantial benefits for Agile teams, their successful implementation depends on strategic deployment, ongoing refinements, and a well-balanced collaboration between AI and human expertise. By following best practices, organizations can optimize AI-assisted code reviews, ultimately improving software quality and streamlining development workflows.*

Keywords *— **AI-powered code review, Agile software development, developer productivity, integration challenges, and best practices.***

I. INTRODUCTION

The field of software engineering has undergone significant advancements, driven by rapid technological progress and the increasing complexity of software requirements. From its inception, software development methodologies have evolved

continuously, transitioning from the structured waterfall approach to more flexible and iterative frameworks such as agile. These changes have been geared toward improving efficiency, adaptability, and software quality. The incorporation of DevOps, continuous integration, and automated testing has revolutionized the development, testing, and deployment processes. However, challenges such as human errors in manual coding, inefficiencies in feedback cycles, and resource management constraints continue to persist, prompting ongoing innovation. [1]. Artificial Intelligence (AI) has become a fundamental component of contemporary software development, providing transformative capabilities that enhance multiple stages of the development lifecycle. In high-tech industries, where innovation and efficiency are critical, utilizing AI-driven insights plays a vital role in sustaining a competitive edge. [2]. AI's capacity to process extensive datasets, recognize patterns, and generate predictive recommendations empowers developers to optimize workflows, minimize errors, and expedite product deployment. The significance of AI insights for high-tech companies cannot be underestimated. These insights support well-informed decision-making, enhance code quality, and streamline project management. By automating repetitive tasks, AI enables developers to concentrate on creative and complex problem-solving. Furthermore, AI-powered analytics can anticipate potential challenges before they emerge, significantly lowering the likelihood of expensive post-release corrections and improving overall product dependability. [3].

AI-powered code generation is revolutionizing software development in high-tech industries by automating repetitive coding tasks, optimizing code structure, and significantly boosting developer productivity. The automation of routine coding processes through AI represents a major advancement in software engineering. [4] Utilizing machine learning algorithms and natural language processing, AI tools can recognize coding patterns, identify common functionalities, and generate boilerplate code automatically. This not only reduces the time developers spend on repetitive tasks but also lowers the likelihood of human errors associated with manual coding. Consequently, developers can concentrate on complex problem-solving and creative aspects of software development, leading to higher-quality software solutions. Another key advantage of AI-driven code generation is its ability to optimize existing codebases. AI-powered tools assess code structures, pinpoint inefficiencies, and provide recommendations or implement improvements autonomously. For example, AI can eliminate redundant code, enhance loop efficiency, and improve memory utilization, resulting in more efficient software performance. Additionally, AI-driven analysis allows developers to evaluate how different optimization techniques impact overall system functionality, enabling more informed decision-making. This continuous learning process ensures that AI tools adapt to evolving coding standards and industry best practices, maintaining optimized and up-to-date code. [5].

The use of AI-driven automated code reviews in Agile development is reshaping how software teams enhance code quality, streamline workflows, and speed up software delivery. Agile development is built on iterative progress, teamwork, and continuous improvement, making AI-powered automation an ideal addition to modern development processes. By utilizing machine learning (ML) and natural language processing (NLP), AI-based code review tools can evaluate code structure, identify inefficiencies, and offer instant feedback, reducing the reliance on manual reviews. These tools improve both the speed and accuracy of code assessment, allowing Agile teams to maintain rapid development cycles while ensuring high software quality. AI-driven automated code review tools function by scanning source code and detecting issues such as syntax errors, security risks, performance inefficiencies, and deviations from coding best practices Traditional code reviews often require experienced developers to manually examine code, which is both time-consuming and susceptible to human error. In contrast, AI-powered tools can quickly analyze large codebases, offering instant recommendations and flagging potential problems that might otherwise be overlooked. This consistency in enforcing coding standards across teams improves software quality and simplifies maintenance. Additionally, these AI tools continuously evolve by learning from extensive code repositories, improving their ability to recognize problems and suggest enhancements over time. [6].

A key advantage of AI-driven code reviews in Agile development is the reduction of technical debt. Technical debt arises when speed is prioritized over long-term code quality, resulting in inefficiencies that complicate future development efforts. AI tools help mitigate this risk by detecting poor coding practices, outdated dependencies, and security vulnerabilities early in the development process. Addressing these issues proactively ensures that software remains scalable, secure, and aligned with industry best practices. Furthermore, AI-powered reviews promote consistency in coding guidelines across distributed Agile teams, minimizing inconsistencies that can occur in manual reviews conducted by different developers. In Agile environments where continuous integration and continuous deployment (CI/CD) play a crucial role, AI-driven code reviews optimize the development pipeline by delivering real-time feedback. Integrating AI into CI/CD workflows allows developers to receive recommendations before merging code into production, reducing the chances of introducing bugs or security vulnerabilities. This automation not only speeds up development cycles but also ensures that frequent software updates do not compromise reliability. Additionally, AI-assisted reviews ease the burden on senior developers, enabling them to focus on complex problem-solving and architectural decisions instead of spending time on routine code evaluations. [7]

Beyond improving efficiency and code quality, AI-driven code review fosters collaboration and knowledge-sharing among developers. Junior developers, who may not yet have extensive experience with writing optimized code, benefit from AI-generated suggestions that guide them toward best practices and alternative coding approaches. This learning process enhances the overall skill level within the team, leading to better productivity and stronger code quality over time. Moreover, AI tools do more than just highlight problems; they provide explanations for flagged issues, helping developers understand their mistakes rather than just applying automatic fixes. This approach supports a culture of continuous learning, reinforcing Agile principles of adaptability and incremental progress. [8]. Despite its many benefits, implementing AI-driven code review in Agile development comes with challenges. AI tools require proper training and fine-tuning to align with a project's unique requirements and coding standards (Kwakye, Ekechukwu & Ogundipe, 2024). False positives and false negatives can occasionally arise, making human oversight necessary to validate AI-generated recommendations. Additionally, some developers may resist automation, preferring traditional peer reviews over AI-assisted suggestions. To successfully adopt AI-driven code reviews, organizations must define clear guidelines on how automation complements manual reviews, ensuring a well-balanced approach that leverages both AI efficiency and human expertise. [9].

1.1 Benefits of AI-Driven Automated Code Review in Agile Development

AI-powered automated code reviews are revolutionizing Agile development by enhancing efficiency, improving code quality, and boosting overall productivity. One of the most notable advantages is ensuring consistency in coding standards. AI-driven tools help maintain uniformity by enforcing best practices across development teams, reducing human errors and improving software reliability. By automating the detection of syntax errors, security vulnerabilities, and performance inefficiencies, these tools free up developers to focus on solving complex problems rather than spending time on routine checks. Another key benefit is increased developer productivity. [10] Traditional code reviews often require significant time and effort, potentially slowing down development cycles. AI-driven tools provide real-time feedback, allowing developers to promptly identify and fix issues, thereby accelerating Agile workflows. This immediate feedback is especially valuable in continuous integration and continuous deployment (CI/CD) environments, where speed and quality must go hand in hand. AI-driven code review tools also play a crucial role in minimizing technical debt. These tools proactively detect inefficient code patterns, outdated dependencies, and security risks before they become major concerns. Addressing such issues early in the development process helps reduce rework, enhance software maintainability, and ensure long-term scalability. [11].

1.2 Challenges of AI-Driven Automated Code Review in Agile Development

Despite its numerous advantages, integrating AI-driven automated code reviews into Agile development presents several challenges. One major issue is the accuracy of AI-generated feedback. These tools may produce false positives, flagging correct code as problematic, or false negatives, overlooking actual issues, which can frustrate developers and reduce trust in automation [12] . Additionally, AI tools often struggle with adapting to diverse coding styles and domain-specific requirements. Since AI models are trained on general datasets, they may not fully understand unique project needs, leading to incorrect or irrelevant suggestions . Another challenge is the potential over-reliance on automation, which may discourage developers from engaging in deep code analysis and critical thinking. While AI can streamline code review, it cannot fully replace human judgment, particularly for complex architectural decisions and nuanced code improvements. Moreover, implementing AI-driven code review tools requires significant initial investment in terms of cost, training, and integration into existing workflows. Some developers may also resist AI adoption, fearing job displacement or perceiving automation as intrusive rather than supportive. To overcome these challenges, organizations must establish a balanced approach where AI enhances, rather than replaces, human expertise. Continuous monitoring and fine-tuning of AI models, along with clear guidelines on AI-human collaboration, can help ensure that AI-driven code reviews contribute effectively to Agile development. [13].

1.3 Best Practices of AI-Driven Automated Code Review in Agile Development

To maximize the benefits of AI-driven code review, Agile teams should adopt best practices that enhance efficiency and ensure code quality. One key practice is integrating AI tools into continuous integration and continuous deployment (CI/CD) pipelines. This ensures that AI feedback is incorporated early in the development process, preventing the buildup of technical debt and minimizing extensive rework. Another crucial practice is maintaining a balance between AI automation and human oversight. While AI-driven tools efficiently detect coding issues, human developers provide contextual understanding and nuanced decision-making that AI lacks. Establishing a review process where AI suggestions are validated by experienced developers enhances accuracy and reliability. [14]. Customizing AI tools to align with specific project requirements is also essential. Organizations should fine-tune AI models based on their development standards, industry needs, and unique coding practices. Regular updates and refinements to AI algorithms improve their effectiveness in detecting relevant issues and offering meaningful recommendations. Encouraging collaboration between AI tools and development teams fosters greater acceptance and efficiency. Developers should be trained on how to leverage AI-driven insights effectively and understand how automated feedback complements traditional code reviews. A transparent approach that presents AI as an aid rather than a replacement helps build trust among developers and facilitates smoother adoption . Finally, continuous monitoring and improvement of AI tools are crucial for long-term success. Organizations should gather feedback from developers on AI performance, analyze trends in AI-generated reviews, and make necessary adjustments to enhance accuracy. Regular evaluations of AI's impact on code quality and development efficiency help teams refine their processes and maximize the value of AI-driven automated code reviews. [15]

II. REVIEW OF LITERATURE

2.1 Relvent Research

The adoption of AI-driven automation in Agile software development is rapidly transforming the industry, with large language models (LLMs) playing a key role in optimizing workflows. This research examines the effectiveness of multi-agent LLM systems in various software engineering tasks, including code generation, bug detection, documentation, and project management. By utilizing multiple AI agents that work collaboratively, we explore how automation enhances development efficiency while maintaining high code quality and adaptability. Our study implements and assesses a multi-agent framework, focusing on its impact on sprint planning, automated testing, and continuous integration pipelines. The findings reveal that multi-agent LLMs can significantly shorten development

cycles, boost team productivity, and offer real-time decision-making support, making them valuable assets in Agile environments. However, challenges such as model interpretability, the risk of error propagation, and the need for seamless collaboration between AI and human developers remain key concerns. [16].

Artificial Intelligence (AI) is transforming software development in high-tech companies by providing innovative tools and insights that enhance productivity, efficiency, and code quality. This review examines the role of AI in modern software development, focusing on its impact on key areas such as code generation, bug detection, project management, and testing. AI-powered tools enable developers to automate repetitive tasks, optimize code structure, and detect potential issues before they escalate, ultimately reducing development time and improving software reliability. Machine learning algorithms leverage data from previous projects to offer predictive analytics, helping teams make informed decisions and allocate resources effectively. Additionally, natural language processing (NLP) improves interactions with development tools, facilitating better communication and collaboration among team members. AI also plays a crucial role in enhancing continuous integration and continuous deployment (CI/CD) pipelines by automating testing and deployment processes. This minimizes human intervention while ensuring that code changes are seamlessly integrated and deployed. By embracing AI-driven automation, high-tech companies can adopt more agile methodologies, quickly adapt to market demands, and deliver high-quality software solutions. [17].

Integrating AI-driven performance metrics into agile software development can significantly enhance productivity, streamline workflows, and improve team collaboration. Traditional methods of evaluating developer performance often rely on outdated key performance indicators (KPIs) or subjective assessments that fail to capture real-time contributions accurately. AI-powered analytics provide a more objective and data-driven approach by analyzing coding patterns, pull request activity, issue resolution times, and overall collaboration dynamics. By utilizing machine learning models and natural language processing (NLP), AI-driven metrics offer deeper insights into both individual and team productivity while minimizing the biases associated with manual assessments. These tools can identify productivity trends, pinpoint workflow bottlenecks, and highlight areas where additional support or skill development is needed. Additionally, real-time feedback mechanisms allow developers to make informed adjustments, helping teams refine their processes and continuously improve efficiency. [18].

The integration of Artificial Intelligence (AI) into DevOps is transforming continuous integration and continuous deployment (CI/CD) pipelines by automating repetitive tasks, minimizing manual effort, and enhancing overall efficiency. AI-driven automation accelerates development cycles, reduces operational costs, and shortens time-to-market. By leveraging AI for automated code reviews, bug detection, and security testing, software quality improves while testing time is significantly reduced. AI-powered fault detection enables proactive issue identification and real-time resolution, minimizing downtime and ensuring system stability. Additionally, AI enhances deployment efficiency through automated release management, intelligent resource allocation, and predictive scaling. A comparison between traditional DevOps and AI-driven DevOps highlights substantial improvements in time-to-market and cost savings. With AI handling routine processes, DevOps teams can focus on strategic initiatives such as fostering innovation and streamlining software development. [19].

2.2 The role and applications of AI in agile workflows

While Agile methodologies have proven highly effective, the increasing complexity of software projects presents new challenges. Managing vast amounts of data and making rapid, informed decisions has become more demanding. AI addresses these challenges by automating repetitive tasks, providing predictive insights, and streamlining workflows within Agile environments. Specifically, AI enhances various Agile phases, such as sprint planning, resource management, and automated code reviews, all of which contribute to increased team efficiency and faster value delivery. AI is also gaining traction in automating routine tasks within Agile pipelines. For example, AI-powered tools assist in project tracking, bug detection, and code quality

assurance. By handling these time-consuming processes, AI allows Agile teams to focus on more strategic and creative aspects of development, such as problem-solving and feature enhancement. In AI-augmented Agile environments, automation reduces manual effort, significantly boosting overall productivity. Furthermore, AI-driven tools enhance team collaboration by integrating seamlessly with project management platforms, providing real-time updates, and generating automated reports, ensuring efficient communication across teams. [20]

Another significant advantage of AI in Agile development is its role in predictive analysis and decision-making. By analyzing historical project data, AI can identify potential bottlenecks, predict delays, and optimize resource allocation. These forecasting capabilities are particularly valuable in Agile projects, where flexibility and adaptability are crucial. AI-driven insights allow teams to plan sprints more effectively, ensuring that tasks are assigned based on accurate effort and resource estimations. Additionally, AI integration enhances continuous integration and continuous delivery (CI/CD) pipelines in Agile workflows. AI-driven systems streamline workflows by automating code testing and deployment, reducing the repetitive burden of manual validation. This not only improves software quality but also accelerates the feedback loop, allowing teams to deliver faster and more frequent updates. By embedding AI into CI/CD processes, organizations can enhance software reliability and provide customers with more timely and efficient system improvements. [21].

III. METHODOLOGY

3.1 . Research Design

This research follows a mixed-methods approach, integrating both qualitative and quantitative strategies to explore the advantages, challenges, and best practices associated with AI-driven automated code reviews in Agile development. To ensure a well-rounded analysis, the study will utilize surveys, case studies, and experimental evaluations.

3.2 Data Collection Methods

Surveys and Interviews

To gather insights from industry professionals, structured surveys and semi-structured interviews will be conducted with software developers, DevOps engineers, and Agile practitioners across different sectors. The primary focus will be to understand their experiences, perceptions, and opinions on the effectiveness of AI-powered code review tools.

Case Studies

This study will examine real-world cases of organizations that have incorporated AI-driven code review tools into their Agile workflows. The case studies will track the adoption journey, assess the influence on code quality, and evaluate its role in improving efficiency within Agile teams.

Experimental Evaluation

A controlled experiment will be carried out by integrating an AI-based code review tool into an Agile team's development process. Key performance indicators, including defect detection rates, review turnaround time, and developer productivity, will be measured and compared against traditional manual code review methods.

3.3 Data Analysis Methods

A. Qualitative Analysis

Data collected from interviews and case study reports will undergo thematic analysis to identify common patterns, challenges, and best practices related to AI-driven code reviews.

B. Quantitative Analysis

Survey responses will be examined using statistical techniques such as descriptive analysis and inferential testing. Additionally, experimental data will be analyzed using hypothesis testing to compare the effectiveness of AI-driven and manual code review processes.

IV. RESULTS

The integration of AI-driven automated code review tools into Agile development was assessed using both qualitative and quantitative approaches. The findings are grouped into three main areas: benefits, challenges, and best practices.

1. Advantages of AI-Driven Automated Code Review

The adoption of AI-powered code review tools brought notable improvements in efficiency, code quality, and teamwork. The key benefits observed include:

- **Faster Code Reviews**: AI tools significantly reduced the time required for manual code evaluations by automating repetitive tasks.
- **Better Code Quality**: Automated suggestions ensured consistency, helping to identify errors and security vulnerabilities early in the development cycle.
- **Increased Developer Productivity**: Developers were able to focus more on writing and refining code rather than spending excessive time on reviews.

2. Challenges Faced During Implementation

Despite its benefits, integrating AI-driven code review tools came with certain challenges, such as:

- **Accuracy Limitations**: AI tools occasionally struggled with identifying complex issues or making suggestions within the broader project context.
- **Compatibility with Legacy Systems**: Integrating AI-driven tools into existing workflows, particularly with older systems, posed technical difficulties.
- **Adoption Resistance**: Some team members were hesitant to embrace AI-driven reviews, fearing reduced human involvement in the development process.

3. Best Practices for Effective Integration

To maximize the effectiveness of AI-driven automated code review tools, the following best practices were identified:

- **Blended Approach**: AI tools should support, rather than replace, human expertise to ensure the best outcomes.
- **Ongoing Training & Updates**: Regular updates and continuous training help AI tools remain relevant and improve their performance.
- **Transparent Communication**: Clear discussions about the role of AI in the development process can help address concerns and encourage smoother adoption.

4.1 Benefits of AI-Driven Automated Code Review

One of the most significant advantages of AI-powered code review tools is the reduction in code review time. Traditional code reviews often require extensive manual effort, which can slow down the development process. AI tools streamline this by automating repetitive tasks such as detecting syntax errors, identifying coding standard violations, and suggesting improvements. This automation allows developers to spend less time on reviews and more time on actual coding, leading to improved time efficiency in the software development lifecycle.

Another crucial benefit is improved code quality. AI-driven tools provide consistent and standardized code analysis, reducing human errors and minimizing security vulnerabilities. By offering automated suggestions based on best practices and coding standards, these tools help developers maintain high-quality code throughout the development process. As a result, the overall software quality improves, reducing the chances of post-deployment issues and ensuring quality improvement in the final product.

Additionally, the integration of AI tools enhances developer productivity. Since developers no longer have to spend excessive time on tedious manual code reviews, they can focus more on core development tasks such as designing new features, optimizing performance, and resolving complex technical challenges. This shift enables teams to work more efficiently, accelerating project timelines and increasing overall productivity in software development.

By implementing AI-driven code review tools, Agile teams can achieve faster development cycles, maintain high code quality, and enhance the productivity of developers, ultimately leading to better software outcomes.

Table 1: Summary of Benefits from AI-Driven Automated Code Review

Benefit	Description	Impact Development
Reduction in Code Review Time	AI tools reduced manual code review time by automating repetitive tasks	Time Efficiency
Improved Code Quality	AI tools provided consistent suggestions, reducing errors and vulnerabilities.	Quality Improvement
Enhanced Developer Productivity	Developers were freed from tedious reviews, focusing more on feature development.	Productivity Increase

4.2 Key Challenges of AI-Driven Code Review Integration

One of the biggest challenges of AI-driven code review tools is accuracy. While these tools perform well in identifying syntax errors and enforcing coding standards, they often fall short when handling complex code logic that requires contextual understanding. As a result, AI may generate false positives or miss critical issues, requiring developers to manually verify and refine its suggestions. This can impact overall code quality, making it essential to combine AI assistance with human expertise to ensure more reliable code reviews. Another significant challenge is integration with legacy systems. Many organizations still rely on older software infrastructures that are not fully compatible with modern AI-powered tools. Implementing AI-driven code reviews in these environments often requires extensive customization, which can be both time-consuming and resource-intensive. If not managed properly, this integration process can disrupt workflows and slow down development, making it difficult to realize the full potential of AI assistance.

Resistance to change is another common hurdle when adopting AI-driven code reviews. Some developers may be skeptical about AI's role in the review process, fearing job displacement or a loss of control over code quality decisions. This hesitation can create friction within teams, slowing down adoption and reducing trust in AI-powered solutions. Without proper training and clear communication, organizations may struggle to integrate these tools effectively, leading to adoption barriers that hinder progress. Overcoming these challenges requires a strategic approach—leveraging AI as a supportive tool rather than a replacement, ensuring smooth system integration, and fostering a culture of adaptability within development teams.

Table 2: Key Challenges of AI-Driven Code Review Integration

Challenge	Description	Impact on Development
Tool Accuracy	AI tools occasionally missed complex issues or failed to offer context-sensitive suggestions.	Quality Limitations
Integration with Legacy Systems	Difficulty in integrating AI tools with existing or outdated systems.	Workflow Disruption
Resistance to Change	Some team members were hesitant to adopt AI-driven tools due to concerns over job displacement.	Adoption Barriers

4.3 Best Practices for Successful Integration

Table 3 describes the best practices for integrating AI-driven automated code review tools. A hybrid approach that blends AI assistance with human expertise, along with ongoing training and clear communication, helps achieve the desired outcomes in terms of efficiency, effectiveness, and team acceptance.

Table 3: Best Practices for Successful Integration

Best Practice	Description	Expected Outcome
Hybrid Approach	Combining human oversight with AI tools ensures better decision-making and code quality.	Balanced Development
Continuous Training	Regular updates and training of AI tools for adaptability and accuracy.	Improved tools Effectiveness
Clear Communication	Transparent discussions about AI tool integration to mitigate resistance.	Successful Adoption

V. CONCLUSION

The use of AI-driven automated code review tools in Agile development has brought noticeable improvements in efficiency, code quality, and developer productivity. By automating repetitive tasks, these tools help streamline the review process, ensure consistency, and identify security vulnerabilities early. However, some challenges remain, including occasional inaccuracies, difficulties in integrating with older systems, and resistance from developers who may be hesitant to rely on AI-driven evaluations. To fully leverage the advantages of AI-powered code reviews, organizations should adopt a balanced approach that combines AI insights with human expertise. This ensures that complex issues are accurately identified and resolved within the appropriate context. Regular training and updates will help AI tools stay relevant and effective, while clear communication about their role can ease concerns and encourage team-wide adoption. When implemented strategically, AI-driven code reviews can enhance development workflows, improve software quality, and contribute to a more efficient and productive Agile environment.

VI. RECOMMENDATIONS

To successfully integrate AI-driven automated code review tools into Agile development while overcoming challenges, organizations should consider the following strategies:

1. **Combine AI with Human Expertise**

   AI should enhance, not replace, human oversight in code reviews. While AI excels at detecting syntax errors and enforcing coding standards, it may struggle with complex logic. A hybrid approach, where AI handles repetitive tasks and developers provide contextual insights, ensures higher code quality and better decision-making.

2. **Invest in Continuous AI Training and Updates**

   Regular training and updates are essential to keep AI tools accurate, relevant, and aligned with evolving coding practices. Organizations should prioritize fine-tuning AI models based on real-world feedback to enhance their performance over time.

3. **Ensure Smooth Integration with Existing Systems**

   Compatibility with legacy infrastructure can be a challenge. Organizations should evaluate their current workflows and implement gradual integration strategies, such as using middleware or custom adapters, to avoid major disruptions and ensure seamless adoption.

4. **Promote Team-Wide Acceptance through Clear Communication**

   Developers may hesitate to adopt AI-powered tools due to concerns about job security or reduced control over the review process. Transparent discussions about AI's role as a supportive tool can help ease these concerns. Hands-on training and clear demonstrations of AI's benefits can further encourage adoption.

5. **Implement a Validation Process for AI Suggestions**

Since AI-generated recommendations may include false positives or miss context-specific issues, organizations should establish a review mechanism where developers validate AI-suggested changes before implementation. This ensures accuracy and prevents potential coding errors from being introduced.

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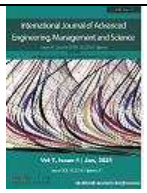

Job Satisfaction Determinants Among Faculty Members: A Comprehensive Analysis of College of Management and Business Technology

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Abstract *— This study explores the job satisfaction of faculty members at the College of Management, Business, and Technology (CMBT). The results indicate high satisfaction levels regarding compensation, recognition, and work-life balance, with faculty members feeling particularly valued by their superiors, colleagues, and students. Opportunities for career growth and the work environment also received positive feedback, though to a slightly lesser extent. Interpersonal relations were highly rated, suggesting strong professional connections within the faculty. This study provides valuable insights into the factors influencing job satisfaction among CMBT faculty, offering guidance for institutional policies to enhance faculty well-being and professional fulfillment.*

Keywords **— Career growth, Compensation, Faculty members, Job satisfaction, Work-life balance**

I. INTRODUCTION

Job satisfaction is a critical factor in the performance, retention, and overall well-being of faculty members in higher education institutions. It encompasses various aspects of an individual's work life, including the nature of the work, relationships with colleagues, opportunities for professional growth, and compensation (Spector, 1997). In the College of Management and Business Technology, understanding job satisfaction levels among faculty members is vital for ensuring a supportive and productive academic environment.

Recent studies have highlighted the significance of job satisfaction in higher education, linking it to both personal and institutional outcomes. For instance, job satisfaction among faculty members has been shown to correlate with higher levels of teaching effectiveness, research productivity, and student satisfaction (Johnsrud, 2017; Bentil et al., 2020). Conversely, low job satisfaction can lead to higher turnover rates, reduced morale, and diminished institutional reputation (Kusku, 2020).

Faculty members in the fields of management and business technology may experience unique job satisfaction determinants due to the dynamic and evolving nature of these disciplines. Rapid technological advancements and changes in business practices require continuous learning and adaptation, which can influence job satisfaction levels.

A study by Hagedorn (2019) explored job satisfaction among business faculty and found that engagement with current industry practices and opportunities for consulting work significantly enhance job satisfaction. Furthermore, the relevance of their academic work to real-world applications contributes to a sense of accomplishment and satisfaction.

In the realm of business technology, faculty members often face the challenge of keeping up with rapid technological changes. According to Rehman et al. (2021), institutions that provide adequate resources for technology integration and continuous

professional development in emerging technologies report higher job satisfaction among their faculty members.

Recent literature has highlighted several emerging trends and challenges affecting job satisfaction in higher education. The increasing reliance on adjunct and part-time faculty has raised concerns about job security and equitable compensation, which directly impact job satisfaction (Kezar & Maxey, 2018). Additionally, the COVID-19 pandemic has introduced new stressors, such as the need for remote teaching and balancing work-life demands, which have affected faculty job satisfaction (Johnson et al., 2021).

This study aims to investigate the job satisfaction of faculty members within the College of Management and Business Technology. By identifying the factors that contribute to or detract from job satisfaction, the study seeks to provide insights that can inform policy and practice within the college, ultimately enhancing the work environment and supporting faculty members' professional growth and well-being.

II. METHODOLOGY

This study employs a quantitative research design to assess the job satisfaction levels among faculty members of the College of Management and Business Technology in terms of compensation, recognition, promotion, and opportunity for growth, work environment, work-life balance, and interpersonal relations. A survey methodology is utilized to collect data from the participants, ensuring a systematic and comprehensive examination of the various dimensions of job satisfaction.

The target population for this study includes all full-time faculty members employed at the College of Management and Business Technology. A stratified random sampling technique will be used to ensure representation across different departments and academic ranks within the college.

The questionnaire with 4-point Likert scale are distributed electronically via Google Form with follow-up reminders sent to maximize response rates. Participation in the survey will be voluntary, and confidentiality will be maintained throughout the study.

Table 1 Table of Equivalence

Score	Data Analysis Parameter	Verbal Interpretation	Qualitative Description
4	3.25-4.00	Strongly Agree	Very Satisfied
3	2.50-3.24	Agree	Satisfied
2	1.75-2.49	Disagree	Dissatisfied
1	1.00-1.74	Strongly Disagree	Very Dissatisfied

III. RESULTS AND DISCUSSION

Table 2 Profile of CMBT Faculty Members

Sex		
Male	12	34.29%
Female	23	65.71%
Age		
21-30	4	11.43%
31-40	8	22.86%
41-50	18	51.43%
51-60	4	11.43%
61-above	1	2.86%
Status of Appointment		
Regular	35	100.00%
Years in Service		
1-5	5	14.29%
6-10	12	34.29%
11-15	9	25.71%
16-20	2	5.71%
20 and above	7	20.00%
Academic Rank	**Frequency**	**Percentage**
Instructor	5	14.29%
Assistant Professor	8	22.86%
Associate Professor	19	54.29%
Professor	3	8.57%
Educational Attainment		
with Doctorate Units	13	37.14%
Doctorate Degree	22	62.86%

The majority of faculty members are female, comprising approximately 65.71% of the total, while males account for 34.29%. This gender distribution indicates a significant female representation among the faculty members. This could reflect broader trends in educational employment, where certain fields may see higher female participation.

The age distribution highlights that a substantial portion of the faculty is in the middle age bracket of 41-50 years. This age group typically encompasses individuals with significant professional experience and possibly at the peak of their academic careers. The smaller representation of younger (21-30) and older (61 and above) faculty members suggests limited recent hiring and fewer faculty working past the typical retirement age. The diversity in age can bring varied perspectives and mentoring opportunities within the faculty.

All faculty members have a regular appointment status, indicating job stability and potentially contributing positively to job satisfaction. This stability is likely to contribute positively to job satisfaction, as faculty members can focus on their teaching and research activities without the uncertainty of contract renewals. It also suggests that the institution values and invests in long-term faculty development, which can enhance the overall academic environment.

The distribution of years in service reveals that the faculty has a blend of relatively new and highly experienced members. The largest group has been in service for 6-10 years, indicating a period where a significant number of faculty were likely hired. The presence of faculty with over 20 years of service demonstrates institutional loyalty and a depth of experience. Such a range can foster mentorship opportunities and the transfer of institutional knowledge. However, it also suggests the need for succession planning and career development opportunities for newer faculty members to maintain continuity and motivation across all service years.

The predominance of Associate Professors suggests that many faculty members are in the mid-stages of their academic careers, having progressed beyond the initial ranks. This could be a reflection of the institution's promotion policies and the faculty's achievements. The smaller number of full Professors might indicate stringent promotion criteria or a relatively younger institution. The distribution of academic ranks can influence job satisfaction, as it affects faculty members' roles, responsibilities, and professional development opportunities. Ensuring clear pathways for promotion and professional growth is crucial for maintaining high job satisfaction levels.

A significant proportion of the faculty members have attained a Doctorate Degree (62.86%), with the remaining 37.14% holding Doctorate Units. This high level of educational attainment is likely a positive factor in job satisfaction and academic quality.

Table 3 Job Satisfaction in terms of Compensation

Statement	Weighted Mean	Verbal Interpretation	Qualitative Description
I am satisfied with my salary.	3.27	Strongly Agree	Very Satisfied
I am satisfied with the bonuses I received	3.34	Strongly Agree	Very Satisfied
Average Weighted Mean	**3.30**	**Strongly Agree**	**Very Satisfied**

Table 3 shows that the respondents agreed that they are very satisfied in terms of salary (3.27), and bonuses (3.34) they received.

The overall weighted mean of 3.30 means that the employees of NEUST CMBT are very satisfied in terms of compensation. This high level of satisfaction in compensation is consistent with studies that identify fair remuneration as a critical factor for job satisfaction (Parker & Wright, 2016) and that competitive compensation is critical for job satisfaction in academia (Liu et al., 2021).

Table 4 Job Satisfaction in terms of Recognition

Statement	Weighted Mean	Verbal Interpretation	Qualitative Description
I feel valued, recognized and appreciated by my superior.	3.30	Strongly Agree	Very Satisfied
I feel valued, recognized and appreciated by my co-workers.	3.31	Strongly Agree	Very Satisfied
I feel valued, recognized and appreciated by my co-workers from other departments.	3.01	Agree	Satisfied
I feel valued, recognized and appreciated by my students	3.25	Strongly Agree	Very Satisfied
Average Weighted Mean	**3.22**	**Agree**	**Satisfied**

Table 4 shows that the respondents strongly agreed that are very satisfied with their job at NEUST because they feel valued, recognized, and appreciated by their superior (3.30), co-workers, (3.31) and students (3.25), while they are satisfied with the recognition of their co-workers from other departments (3.01).

Based on this, it can be gathered from the overall weighted mean of 3.22, with a verbal interpretation of "agree" that employees for NEUST CMBT are satisfied with the recognition that they received from the community. The overall satisfaction mean of 3.22 indicates general contentment with recognition, aligning with findings that recognition is vital to job satisfaction (Bishop, 2018).

Table 5 Job Satisfaction in terms of Promotion and Opportunity for Growth

Statement	Weighted Mean	Verbal Interpretation	Qualitative Description
I am satisfied with my job because I have opportunities for career growth	3.29	Strongly Agree	Very Satisfied
I am satisfied with my job because I have opportunities for positional advancement/ promotion	3.00	Agree	Satisfied
Average Weighted Mean	**3.15**	**Agree**	**Satisfied**

Table 5 shows that the respondents strongly agreed that they were very satisfied because they have opportunity for career growth (3.29) while they agreed on the concern for positional advancement or promotion (3.00). The overall satisfaction mean of 3.15 indicates general satisfaction, though clearer promotion pathways are necessary. (Guthrie et al., 2020).

Table 6 Job Satisfaction in terms of Work-Life Balance

Statement	Weighted Mean	Verbal Interpretation	Qualitative Description
I'm satisfied with my job because it helps me find the ideal balance between my:			
work responsibilities	3.33	Strongly Agree	Very Satisfied
life responsibilities	3.40	Strongly Agree	Very Satisfied
AverageWeighted Mean	**3.36**	**Strongly Agree**	**Very Satisfied**

Table 6 shows that the respondents strongly agreed that they were very satisfied with their jobs because they have a balance with work responsibilities (3.33) and life responsibilities (3.40).

The overall satisfaction mean of 3.15 reflects general satisfaction in this area, though the need for clearer promotion pathways is evident, as supported by research on career development and job satisfaction (Smith & Jones, 2020).

Table 7 Job Satisfaction in terms of Work Environment

Statement	WM	Verbal Interpretation	Statement
I find my organization a good place to work because it provides me:			
appropriate level of privacy	3.00	Agree	Satisfied
sound control in the workplace	2.99	Agree	Satisfied
Adequate materials to use for work	3.20	Agree	Satisfied
good physical condition of the workplace	3.25	Strongly Agree	Very Satisfied
Average Weighted Mean	**3.11**	**Agree**	**Satisfied**

Table 7 shows that the respondents agreed that they were satisfied with their jobs because it provides them an appropriate level of privacy (3.00), sound control of the workplace (2.99) and adequate materials to use for work (3.20). the respondents strongly agree, however, that they are very satisfied with the good physical condition of the workplace (3.25)

The overall mean of 3.11 suggests general satisfaction, though improvements in privacy and sound control could enhance job satisfaction further (Oldham & Fried, 2016).

Table 8 Job Satisfaction in terms of Interpersonal Relations

Statement	WM	Verbal Interpretation	Statement
I am satisfied with my job because I have good relationship with:			
the students	3.33	Strongly Agree	Very Satisfied
the parents	3.06	Agree	Satisfied
my colleagues	3.33	Strongly Agree	Very Satisfied
the administrators	3.27	Strongly Agree	Very Satisfied
Average Weighted Mean	**3.25**	**Strongly Agree**	**Very Satisfied**

Table 8 shows that the respondents strongly agreed that are very satisfied with their job at NEUST because they have good relationship with students (3.33), colleagues (3.33) and the administrators (3.27) while they are satisfied with their relationship with parents (3.06).

The overall mean of 3.25 indicates that positive interpersonal relations are a significant factor in job satisfaction, corroborating studies on workplace relationships (Friedman et al., 2014).

IV. CONCLUSION

The study reveals that faculty members of CMBT are generally satisfied with various aspects of their job, including compensation, recognition, promotion opportunities, work-life balance, work environment,

and interpersonal relations. Compensation and work-life balance are particularly strong areas, indicating that these factors play a significant role in faculty satisfaction. Recognition and interpersonal relations also contribute positively to job satisfaction, though there is a slight need for improved recognition from colleagues in other departments. Promotion and growth opportunities, as well as certain aspects of the work environment, such as privacy and sound control, show potential areas for improvement.

V. RECOMMENDATIONS

o enhance faculty job satisfaction, several key areas should be addressed. First, promotion opportunities should be improved by establishing clearer career advancement pathways and providing more positional promotions, ensuring faculty members feel recognized for their contributions. Additionally, the work environment can be refined by addressing concerns related to privacy and sound control, fostering a more comfortable and productive workspace. Strengthening interdepartmental recognition is also essential, as fostering a culture of appreciation across departments can enhance faculty members' sense of value and acknowledgment. Moreover, continuous professional development should be encouraged, supporting faculty in maintaining high educational attainment and overall job satisfaction. Lastly, work-life balance initiatives must continue to be prioritized, as maintaining a healthy balance between professional and personal life plays a crucial role in faculty well-being. By implementing these improvements, institutions can further enhance faculty satisfaction and professional fulfillment.

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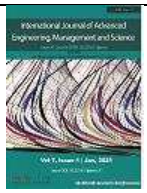

Women's Economic Empowerment through Microfinance - Role of Cooperative Banks of Maharashtra and Karnataka: A Comparative Analysis

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Abstract *– Economic empowerment is a critical driver for achieving gender equality, poverty reduction, and inclusive growth. This study examines the pivotal role of District Central Cooperative (DCC) Banks in empowering women through Self-Help Groups (SHGs) in Maharashtra and Karnataka. By analyzing secondary data from NABARD reports and other scholarly sources, the research compares the growth trajectories, savings patterns, and loan disbursement trends across the two states from 2018-19 to 2022-23. The findings reveal that Maharashtra experienced rapid SHG expansion and increased loan disbursement, while Karnataka maintained higher per-group financial support despite slower growth. The study underscores the importance of cooperative banks in enhancing financial access, promoting savings, and facilitating credit for women SHGs, ultimately contributing to their economic empowerment. Recommendations include targeted regional strategies, financial literacy programs, and digital banking solutions to sustain and expand women's financial inclusion.*

Keywords *– **Economic Empowerment, Self-Help Groups (SHGs), Cooperative Banks, Women's Financial Inclusion, District Central Cooperative Banks***

I. INTRODUCTION

Economic empowerment is defined as women's and men's ability to participate in and contribute to the growth process in ways that recognise the value of their contributions, respect their dignity, and allow for a more equitable distribution of the benefits of growth. ''Economic empowerment increases women's access to economic resources and opportunities including jobs, financial services, property and other productive assets, skill development and market information''(Eyben, R and others 2008).

Social and economic progress is closely linked with women's development, since women account for half of the Indian population. Economic empowerment for women sets the direct way to equality between the genders, eradication of poverty and inclusive economic growth. Women make an enormous to economies, whether in business, in farms, as entrepreneurs or as employees or through unpaid home care. Improving the economic conditions of Indian women, the District Central Cooperative Banks played an important role in providing them with financial opportunities.

A report by the National Bank for Agriculture and Rural Development (NABARD) in 2022 emphasized that women-led cooperatives play a crucial role in improving family and community wellbeing by expanding access to essential services.

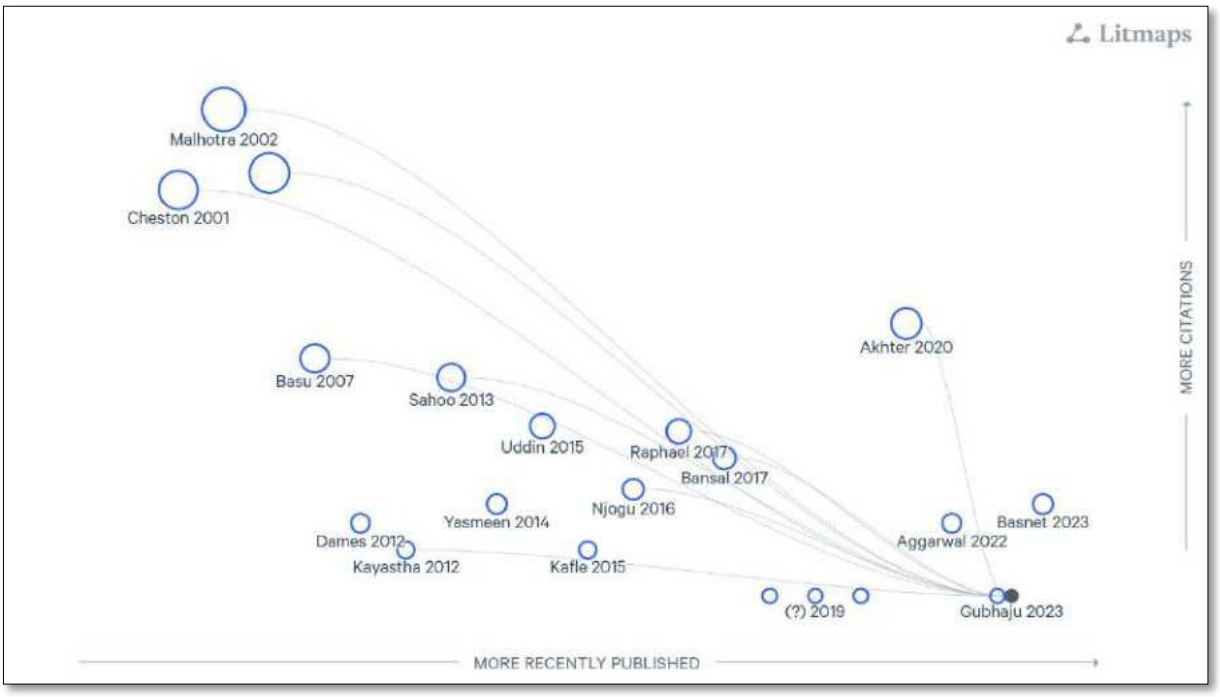
II. REVIEW OF LITERATURE

Numerous studies have been conducted to assess the impact of microfinance on women's economic empowerment. Several studies have found that microfinance benefits women's economic and social empowerment. Table 1.1 summarises key studies on microfinance and economic empowerment of women:

Table 1 Summarises key studies on microfinance and economic empowerment of women:

Author	Year	Country/ State	Theme/Focus	Results
Rajiv Gubhaju	2023	India	The impact of microfinance on women's empowerment in Rautahat district.	Microfinance has brought significant impact on empowerment of women. Based on these findings, microfinance emerges as a vital tool for poverty reduction and driving social change, which are key factors in promoting women's empowerment. The study highlights the significant role of self-help group microfinance empowering women.
Sanjeev Kumar	2022	India	The benefits of self-help groups achieving women empowerment	Women being members of self-help groups experience an improved standard of living and greater educational awareness for their children. They become active contributors to social development rather than passive observers. The increased financial benefits from these groups directly enhance the socio-economic development of women.
Dr. Deepak S. Vede	2021	India Maharashtra	Women empowerment from the view point of economic growth	Economic growth reduces poverty, and women's situations improve in two ways: poverty is reduced, and gender inequality is reduced.
Dr. Jutika Medhi	2021	India	Effectiveness of SHGs in economic empowerment of women	From formation of SHGs increases the savings of the women and thus their economic independencies increase over period of time. Income generation among the women beneficiaries are high due to which their economic conditions also improved.
Smt. Ranjitha BR & Dr. Devrajappa S	2020	India Karnataka	Role of Cooperative Banks empowering women though SHGS	Cooperative banks play an important role in increasing the income of the poor, particularly women. Women have a higher economic participation rate than men.
Dr S. Frankilin Johan, Ms. Nilufar Sathiq	2020	India Kerala	Kudumbashree activities for women's economic empowerment in Ottapalm municipality	Only few entrepreneurial activities are undertaken by the members of Kudumbashree and there is significant difference in their attitude towards women empowerment based on their year of association
Dr Shurti	2019	India	Bank initiatives in	Banks, through various schemes, provide women

Jha			India to promote financial inclusion and women's empowerment	with assistance for earning their livelihoods with the aim of making them self-sufficient.
Rashmi Singel	2018	India Haryana	Micro financing delivered through Banks and MFI's have helped women to achieve economic empowerment in rural areas.	Micro financing has led to economic empowerment of rural women in India. Results of the Anova model, T-test showed that demographic factors like age, family income, had a positive and significant influence on economic empowerment of rural women availing micro financing.



1. Objectives of the Study:

On the basis of the gaps found in the literature review, the research study's objectives were established as follows:

1. To assess the role of Cooperative banks in the economic empowerment of women.

2. To study and compare the economic empowerment of women provided by DCC banks in Maharashtra and Karnataka.

III. RESEARCH METHODOLOGY

Maharashtra and Karnataka were selected for a comparative analysis on the study as of their extensive cooperative banking systems, high SHG engagement, and major contributions to India's GDP. Both states are leaders in women-cantered microfinance, with Maharashtra supporting over 400,000 SHGs and Karnataka 320,000, enabling broad rural reach. State policies, such as Maharashtra's "Maha SHG Credit Scheme" and Karnataka's "Udyogini Scheme," further enhance women's economic empowerment. By 2024, cooperative banks in these states have granted financial access to nearly 2 million rural women, improving income, education, and healthcare, making them ideal for this

To meet the objectives of the study, the researcher used secondary data. The main data is taken from the status report of NABARD's microfinance annual

reports. Other data have been collected from different journals and various publications from other agencies.

IV. DATA ANALYSIS AND INTERPRETATION

The Role of Cooperative Banks in Economic Empowerment of Women through SHGs

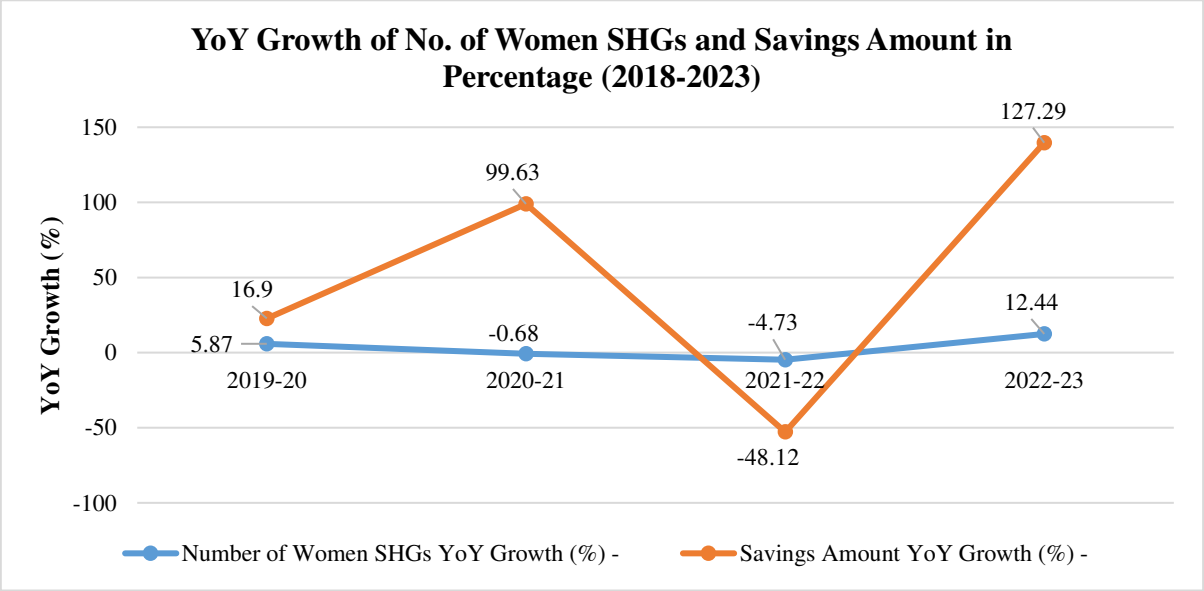


Fig.1 Year over Year Growth of No. of Women SHGs and Savings Amount in Percentage (2018-2023)

(₹ in Lakhs)

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

Figure 01 illustrates the trends in the growth of Women Self-Help Groups (SHGs) and their collective savings over five financial years, from 2018-19 to 2022-23. The number of SHGs initially grew from 13.08 lakh in 2018-19 to 13.85 lakh in 2019-20, reflecting a 5.87% year-on-year (YoY) increase. However, the following years saw slight fluctuations — a minor decline of -0.68% in 2020-21 and a more pronounced drop of -4.73% in 2021-22. By 2022-23, SHG numbers rebounded to 14.7 lakh, marking a strong 12.44% recovery.

Savings trends exhibited greater volatility. A significant surge of 99.63% was observed in 2020-21, followed by a sharp decline of -48.12% in 2021-22. The momentum shifted positively again in 2022-23, with savings soaring by 127.29%, reaching ₹5,70,417.10 lakh — signalling a robust revival.

Overall, while SHG membership experienced moderate fluctuations, savings patterns displayed more pronounced year-to-year variability, reflecting the dynamic economic environment and resilience of women's collective financial initiatives.

Figure 02 depicts fluctuating trends in the number of Women Self-Help Groups (SHGs) and the loan amounts disbursed from 2018-19 to 2022-23. The number of SHGs saw a modest rise in 2019-20 but declined in subsequent years, with a significant drop in 2021-22. Despite this, loan disbursements exhibited consistent growth, culminating in a sharp rise in 2022-23. That year saw a notable rebound, with SHG numbers increasing by 21% and loan disbursements surging by 31.88%. This trend indicates a continued emphasis on enhancing financial support to women's groups, even as their numbers experienced periodic declines.

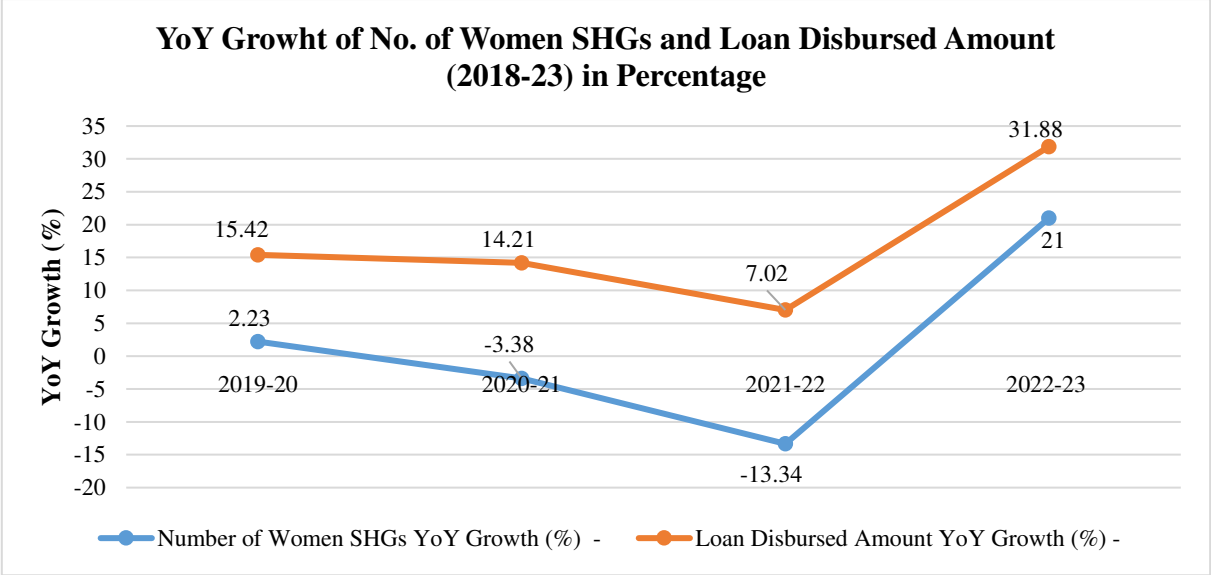


Fig.2 Year over Year Growth of No. of Women SHGs and Loan Disbursed Amount (2018-23) in Percentage

(Amount ₹ Lakh)

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

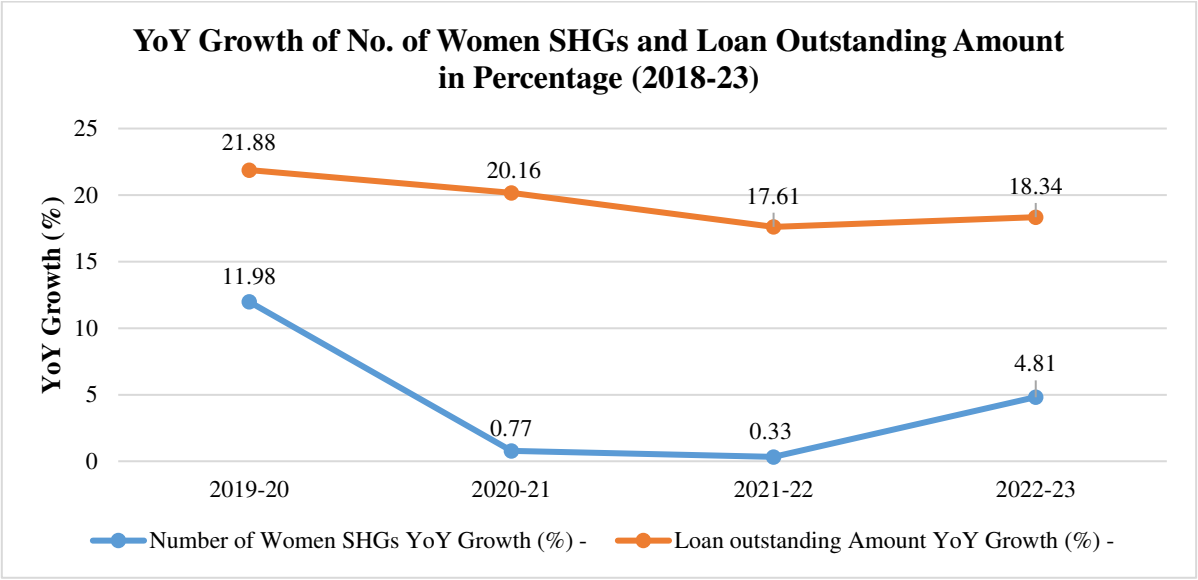


Fig.3 YoY Growth of No. of Women SHGs and Loan Outstanding Amount in Percentage (2018-23) (Amount ₹ Lakh)

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

Figure 03 showcases the growth in the number of Women Self-Help Groups (SHGs) and the loan outstanding amounts over five financial years from 2018-19 to 2022-23. The number of SHGs demonstrated consistent, albeit slowing, growth — rising from 4.49 lakh in 2018-19 to 5.03 lakh in 2019-20, marking an 11.98% year-on-year (YoY) increase. Growth rates then tapered, with marginal rises of 0.77% in 2020-21 and 0.33% in 2021-22. By 2022-23, SHG numbers reached 5.33 lakh, reflecting a more substantial 4.81% increase.

In parallel, the loan outstanding amounts grew steadily, starting from ₹4,96,511.84 lakh in 2018-19. Each year saw notable growth, with rates ranging between 17.61% and 21.88%. By 2022-23, the total loan outstanding had more than doubled, reaching ₹10,10,288.48 lakh — underscoring sustained

expansion in credit availability to SHGs, even as the rise in group numbers slowed.

Table.1 the Role of DCC Banks in Number of SHGs and Saving Amount Comparative Analysis

(Amount ₹ Lakh)

Sr. No	Year	Maharashtra State			Karnataka State		
		Number of women SHGs	Saving amount	Saving Amount Per SHG	Number of women SHGs	Saving amount	Saving Amount Per SHG
1	2018-19	3,37,925	39,397.90	0.12	2,24,966	42,385.22	0.19
2	2019-20	3,99,613	42,028.52	0.11	2,35,356	42,748.68	0.18
3	2020-21	3,59,231	1,42,981.04	0.40	2,41,009	46,419.15	0.19
4	2021-22	3,67,754	37,362.85	0.10	2,42,771	50,382.02	0.21
5	2022-23	14,73,363	5,70,417.10	0.39	2,55,897	48,648.04	0.19
CAGR (%)		44.50	95.07	-	3.27	3.51	-
Average		-	-	0.22	-	-	0.19

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

Table 01 highlight contrasting growth trends in Women Self-Help Groups (SHGs) and total savings between Maharashtra and Karnataka from 2018-19 to 2022-23.

Maharashtra witnessed remarkable expansion, with a Compound Annual Growth Rate (CAGR) of 44.50%. The number of SHGs surged from 3.37 lakh in 2018-19 to 14.73 lakh in 2022-23, while total savings skyrocketed from ₹39,397.90 lakh to ₹5,70,417.10 lakh. Savings per SHG fluctuated during this period, peaking at ₹0.40 lakh in 2020-21, with an overall average of ₹0.22 lakh.

In contrast, Karnataka experienced slower growth, with a modest CAGR of 3.27%. SHG numbers rose from 2.25 lakh in 2018-19 to 2.56 lakh in 2022-23, and total savings increased from ₹42,385.22 lakh to ₹48,648.04 lakh. Savings per SHG remained steady, averaging ₹0.19 lakh throughout the years.

The data underscores Maharashtra's rapid expansion in both SHG formation and savings accumulation, while Karnataka maintained stability with gradual growth.

Table 02 compares loan disbursement trends for Women Self-Help Groups (SHGs) in Maharashtra and Karnataka from 2018-19 to 2022-23, highlighting contrasting growth patterns.

Maharashtra experienced remarkable growth in loan disbursement per SHG, rising from ₹0.71 lakh in 2018-19 to ₹3.13 lakh in 2022-23, driven by an impressive Compound Annual Growth Rate (CAGR) of 123.6%. The number of SHGs expanded significantly, from 42,369 in 2018-19 to 2,41,142 in 2022-23, reflecting a substantial increase in outreach and financial inclusion. The average loan disbursed per SHG over the five years stood at ₹1.23 lakh.

Karnataka, on the other hand, showed moderate but steady growth. Loan disbursement per SHG increased from ₹2.75 lakh in 2018-19 to ₹4.49 lakh in 2022-23, with a CAGR of 24.5%. Total loan disbursement rose from ₹82,646.59 lakh to ₹1,98,374.51 lakh over the period. Notably, Karnataka consistently maintained a higher loan amount per SHG than Maharashtra, with an average loan disbursement per SHG of ₹3.62 lakh.

The data underscores Maharashtra's rapid expansion in SHG numbers alongside growing loan support, while Karnataka sustained a more stable, higher loan-per-group model, prioritizing larger credit access to fewer groups.

Table No. 02: The Role of DCC Banks in Number of SHGS and Loan Disbursed Comparative Analysis

(Amount ₹ Lakh)

Sr. No	Year	Maharashtra State			Karnataka State		
		Number of women SHGs	Loan disbursed during the year	Loan disbursed during the year per SHG	Number of women SHGs	Loan disbursed during the year	Loan disbursed during the year per SHG
1	2018-19	42,369	30,231.30	0.71	30,103	82,646.59	2.75
2	2019-20	48,966	33,832.39	0.69	34,271	1,13,792.19	3.32
3	2020-21	30,688	23,670.19	0.77	32,332	1,15,150.43	3.56
4	2021-22	32,585	27,558.46	0.85	32,136	1,27,555.45	3.97
5	2022-23	2,41,142	7,55,049.95	3.13	44,204	1,98,374.51	4.49
CAGR (%)		54.4	123.6	-	10.1	24.5	-
Average (Rs. In Lakh)		-	-	1.23	-	-	3.62

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

Table.3: The Role of DCC Banks in Number of SHGS and Loan Outstanding Comparative Analysis

(Amount ₹ Lakh)

Sr. No	Year	Maharashtra State			Karnataka State		
		Number of women SHGs	Total Bank Loan Outstanding during the year	Total Bank Loan Outstanding during the Year per SHG	Number of women SHGs	Total Bank Loan Outstanding during the year	Total Bank Loan Outstanding during the Year per SHG
1	2018-19	52,042	22,858.45	0.44	65,801	1,04,163.91	1.58
2	2019-20	30,161	27,509.50	0.91	69,544	1,25,773.97	1.81
3	2020-21	34,042	31,272.43	0.92	68,199	1,50,994.63	2.21
4	2021-22	30,952	28,979.53	0.94	75,663	1,80,995.62	2.39
5	2022-23	5,32,851	10,10,288.48	1.90	84,104	2,39,176.62	2.84
CAGR (%)		78.9	157.8	-	6.3	23.1	-
Average (Rs. In Lakh)		-	-	1.02	-	-	2.17

Source: Status of Microfinance Report of NABARD (2018-19 to 2022-2023)

Table 03 compares the total bank loan outstanding for Women Self-Help Groups (SHGs) in Maharashtra and Karnataka from 2018-19 to 2022-23, revealing notable differences in growth patterns.In Maharashtra, SHG numbers surged from 52,042 in 2018-19 to 5,32,851 in 2022-23. Total bank loan outstanding saw an extraordinary rise from ₹22,858.45 lakh to ₹10,10,288.48 lakh over the same period. Loan per SHG increased sharply from ₹0.44 lakh in 2018-19 to ₹1.90 lakh in 2022-23, reflecting an

impressive Compound Annual Growth Rate (CAGR) of 157.8%. The average loan outstanding per SHG during this period stood at ₹1.02 lakh. In Karnataka, SHG numbers grew more gradually, from 65,801 in 2018-19 to 84,104 in 2022-23. Total loan outstanding increased from ₹1,04,163.91 lakh to ₹2,39,176.62 lakh. Loan per SHG rose from ₹1.58 lakh in 2018-19 to ₹2.84 lakh in 2022-23, with a CAGR of 23.1%. The average loan outstanding per SHG was ₹2.17 lakh — consistently higher than Maharashtra's.The data highlights Maharashtra's rapid expansion in SHG numbers and total loan support, reflecting a large-scale push for financial inclusion. Karnataka, by contrast,maintained slower but stable growth, with higher loan outstanding per SHG, suggesting a focus on deeper financial backing for each group.

V. FINDINGS OF THE STUDY

- **Growth and Fluctuation in SHGs and Savings Across Years**

From 2018-19 to 2022-23, Women Self-Help Groups (SHGs) demonstrated overall growth**,** despite yearly fluctuations. SHG numbers initially increased, faced a slight decline, and then rebounded significantly by 2022-23. Total savings followed a similarly volatile trajectory — showing notable growth in 2020-21**,** a decline in 2021-22, and a strong recovery in 2022-23**.** This pattern reflects resilient efforts to rebuild and expand group savings after periods of instability.

- **Loan Disbursement Trends**
  Loan disbursement amounts consistently increased year-over-year, signaling growing financial support to women SHGs. The YoY growth in loans was especially pronounced in 2022-23, demonstrating a marked increase in access to credit for SHGs despite some volatility in the number of SHGs. This suggests a focused attempt by cooperative banks to strengthen women's economic empowerment through steady loan disbursements.
- **Growth in Loan Outstanding Amounts**
  Both Maharashtra and Karnataka saw growth in SHG loan outstanding amounts, although at differing rates. The total outstanding amounts in Maharashtra grew significantly more rapidly than in Karnataka, with a much higher CAGR. This indicates that Maharashtra's SHGs are accumulating larger loan balances, possibly due to higher borrowing needs or increased lending limits by cooperative banks, compared to Karnataka.
- **Comparison Between Maharashtra and Karnataka in SHG Savings and Loan Disbursements**
  Maharashtra experienced a much higher growth rate in both SHG numbers and total savings compared to Karnataka. The savings per SHG in Maharashtra varied, peaking in 2020-21, while Karnataka's savings per SHG remained relatively consistent. For loan disbursements, Maharashtra's growth rate in loan amounts per SHG was markedly higher, indicating significant expansion of financial services. However, Karnataka consistently provided a higher loan amount per SHG, suggesting stronger per-group financial support in Karnataka.
- **Loan Outstanding Comparison Between Maharashtra and Karnataka**
  Maharashtra saw substantial growth in total bank loan outstanding per SHG, with a high CAGR in loan per SHG over five years, reflecting increasing financial dependency or banking support. Karnataka's growth was more moderate, yet it maintained a consistently higher loan per SHG, emphasizing quality over quantity in its support structure.

VI. RECOMMENDATIONS

- Enhance Cooperative Banks' Support to Women SHGs for Economic Empowerment
  Cooperative banks should strengthen their financial services for Women SHGs by providing consistent and adaptable credit support, especially during periods of economic uncertainty. Programs that offer flexible loan terms, repayment holidays, or lower interest rates during difficult times can stabilize savings and help SHGs manage financial volatility, as seen in the fluctuating savings and loan growth patterns from 2018-19 to 2022-23.
- Adopt Targeted Approaches for Regional Growth in Maharashtra and Karnataka
  Given the high growth in Maharashtra and the slower, steady expansion in Karnataka, cooperative banks should implement customized

regional strategies to optimize SHG empowerment. In Maharashtra, banks could focus on financial literacy and investment programs to ensure effective utilization of the rapidly growing loans and savings. In Karnataka, banks should focus on expanding SHG numbers and increasing credit access, given the region's higher average loan per SHG but more gradual SHG growth.

- Strengthen Financial Literacy and Savings Incentives in Maharashtra
  With Maharashtra's savings per SHG displaying significant growth but also variability, cooperative banks should emphasize financial literacy programs that encourage SHGs to consistently save and reinvest. Introducing incentives like savings-linked rewards or matching contributions could help stabilize savings rates and foster sustainable financial growth.
- Increase Loan Accessibility and Responsiveness in Karnataka
- While Karnataka's SHGs receive a higher average loan per SHG, there is room for growth in SHG numbers and total loans. Cooperative banks should work to streamline loan access procedures and increase outreach efforts, especially in underserved areas. Additionally, cooperative banks could offer higher credit limits and streamlined loan renewal processes to help SHGs expand their operations more effectively.
- Promote Digital and Financial Inclusion for Both States
  Digital banking solutions tailored for SHGs could simplify transactions and loan management, particularly for rural SHGs that may have limited access to physical bank branches. Cooperative banks should develop mobile apps or online portals that allow SHGs to view balances, manage loans, and receive alerts on savings opportunities. Such digital solutions would enhance accessibility and improve financial tracking for SHGs in both Maharashtra and Karnataka.
- Expand Training Programs for Sustainable SHG Management and Growth
  To maximize the benefits of loans and savings, cooperative banks should introduce training programs focused on sustainable business practices, including entrepreneurship, budgeting, and debt management. These programs should be designed to empower SHG members to leverage loan funds for income-generating activities, reduce debt dependency, and ensure responsible financial practices.
- Facilitate Knowledge Exchange Between Maharashtra and Karnataka
  Given the different growth trajectories in Maharashtra and Karnataka, cooperative banks should facilitate knowledge exchange between SHGs in both states. Maharashtra's SHGs could learn from Karnataka's effective loan utilization, while Karnataka could benefit from Maharashtra's strategies for rapid SHG expansion. This knowledge-sharing platform could include workshops, webinars, and cross-state SHG networking events, fostering collaborative growth and skill development.
- Conduct Regular Impact Assessments
  Cooperative banks should conduct regular impact assessments to evaluate how loans and savings are improving the economic empowerment of SHG members. By tracking metrics like income growth, business sustainability, and financial independence, banks can refine their support programs and ensure they are meeting the empowerment goals outlined in their mission.

VII. CONCLUSION

The data reveals that cooperative banks play a pivotal role in supporting Women SHGs, as evidenced by their commitment to expanding loan disbursements and facilitating savings. Cooperative banks, especially District Cooperative Central (DCC) banks, appear to be instrumental in empowering women economically by ensuring credit access and promoting financial growth among SHGs.

In comparing Maharashtra and Karnataka, Maharashtra has demonstrated greater growth in SHG numbers and total loan disbursed amounts, highlighting rapid expansion and robust support mechanisms from DCC banks. Karnataka, though showing a slower growth trajectory in SHG numbers and loan disbursement amounts, has consistently provided a higher per-SHG loan amount,

emphasizing a more concentrated financial empowerment strategy per group. Thus, while Maharashtra's DCC banks emphasize broad-based SHG growth, Karnataka's banks focus on providing substantial individual support per SHG.

In summary, cooperative banks, particularly DCC banks in both states, are vital for advancing the economic empowerment of women. While approaches vary between Maharashtra and Karnataka, both regions show that increasing loan access, supporting savings growth, and providing significant loan amounts per SHG are effective strategies for strengthening women's economic agency. This study underscores the important role of cooperative banks in fostering financial resilience and empowerment among women SHGs in India.

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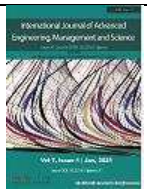

The Control Analysis of Single Capacity Water Tank Liquid Level System Based on PSO Optimized Fuzzy PID

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Abstract *— The liquid level automatic control system of a single-capacity water tank is a common industrial process control system, which is widely used in industrial production. Through simulation research, it can effectively ensure the stability of the liquid level of the water tank and meet the requirements of liquid level control in the production process. In this paper, the automatic control system model of a single-volume water tank level is established by MATLAB/Simulink, and its control system is studied and compared. Firstly, the physical modeling of the control system is carried out to obtain its transfer function, which is the basis for subsequent simulation. Then, the influence of Proportional–Integral–Derivative (PID) control parameters on the dynamic characteristic curve of the system is understood, and then the characteristics and application occasions of fuzzy PID control and Particle-Swarm-Optimization (PSO) control are deduced. Finally, the system dynamic characteristic curves of PID control, fuzzy PID control, and PSO control are compared and analyzed. The simulation results show that PID control, fuzzy PID control, and PSO control are suitable for different occasions, and appropriate control strategies can be adopted according to different control system conditions.*

Keywords *— **Simulink simulation, Proportional–Integral–Derivative (PID) control, fuzzy PID control, Particle-Swarm-Optimization (PSO) particle swarm optimization algorithm, automatic control system***

I. INTRODUCTION

The liquid level control system of a single-capacity water tank is one of the most widely used automatic control systems in industrial production. It has the characteristics of simple structure, high control accuracy, good stability, fast

response speed, and wide application range [1], which can effectively ensure the stability of the liquid level of the water tank and meet the requirements of liquid level control in the production process. Its control system usually adopts PID control, which has the characteristics of high stability, good flexibility, and simple implementation [1, 2].

The goal of this paper is to obtain the transfer function of the system by establishing the physical model of the single-volume water tank liquid level system and importing the physical model into MATLAB software for simulation based on MATLAB, PID control, and fuzzy PID control. The dynamic characteristics of the single-volume water tank liquid level automatic control system can be observed and compared, and the results of classical PID control and fuzzy PID control are compared [3] so as to verify the advantages of the fuzzy PID control system in all aspects.

II. RESEARCH METHODOLOGY

2.1 Establish the physical model of the liquid level control system of a single-volume water tank

Firstly, the physical model of the single-volume water tank liquid level automatic control system based on PID control is established, and the dynamic analysis of the model is carried out. The physical model is shown in Figure 1:

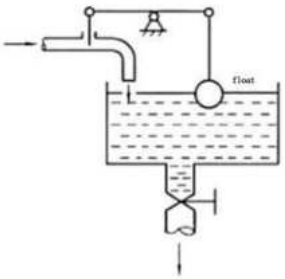

Fig.1 Model of automatic liquid level control system for single capacity water tank

The inlet and outlet flow rates of the water tank are W1 and W2, respectively, and the liquid level height of the water tank is E. The mathematical model of the system can be obtained by calculation. The transfer function of the water tank is formula (1):

$$G(s) = \frac{G(s)}{W_1(s)} = \frac{R_2}{R_2Cs+1} = \frac{K}{Ts+1} \quad (1)$$

According to the inertia link transfer function of the first-order system, $T=R_2C$ is the time coefficient of the control system, and $K=R_2$ is the proportional coefficient of the control system. For the water tank level control, the PID regulator in the mechanical engineering control foundation is applied to the automatic control of the water tank level. In the closed-loop control system, the actual value of the water tank liquid level is returned to the input through negative feedback, and the deviation between the given value and the actual output is compared and calculated. The output value is obtained by the PID algorithm, and the speed of the AC inverter and motor is controlled by digital-to-analog conversion. Finally, the automatic control of the water tank liquid level is realized. The transfer function of the overall control system is shown in Figure 2. The transfer function is formula (2).

$$G_C(s) = \frac{N(s)}{E(s)} = K_p\left(1 + \frac{1}{K_i s} + K_d s\right) \quad (2)$$

Where K_P is the proportional coefficient, K_i is the integral coefficient, and K_d is the differential coefficient.

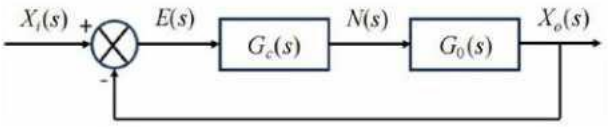

Fig.2 Transfer function block diagram of PID automatic liquid level control for a single-volume water tank

2.2 Classic PID control principle

In a general control system, the most common control mode is classical PID control. PID control can effectively adjust the system deviation through the synergy of proportional (P), integral (I) and differential (d) and has the characteristics of strong adaptability and flexible adjustment [1, 2]. The classic PID control system is shown in Figure 3.

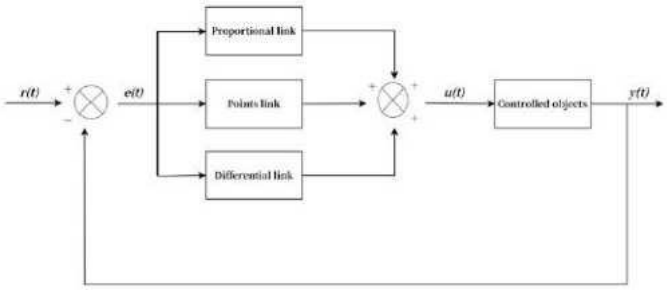

Fig.3 The PID system structure

The expression of a classical PID controller usually has two forms: time domain and frequency domain. The expressions of the time domain and frequency domain are formula (3) and formula (4), respectively:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)\,dt + K_d \frac{de(t)}{dt} \quad (3)$$

$$G(s) = K_p + \frac{K_i}{s} + K_d s \quad (4)$$

In Figure 3, the proportional link (P), integral link (I), and differential link (d) correspond to the proportional coefficient K_P, integral coefficient K_i and differential coefficient K_d in the expression, respectively. The proportional coefficient determines the response strength of the controller to the current deviation. The larger the proportional coefficient, the faster the controller responds to the deviation. The integral coefficient determines the response strength of the controller to the accumulated deviation. The larger the integral coefficient, the stronger the ability of the controller to eliminate the steady-state error. The differential coefficient determines the response strength of the controller to the deviation change rate. The larger the differential coefficient, the stronger the predictive ability of the controller to the deviation change. In PID control, when the system order is high and the open-loop transfer function is unknown, it is necessary to optimize and analyze the gain margin, phase margin, and dynamic response performance. In the face of complex systems or special control requirements, it is necessary to consider the frequency domain analysis. Since the selected automatic control system for the liquid level of a single-capacity water tank is relatively simple and stable, and the open-loop transfer function is known, it is not necessary to consider the frequency domain analysis.

2.3 Fuzzy PID control principle

Fuzzy PID controller is a control strategy that combines fuzzy logic with traditional PID control. It uses fuzzy logic and certain fuzzy rules to optimize PID parameters in real time so as to overcome the disadvantage that traditional PID parameters cannot adjust PID parameters in real time [6][7]. It is mainly used to deal with nonlinear, time-varying, and uncertain systems [4, 5]. The fuzzy PID controller has the advantages of adaptive characteristics, which can automatically adjust the control parameters according to the dynamic changes of the system, achieve rapid response, reduce the rise time and overshoot of the system, and reduce the complexity and time-consuming of parameter setting, making it an effective tool to deal with complex control problems. The structure of the fuzzy PID control system is shown in Figure 4:

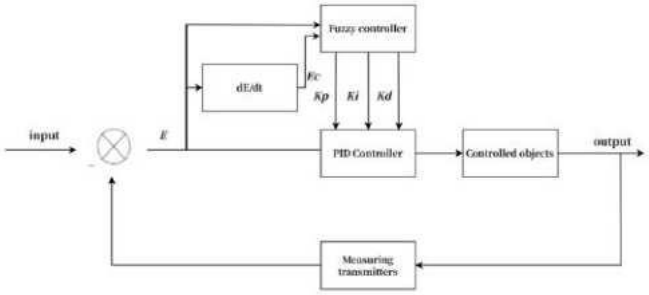

Fig.4 Structure diagram of fuzzy PID control system

In Figure 4, the fuzzy controller is mainly composed of three modules: fuzzification, fuzzy reasoning, and clarity (Figure 5).

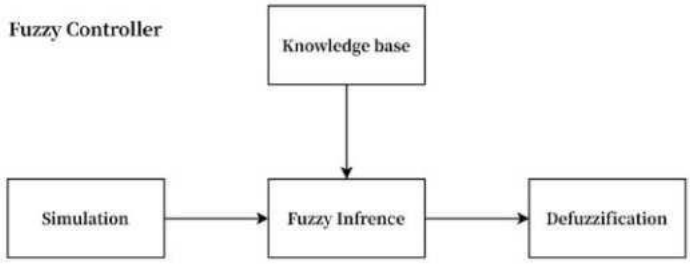

Fig.5 Structure of fuzzy rule base

In the fuzzy PID control system, error E and error change rate EC are the two inputs of the fuzzy PID controller, and K_P、K_i、and K_d are the three outputs of the controller [5].

Set the definition domain and display range of E and EC to [-2, 2], and its fuzzy subset is E = ES = {negative large, negative small, zero, positive small, positive large} = {Nb, N, ZE, P, PB}. Input and select the gauss2mf waveform membership function, output and select the trimf waveform membership function, and establish fuzzy rules according to fuzzy rule Table 1.

Table 1 Table of fuzzy rules

e(t)\ △e(t)	NB	N	ZE	P	PB
NB	$K_p = B$ $K_i = MB$ $K_d = S$	$K_p = B$ $K_i = MB$ $K_d = MS$	$K_p = MB$ $K_i = MS$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = S$	$K_p = S$ $K_i = MB$ $K_d = B$
N	$K_p = B$ $K_i = MB$ $K_d = MS$	$K_p = MB$ $K_i = MS$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = MS$	$K_p = S$ $K_i = MB$ $K_d = MS$	$K_p = S$ $K_i = MB$ $K_d = B$
ZE	$K_p = MB$ $K_i = MS$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = MS$	$K_p = S$ $K_i = MB$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = MS$	$K_p = MB$ $K_i = MB$ $K_d = B$
P	$K_p = S$ $K_i = MB$ $K_d = MB$	$K_p = S$ $K_i = MB$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = MS$	$K_p = MB$ $K_i = MS$ $K_d = MS$	$K_p = B$ $K_i = MB$ $K_d = S$
PB	$K_p = S$ $K_i = MB$ $K_d = B$	$K_p = S$ $K_i = MB$ $K_d = MS$	$K_p = MS$ $K_i = MS$ $K_d = MS$	$K_p = MB$ $K_i = MS$ $K_d = MS$	$K_p = B$ $K_i = MB$ $K_d = S$

2.4 Basic control principle of PSO algorithm

Particle-swarm-optimization (PSO) is an optimization algorithm based on swarm intelligence. The inspiration of this algorithm comes from the research on the foraging behavior of birds, and the optimal solution is found by simulating the cooperation and information sharing among individuals in the group [6, 8].

PSO simulates birds in a flock of birds by designing a massless particle. The particle has only two attributes: speed and position. Speed represents the velocity of movement, and position represents the direction of movement. Each particle searches for the optimal solution separately in the search space

and records it as the current individual extremum and shares the individual extremum with other particles in the whole particle swarm to find the optimal individual extremum as the current global optimal solution of the whole particle swarm. All particles in the particle swarm adjust their speed and position according to the individual extremum they find and the current global optimal solution shared by the whole particle swarm so as to approach the global optimal solution. The update formulas for speed and position are (5) and (6):

$$v_i^{(t+1)} = v_i^{(t)} + c_1 + r_1\left(pbest_i - x_i^{(t)}\right) + c_2 r_2\left(gbest - x_i^{(t)}\right) \quad (5)$$

$$x_i^{(t+1)} = x_i^{(t)} + v_i^{(t+1)} \quad (6)$$

Where pbest represents the individual optimal position of particles and gbest represents the global optimal position of particles.

The PSO particle swarm optimization algorithm has been widely used in the application fields of function optimization, neural network training, engineering system control, and other genetic algorithms. In PID control, the particle swarm optimization algorithm is mainly used to optimize the parameters of the PID controller (proportional gain K_P, integral gain K_i and differential gain K_d) to improve the performance of the control system.

The process of PSO optimizing PID parameters can be divided into the following steps:

(1) Initialize

Randomly initialize the position and velocity of the particle swarm. The position of each particle represents a set of PID parameters (K_P、K_i、K_d), and the speed represents the change of parameters. Define the upper and lower limits of particles, such as K_P、K_i、K_d value range.

(2) Calculate fitness

The position of each particle (PID parameter) is substituted into the control system to run the simulation model (such as the Simulink model). Calculate the performance indicators of the system, such as ITAE (integral of the product of time and absolute value of error) and IAE (integral of the absolute value of error), and take this value as the fitness value of particles.

(3) Update particle position and velocity

According to the velocity and position update formula of PSO, the velocity and position of each particle are updated, and the individual optimal position (pbest) and global optimal position (gbest) of particles are updated.

(4) Iterative optimization

Repeat the above steps until the termination conditions are met (such as the maximum number of iterations or the fitness value is small enough)

The global optimal position is output as the optimal PID parameter. In this way, PSO plays an important role in PID control, and provides an efficient and reliable solution for parameter optimization of complex control systems.

III. ANALYSIS AND RESULTS

3.1 Establish the PID control simulation model

In order to observe the influence of the PID controller and fuzzy PID controller on the control system, the PID controller model is established first. The liquid level of the water tank is selected as the control object, and the PID controller is used to realize the automatic control of the liquid level of the water tank. In order to intuitively show this process, a simulation model of PID automatic liquid level control for a water tank is built based on the MATLAB/Simulink platform (Figure 6). In this model, the set input value is the desired liquid level (i.e., the set value), and the output result reflects the water inflow of the tank. Through this model and dynamic simulation process, we can intuitively observe the working principle of the PID controller and the influence of parameter adjustment on system performance.

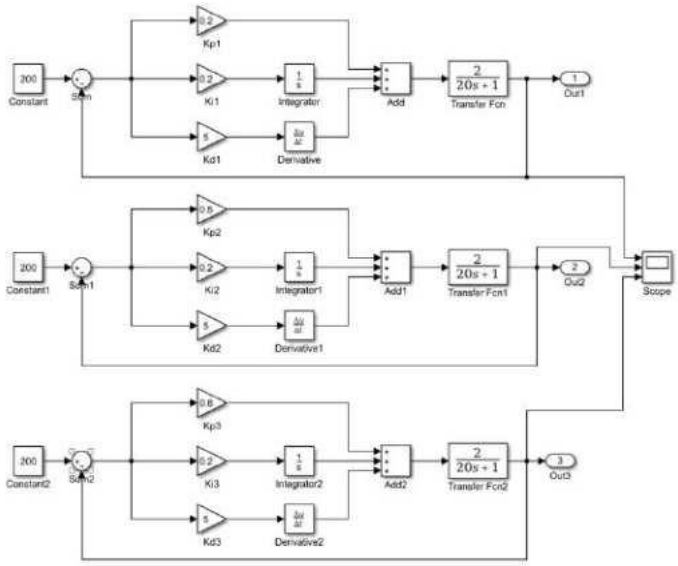

Fig.6 Simulation model of PID automatic liquid level control of a water tank based on MATLAB/Simulink.

3.2 Influence of parameters in PID controller on dynamic characteristics of water tank system

3.2.1 Effect of proportional parameter Kp on dynamic characteristics of water tank system

In the simulation process, the set value of the water tank liquid level is 200, and K_P is set to 0.2, 0.5, and 0.8, respectively. Observe the simulation dynamic characteristic curve of the model under different scale parameters. As shown in Figure 7.

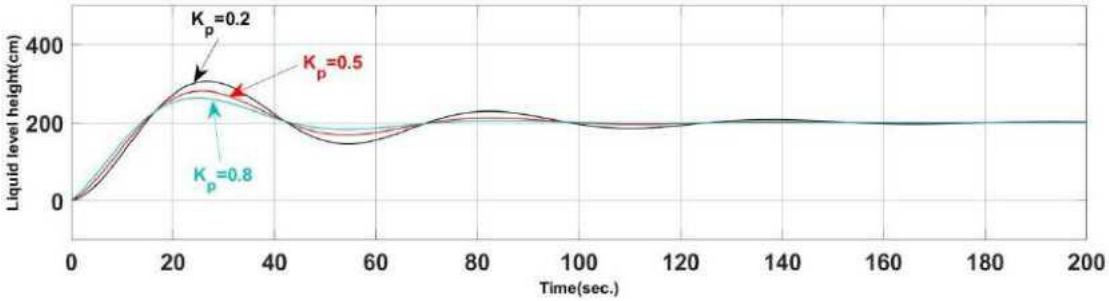

Fig.7 Effect of different proportional parameters Kp on dynamic characteristics of water tank system

It can be observed from Figure 7 that no matter what value K_P is taken, the liquid level will tend to be stable after a certain fluctuation. It should be noted that with the increase of K_P value, the maximum overshoot of the system shows a decreasing trend, and the response time required to reach the steady state is correspondingly shortened, and the response speed is accelerated. This observation shows that properly increasing the proportional coefficient can help to improve the performance of the controller.

3.2.2 Influence of integral parameter Ki and differential parameter Kd on dynamic characteristics of water tank system

In PID control, the integral link and differential link are indispensable parts of the PID controller. In the simulation model of the single-capacity water tank level PID control system, the integral parameter K_i and differential parameter K_d are also adjusted differently to observe the influence of the integral parameter K_i and differential parameter K_d on the dynamic characteristics of the system. The effects of

integral parameter K_i and differential parameter K_d on the dynamic characteristics of the system are shown in Figure 8 and Figure 9, respectively.

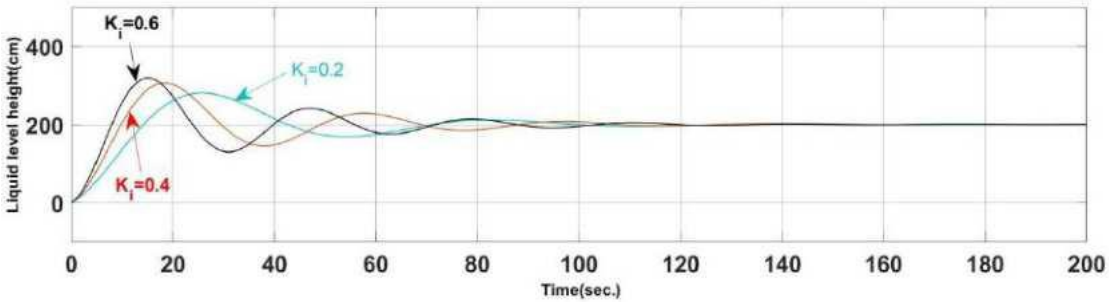

Fig.8 Effect of different integration parameters Ki on dynamic characteristics of a water tank system

It can be observed from figure 8 that with the increase of the integral coefficient K_i (K_i =0.2, 0.4, and 0.6), the response speed of the system to reach the steady state becomes slower, the overshoot phenomenon of the system increases, and the stability decreases. The increase of the integration coefficient leads to the system needing more time to accumulate errors and makes the phase lag of the system, which makes the system more prone to oscillation and makes the system unstable.

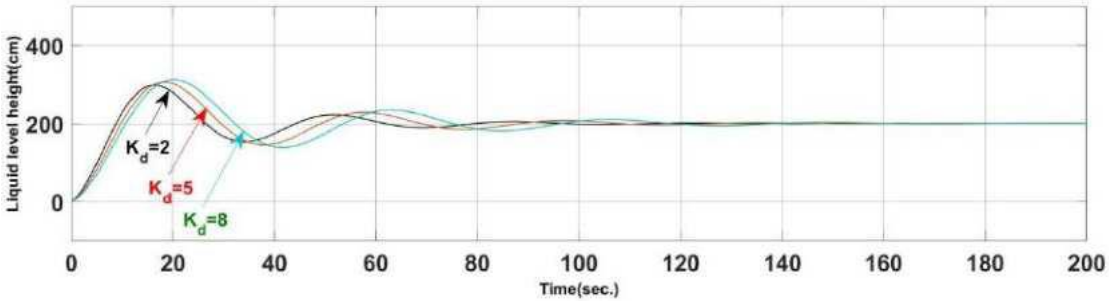

Fig.9 Effect of different differential parameters Kd on dynamic characteristics of water tank

It can be observed from Figure 9 that as the differential parameter K_d increases (K_d is 2, 5, and 8), the stability of the system gradually deteriorates, the maximum overshoot increases, and the adjustment time required to reach the steady state also increases accordingly.

3.3 Fuzzy PID control of simulation model of water tank control system

As a classical control strategy, the PID controller is widely used in various industrial process controls because of its simplicity, universality, stability, economy, and other characteristics, but it has some limitations in dealing with nonlinear, time-varying, and other systems. The automatic liquid level control system of a single-capacity water tank is generally PID control, but more uncontrollable factors need to be considered when dealing with some special occasions, so it is necessary to consider fuzzy PID control for the control system [3, 4, 9]. In order to compare with PID control, the fuzzy PID control simulation model of the single-capacity water tank liquid level control system is established through the MATLAB/Simulink platform, as shown in Figure 10. Through the model and dynamic simulation process, the influence of the fuzzy PID controller on system performance can be observed intuitively.

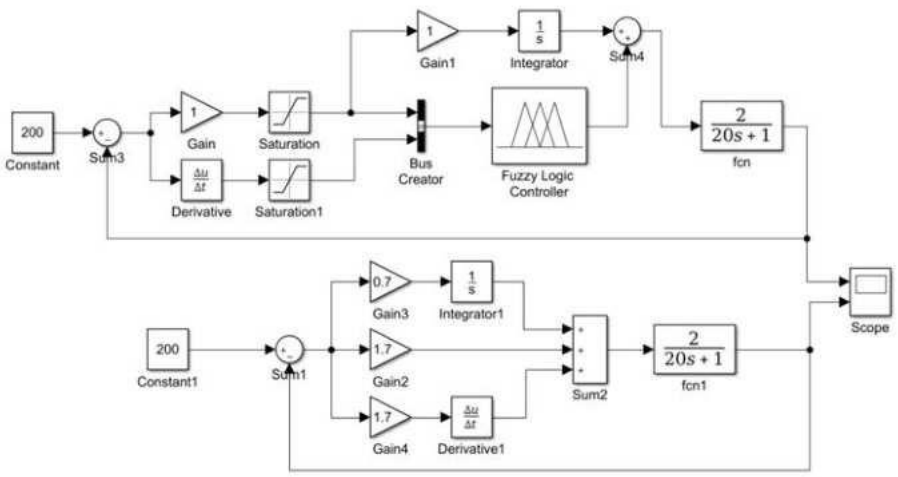

Fig.10 Simulation model of fuzzy PID automatic liquid level control of a water tank based on MATLAB/Simulink.

The system dynamic characteristics of fuzzy PID control and PID control are compared, as shown in Figure 11.

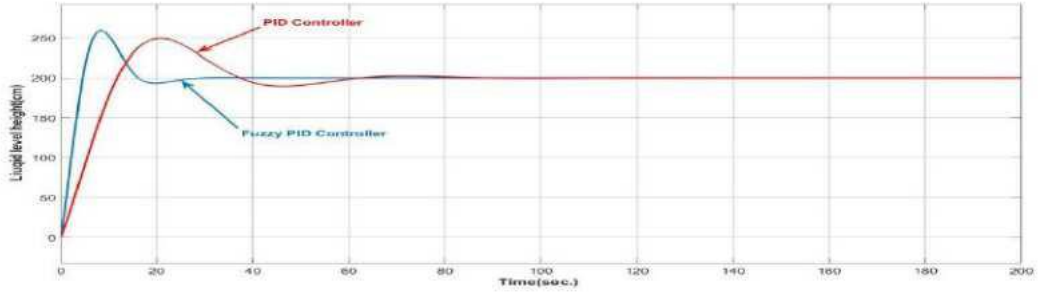

Fig.11 influence of PID control and fuzzy PID control on system dynamic characteristics

It can be observed from Figure 11 that the fuzzy PID control rises rapidly at the initial stage of control and then drops rapidly after reaching the peak value and tends to be stable. The PID control rises smoothly without obvious overshoot and finally tends to be stable. Through observation, it can be concluded that the fuzzy PID controller has a faster response speed and reaches the steady state [7], but there will be a large overshoot; the PID controller provides a smoother response and smaller overshoot, but it takes longer to reach the steady state.

PID controller can achieve faster response speed and reach steady state faster by adjusting parameters. When debugging PID parameters, it is necessary to adjust the proportional link (P), integral link (I) and differential link (d) in turn, and reduce the proportional parameters when the system curve vibrates. In case of floating and large fluctuation, the proportional parameter needs to be increased. When the system curve deviates from the target value, the integral parameter needs to be reduced. When the fluctuation period of the system curve is long, the integral parameter needs to be increased. If the oscillation frequency of the system curve is fast, the differential parameter needs to be reduced. When the fluctuation difference of the system curve is large and the fluctuation is slow, the differential parameter needs to be increased. According to the above pithy formula, the PID controller parameters are debugged to match the PID control with the fuzzy PID control, so that the set expected liquid level and water inflow are stable. The commissioning results are shown in Figure 12.

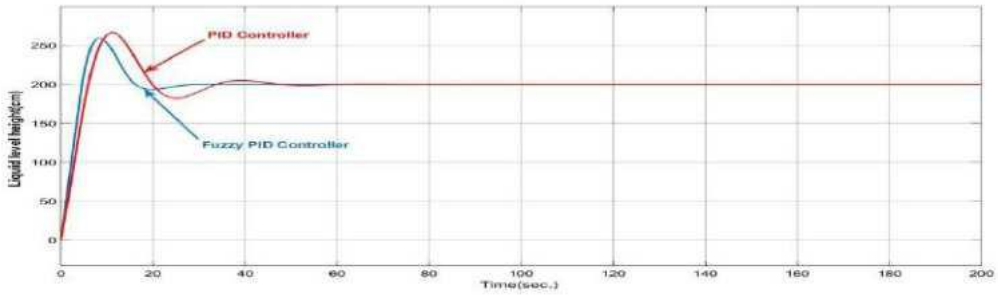

Fig.12 PID control and fuzzy PID control fitting

It can be observed from Figure 12 that even if the PID parameters are debugged to match the fuzzy PID control as much as possible, they cannot be completely matched. Therefore, considering the economic benefits, the control system that selects fuzzy PID control as the automatic control system of the liquid level of a single-capacity water tank will be better than PID control.

3.4 PID control based on PSO algorithm

The PSO algorithm is widely used in engineering system control, which is reflected in the fact that the PSO algorithm can be applied to nonlinear, time-varying, and other complex control systems, and the PID parameters optimized by PSO can significantly improve the stability and response speed of the system and can adapt to complex systems [6,9,10]. At the same time, it can be combined with MATLAB /Simulink and other tools to make the method of PSO optimizing PID parameters more simple and easy. In order to reflect the optimization and debugging of the parameters of the PID controller by the PSO optimization algorithm, the PSO-PID control simulation model of the liquid level control system of the single-capacity water tank is established on the MATLAB/Simulink platform, as shown in Figure 13. Through the model and dynamic simulation process, the results of the optimization of the parameters of the PID controller by the PSO-PID controller can be observed.

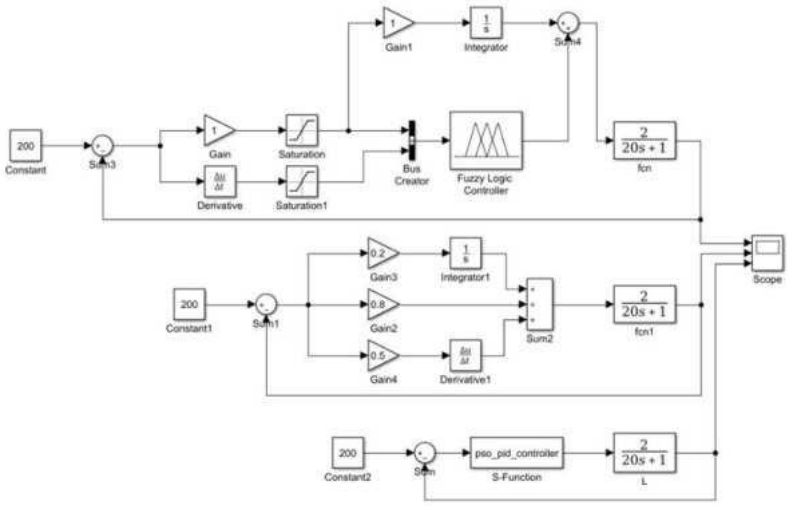

Fig.13 Simulation model of automatic liquid level control of a water tank using PSO-PID based on MATLAB/Simulink

Compare the system dynamic characteristic curve output of the PID controller, fuzzy PID control, and PID control participated in by the PSO algorithm, as shown in Figure 14:

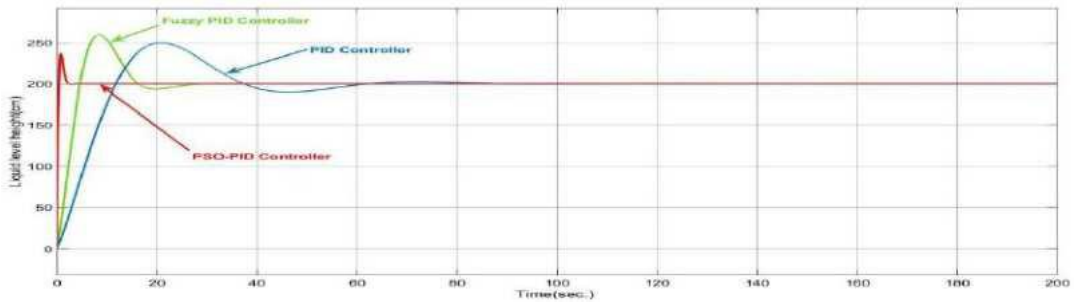

Fig.14 Influence of PSO control, PID control, and fuzzy PID control on dynamic characteristic curve

From the analysis of Figure 14, it can be seen that the fuzzy PID control responds very quickly in the initial stage, reaching a higher value almost immediately.

It reaches the peak at about 10 time units, significantly exceeding the target value, showing a large overshoot. After reaching the peak value, the curve of fuzzy control began to decline, but there was a certain oscillation until it tended to be stable after about 30 time units. This shows that the fuzzy control has a large fluctuation before reaching the stable state. Finally, the response value of fuzzy control is stable around the target value of 200 but may be slightly lower than the target value.

The initial response of PID control is also faster but slower than that of fuzzy control. It reaches the peak at about 15 time units, and the overshoot is small, showing good control performance. After reaching the peak value, the PID control curve gradually decreased and tended to be stable, with small oscillation. The response value of PID control finally stabilized around the target value of 200, showing good control accuracy.

The initial response of PSO control is relatively slow but very stable. There is almost no overshoot, and the curve is smoothly close to the target value. The curve of PSO control has almost no oscillation in the whole process, showing high stability. The response value finally stabilized at the target value of 200, showing the best control accuracy and stability.

In general, from the comparison of response speed, fuzzy control has the fastest response speed, but it is accompanied by large overshoot and oscillation; PID control takes the second place, while PSO control has the slowest response speed. From the comparison of overshoot, the overshoot of fuzzy control is the largest, followed by PID control, and there is almost no overshoot of PSO control. From the stability comparison, the stability of PSO control is the best, and there is almost no oscillation; PID control takes the second place, while fuzzy control has the worst stability and large oscillation. From the comparison of final control accuracy, the final control accuracy of PSO control is the highest, followed by PID control, and the final control accuracy of fuzzy control may be slightly lower than the target value.

IV. CONCLUSION

As a common industrial process control system, the automatic control system of a single-volume water tank liquid level is widely used in industrial production. The general automatic control system of a single-volume water tank liquid level adopts PID control, which can not only achieve stable control but also meet economic benefits. In this paper, the influence of the parameters of each link of the PID controller on the dynamic characteristics of the system is analyzed by taking the single-capacity water tank level control system as an example. At the same time, PID control, fuzzy PID, and PSO optimization control are studied and compared. The results show that if the system requires a high response speed but can tolerate a certain degree of overshoot and oscillation, fuzzy control can be considered. If the system needs better balance, response speed, and stability, PID control is a better

choice. If the system requires very high stability and final accuracy, PSO control is the best choice, although its response speed may be slow.

In general, the automatic control system of water tank level needs both response speed and stability, and PID control can be used. When a higher response speed is needed, fuzzy PID control is a better choice. If it is necessary to further pursue higher control accuracy and better stability, PSO control is the optimal choice.

ACKNOWLEDGMENTS

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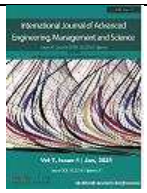

Handover Optimization Scheme for 5G Heterogeneous Network

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Abstract *— The worldwide boom in the use of wireless services has led to previously unheard-of levels of expansion for mobile connections and apps. Data traffic has increased dramatically as a result of this rise in activity, which has led to a research into solutions to meet this need. mm wave bands and very dense deployment are two of main features of fifth-generation (5G) networks. These solutions have resulted in a noticeable increase in the frequency of handovers (HOs), which has raised the incidence of dropped calls and unnecessary handovers. In order to address these problems during user mobility, it becomes imperative to optimize the control parameters associated with handovers. This research contribution provides a self-optimizing handover technique that leverages fuzzy coordination to enable smooth handovers as users move across multi-radio access networks. The suggested technique employs a fuzzy system that takes into account the S/I (signal-to-interference) plus noise ratio, cell load & user equipment speed to effectively balance the opposing requirements of mobility resilience and load balancing. The suggested approach effectively manages and optimizes mobility in a variety of mobile speed circumstances, decreasing ping-pong handovers, radio link failures, and handover delay. This is shown by simulation results. Additionally, the proposed technique greatly minimizes the outage probability when compared to other schemes discovered in the existing literature.*

Keywords*— *Handover Optimization, Self-optimization, Handover, 5G, Heterogeneous Networks

I. BACKGROUND

With the rise and widespread adoption of wireless services globally, mobile connections and applications are experiencing an unprecedented growth, placing significant demands on data traffic. Hence, mm wave bands & ultra-dense have been identified being crucial enabling solutions for 5G networking. Millimeter-wave (mmWave) bands and ultra-dense deployment are important elements and tactics used in 5G networks to improve network performance and capacity.

Between 30 and 300 gigahertz (GHz), a spectrum of radio frequencies is referred to as millimeter waves. These high-frequency bands allow for very fast data transmission rates and large bandwidths. By using mmWave frequencies, 5G networks can achieve substantially better data throughput and lower latency compared to previous generations of wireless networks. However, it's important to keep in mind that mmWave signals have a limited transmission range and are susceptible to signal attenuation due to barriers like grass and buildings. This issue is resolved by employing state-of-the-art beamforming, beam tracking, and antenna technology to guarantee dependable connectivity.

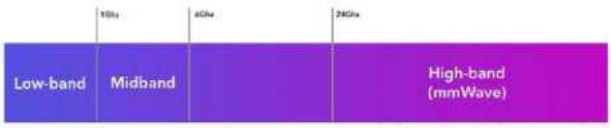

Fig 1.1: mmWave Frequencies

Base stations or small cells are ultra-densely deployed over a certain geographic area. Unlike traditional macrocells, which cover large areas, small cells are compact and may be installed in large numbers to provide targeted coverage and capacity. This technique aims to manage the increasing demand for data traffic by relocating the network closer to users, which reduces signal interference and improves network capacity and performance. A bigger number of concurrent users can be served by numerous tiny cells coexisting nearby thanks to ultra-dense deployment's improved spatial resource usage.

Service providers can take advantage of the benefits of high-frequency spectrum and localised coverage to deliver faster speeds, lower latency, and increased capacity to meet the growing demands of wireless communication and data-intensive applications by incorporating mmWave bands and ultra-dense deployment in 5G networks.

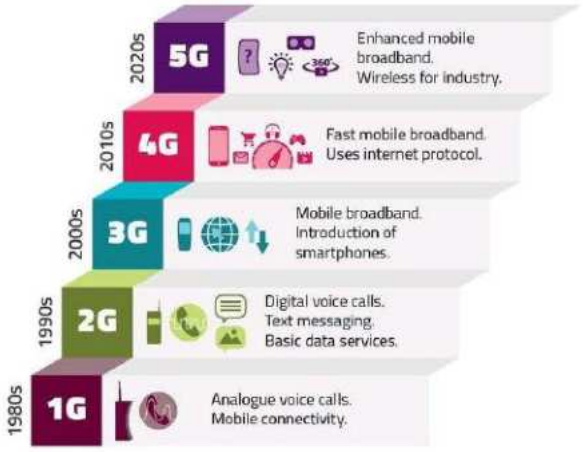

Fig 1.2: Mobile Network Generations

Different generations of mobile networks have developed over time, bringing new technology and capabilities with them. Following are the main mobile network generations:

- 1G stands for the first generation of commercially accessible analogue cellular technology. It had a constrained service area and only supported basic voice communication.
- 2G (Second Generation): 2G introduced digital cellular networks, which provided better call quality, more capacity, and SMS (text message) sending capabilities. GSM (Global System for Mobile Communications) was the most widely used 2G technology.
- Second and a Half Generation, or 2.5G, introduced packet-switched data transfer as a transitional technology between 2G and 3G. It provided faster data transmission rates, allowing for simple web browsing and constrained multimedia capabilities.
- Significant advancements in data transmission, including faster data rates and enhanced multimedia capabilities, were made possible by third-generation (3G) networks. It enabled the usage of mobile internet, video calling, and applications.
- Fourth-generation (4G) networks offer far faster data rates, lower latency, and more efficient networks overall. The introduction of WiMAX and Long Term Evolution (LTE) opened the door for sophisticated mobile applications including smooth multimedia streaming and video conferencing.
- The goal of the fifth generation (5G) of mobile networks is to provide extremely low latency, rapid data rates, and broad coverage. It presents novel technologies such as massive MIMO, mmWave bands, and network slicing. 5G promises to support new technologies such as the Internet of Things (IoT), virtual reality, augmented reality, and driverless vehicles.

Each generation builds on the one that came before it, increasing the capabilities and performance of mobile networks to meet the increasing needs of users for more complex apps and services, faster data rates, and more reliability.

Features	1G	2G	3G	4G	5G
Start/Development	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
AccessSystem	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA
Core Network	PSTN	PSTN	Packet Network	Internet	Internet

Fig 1.3: Mobile Networks Features

In case of these generation of networks, many solutions based on various parameters, introduce a considerable increase in the number of handovers (HOs), leading to higher rates of unnecessary HOs and dropped call probabilities. In this context, the appropriate optimization of handover control parameters (HCPs) emerges as the primary factor for effectively addressing HO-related challenges during user mobility.

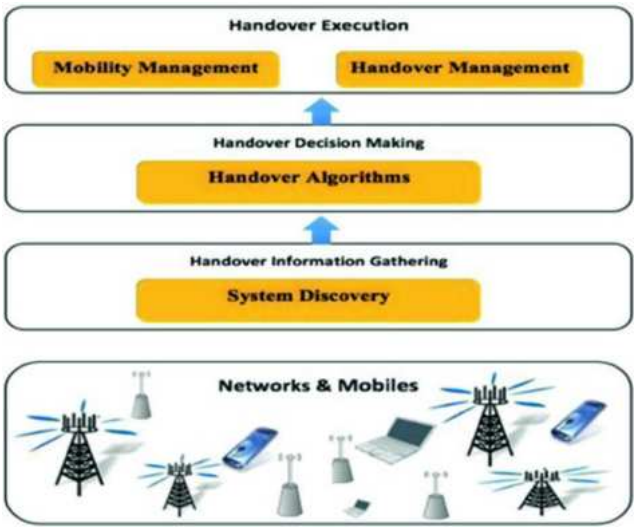

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Fig 1.4: Handover Decision Algorithm for Next Generation

(Source: Sapkale, P., Kolekar, U. 2020)

It is projected that the widespread use of tiny cells in next-generation networks will improve overall network performance. The demand for more capacity and coverage, which is a major challenge for telecommunications carriers, can be addressed by using tiny cells. From a technological perspective, there are a number of difficulties with this new deployment strategy in the context of 5G architectures. The two phases of the 5G rollout are standalone (SA) and non-standalone (NSA), which are standard-based paths for network implementation. Long-term evolution (LTE) and 5G are deployed side by side, with the primary objectives being improved mobile broadband, higher data throughput, and reliable connectivity. Long Term Evolution (LTE) is a standard for high-speed wireless data transport and communication. It is often referred to as 4G technology. With the deployment of this technology, cellular networks can provide mobile data services that are faster and more efficient than those provided by previous wireless technology generations. LTE offers significant improvements in data transfer rates, reduced latency, and increased network capacity over previous technologies such as 3G. It uses advanced modulation techniques, multiple input multiplexing (MIMO) antenna systems, and orthogonal frequency-division multiplexing (OFDM) to boost data throughput and enhance spectral efficiency. Among the many applications and services that LTE makes possible are cloud-based services, video streaming, online gaming, and video conferencing. Voice over LTE (VoLTE) is a technology that enables voice calls over data networks. LTE has been widely adopted globally and forms the backbone of many mobile networks, opening the door for improved mobile internet and the eventual switch to 5G technology.

Fig 1.5: Long Term Evolution (LTE)

After the technology is developed and all 3GPP specifications have been completed, the SA stage is put into practice. Future heterogeneous networks (HetNets) and 5G systems are both greatly impacted by the advent of new radio (NR) bands in terms of communication performance.

Fig.1.6: 5G Heterogeneous Network
(Source: Munir, H., Hassan, S.A., Pervaiz, H.B., Ni, Q., & Musavian, L. 2017)

A network architecture known as 5G Heterogeneous Networks (HetNets) combines various cell and base station types with various coverage areas and capacities to improve network performance and coverage. HetNets are made to handle the difficulties that come with growing data traffic, fluctuating user densities, and a variety of service demands in 5G networks. Different cell types, including as macrocells (which cover huge coverage areas), tiny cells (which cover localized areas), and relay nodes, are deployed in a 5G HetNet. These cells are arranged with care to optimize coverage and capacity in different areas. Microcells, picocells, and femtocells are further classifications for small cells, each with a distinct function in terms of coverage needs.

Advantages of 5G HetNets are as follows:

- By combining macrocells and small cells, HetNets provide more reliable coverage and increased capacity—especially in high-density areas with substantial data traffic. Small cells provide limited coverage and offload data from congested macrocells to improve network performance.
- Enhanced Data speeds: Because HetNets have more base stations per unit and are situated closer to customers, they offer higher data speeds and reduced latency. Small cells, in particular, offer better user experience and faster data transmission in densely populated areas.
- HetNets effectively distribute traffic across multiple cells, allowing for better usage of available spectrum. Interference is reduced and network efficiency is raised as a result.
- HetNets facilitate seamless transitions between different cells. As customers move from one coverage area to another, the network may dynamically switch the connection to the best cell to ensure continuous service.
- Because HetNets are flexible and scalable, it's easy to build new networks and expand ones that already exist. Tinier cells can be deployed in high-demand areas to meet expanding capacity requirements.

All things considered, 5G HetNets optimize network resources, boost capacity and coverage, and enhance user experience by fusing macrocells and tiny cells. In a range of environments, from rural areas with low population densities to metropolitan areas with high user densities, they are crucial for providing robust and consistent connectivity.

Release 16 marked the beginning of the 5G NR's mass development. The 5G NR uses both high-frequency (millimeter wave or mmWave) and low-frequency (sub-6 GHz) bands, with frequencies ranging from 24.25 - 52.6 GHz & 4.5-6 GHz, respectively. 5G New Radio (NR) is the name of the wireless air interface standard for 5G networks. The specification of 5G technology's device communication and data sharing protocols is an essential component. In contrast to previous wireless technology generations, 5G NR is meant to provide significantly faster data rates, reduced latency, and more network capacity.

- Higher Frequency Bands: Sub-6 GHz frequency bands (mid-band and low-band spectrum) and mmWave frequency bands (high-band spectrum) are both used by 5G NR. The utilization of millimeter-wave (mmWave) bands allows for extraordinarily high data rates and wider bandwidths. Beamforming techniques and advanced antenna technology are necessary for these high-frequency signals

because of their limited range and vulnerability to impediments.

- Virtual reality (VR), augmented reality (AR), and other data-intensive apps may be accessed seamlessly with 5G NR's Enhanced Mobile Broadband (eMBB), which provides considerably better internet speeds than its predecessors. Larger MIMO (Multiple-Input Multiple-Output) antenna systems, wider bandwidths, and the use of contemporary modulation techniques all contribute to the higher data speeds.
- 5G NR has exceptionally low latency, making it possible for mission-critical and real-time applications. Ultra-reliable low latency communication (URLLC) is the term for this. Applications like remote robotic surgery, industrial automation, and autonomous cars that demand minimal latency and high reliability depend on this.
- Massive Machine-Type Communication (mMTC): 5G NR, which is designed to support a substantial number of connected devices, is what makes the Internet of Things (IoT) ecosystem viable. This makes it possible to handle a variety of IoT devices effectively, including smart homes and cities and industrial IoT applications.
- Advanced Radio Techniques: In order to improve network capacity, coverage, and spectrum efficiency, 5G NR makes use of advanced radio techniques. Among these techniques are dynamic spectrum sharing, sophisticated interference management, beamforming, and beam tracking. They optimize the use of radio resources, reduce interference, and improve overall network performance.
- One of 5G NR's features is backward compatibility, which aims to ensure it works with older cellular technologies. This makes it possible for 4G and 5G networks to coexist and switch over seamlessly, facilitating a seamless transition from older networks like LTE.

Overall, 5G NR provides increased data rates, low latency, huge connectivity, and support for a variety of use cases and applications, serving as the cornerstone for 5G networks. Significant wireless technology improvements are made as a result, creating new opportunities for consumers, businesses, and sectors of the economy.

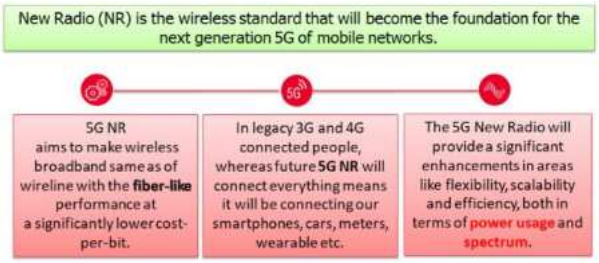

Fig.1.7: 5G New Radio (NR) Characteristics

However, due to the incredibly short wavelengths involved, the high-frequency band only gives a little amount of coverage. User mobility and network installations are critical to communication performance in limited area coverage scenarios because they are directly related to the channel model [4]. Due to the high deployment density and frequent updates of access points required by the mmWave cells' short range, handover, handover failure denoted by HOF, handover ping pong depicted by HOPP and the radio link failure abbreviated as RLF impacts are more likely to occur [5]. Equipment (UE) attributes such as Time to Completion (TTT) and Transition Gap (HOM) and Performance Control Parameters (HCP) determine how an HO state is created based on signal quality and channel status.

Table 1.1: 5G Network Challenges

Issues	Example	Keypoint
Uplink-downlink asymmetry	HetNets presents key asymmetry among the uplink and downlink. The optimal user association for downlink or uplink will be less effective for the opposite direction.	Optimize downlink and uplink performance jointly in the user association design
Backhaul bottleneck	Densely deployed small BSs may bring overwhelming traffic augments for the backhaul link and present small cell backhaul solutions can't deliver sufficiently large data rate	Design backhaul-aware user association for HetNets
Mobility support	User association while avoiding user mobility may outcome in recurrent handovers between the cells in HetNets	Account for the user mobility while creating the user association decision in HetNets to improve the long-term system-level performance and avoid excessive handovers

(Source: Reddy, S.R., & Venkatarama, S. 2023)

MRO & LBO routines compete for attention by independently optimizing handover control parameters (HCPs). The performance of the handover (HO) and the number of radio link failures (RLFs) may both be significantly impacted by this dispute. Existing literature indicates that this conflict's resolution is still an open question, and recent investigations have not yet identified the best answers. The MRO function has been the main focus of recent research, which has suggested ways to optimize the handover margin (HOM), time to trigger (TTT), or both [6-8]. In one study [6], a fuzzy logic control (FLC) method was put forth to modify the HOM in 4G HetNets based on user velocity and radio channel quality. Another study [7] examined several HCP settings under various mobile speed situations to look into the efficiency of HCPs in 5G networks. A compensation between HO performance indicators was evident in simulation. Despite the fact that these suggested remedies improved in terms of lowering RLFs, an ideal solution is still a long way off. Additionally, because of the tiny cell size in ultra-dense HetNets, these solutions are not suitable because the frequency of handovers rises. Coordinating the MRO and LBO operations to adjust HCPs appropriately, it is possible to address this problem and achieve an ideal solution.

Problem Statement

Introduction and popularity of wireless services globally, mobile connections and applications are expanding at a never-before-seen rate, significantly raising demands of data traffic. Due to this, ultra-dense deployment and millimeter-wave bands were taken into account as major enablers for 5G network generations. But these answers dramatically boost no of handovers (HOs), therefore lowering call probabilities and boosting the rate of needless HO. In this sense, the essential element that can effectively manage HO concerns during user mobility is optimizing HO control parameters suitably.

Purpose of the Study

To achieve uninterrupted Handover (HO) as users roam across multi radio networks, this research aims to propose fuzzy coordinated handover scheme which is self-optimizing. The proposed method makes use of fuzzy system that takes into account parameters which include cell load, user equipment (UE) speed, and SINR - signal-to-interference-plus-noise ratio. The aim is to address conflict that exists b/w load balancing & mobility robustness in order to provide seamless HO.

Research Questions

- Are ultra-dense deployment and millimeter-wave bands among the major enablers for fifth-generation (5G) networks?
- Is properly optimizing HO control parameters the key to effectively addressing HO difficulties during user mobility?
- Can users travel freely in multi-radio access networks by adopting fuzzy self-optimizing HO scheme?
- Can a fuzzy system be used in any suggested solution to balance the needs of load balancing functions and mobility robustness, taking into account input parameters of cell load, UE speed, & SINR?

II. SIGNIFICANCE OF RESEARCH

The research findings provide a practical contribution by emphasizing the significance of input parameters and coordination technique while building intelligent handover (HO) systems for densely populated urban HetNets. These results show that when users switch between cells, these characteristics are critical in improving network performance overall.

III. LITERATURE REVIEW

It is projected that the introduction of tiny cells into next-generation networks will improve overall network performance. It is also a workable answer to the problems with capacity and coverage that telecom companies are facing. However, there are a number of technical issues with this new deployment strategy that must be resolved in the context of 5G networks. Non-standalone (NSA) and standalone (SA), which are standardized routes to 5G network

implementation, are the two stages of 5G deployment [1]. The main goals of 5G deployment during the NSA stage are to boost data rates, enhance mobile broadband, and guarantee dependable connectivity.

Once the technology is developed and the 3GPP specifications are complete, the SA stage is put into practice. Future heterogeneous networks (HetNets) and 5G systems are both greatly impacted by new radio (NR) bands in terms of communication performance. Release 16 [2] introduces the development of 5G new radio. It operates between 4.5 GHz and 6 GHz and 24.25 to 52.6 GHz and 52.6 GHz, respectively, in the low-frequency (sub 6 GHz) and high-frequency (mmWave) bands [3]. Due to its incredibly tiny wavelengths, the high-frequency band, however, only provides a little amount of coverage. User mobility and network deployments, which are intricately linked to the channel model and have an impact on communication performance in locations with limited coverage, are two such factors [4].

Deploying mmWave cells in dense topologies with limited range necessitates frequent updates to access points, increasing the risk of radio link failure (RLF), HO failure (HOF), HO ping pong (HOPP), & handover (HO). [5]. The frequency of HO occurrences is dependent on a number of factors, including signal intensity, channel conditions, UE behavior, and HO control parameters (HCP) such time-to-trigger (TTT) and HO margin (HOM). In order to enhance user experience, it's important to look consider communication performance during user mobility in HetNets. Because the MRO and LBO processes are independently optimized for HCP, there is a conflict between them.

RLFs may increase and the overall performance of the HO may be compromised. The available study indicates that there is more work to be done in order to resolve this paradox, and the most optimal solutions have not yet been found. Researchers have focused on the MRO function and offered recommendations for enhancing TTT, HOM [6–8]. A fuzzy logic control (FLC) strategy was put forth to modify HOM in 4G HetNets based on user velocity and radio channel quality.

In [8], the authors examined several HCP settings under various mobile speed scenarios to examine the efficacy of HCPs in 5G networks. The outcomes of the simulation showed a trade-off between the HO performance indicators. Although the reduction of RLFs using these suggested techniques was improved, finding the ideal solution still poses difficulties. Additionally, these techniques do not work in ultra-dense HetNets where the tiny cell size leads to an increase in the frequency of HO events. However, by combining the MRO and LBO operations to modify HCPs appropriately, this problem can be addressed and an ideal solution can be reached.

Because the expected HO control parameters produced are not coordinated. Through an increase in the frequency of RLFs and the risk of outages, this paradox ultimately results in substandard system performance [9–12]. Additionally, in extremely crowded networks with high-speed mobile users, this problem could get worse. Therefore, it is necessary to enhance current solutions even further.

Data traffic has increased dramatically as a result of the rapid development of mobile devices and sophisticated apps. By 2025, there are expected to be 8.9 billion mobile customers, with 88 percent of them using mobile broadband connections, according to an Ericsson report released in June 2021 [13]. Over the next five years, the demand for mobile data will expand 1,000-fold as a result of the internet connectivity of billions of additional gadgets and home appliances [14]. The spectrum gap will expand if this trend persists, requiring the activation of more spectrum bands [15, 16].

Heterogeneous Networks (HetNets) have become a viable and efficient response to the growing demand for high data rates and seamless communication. HetNet is the name of a wireless network that incorporates tiny cells of various shapes and sizes beneath the primary macrocell. HetNet's enhanced coverage, increased throughput, energy efficiency, and Quality of Service (QoS) have drawn considerable attention. As a result, the development of HetNet is seen as a key component of the Fifth Generation (5G) wireless mobile communication systems. Small cells

can be installed in residences, workplaces, retail establishments, sporting venues, airports, and other densely populated locations [17]. Microcells, Pico cells, relay nodes, and femtocells are a few examples of small cell types. In order to meet the demands for high data rates and coverage, researchers and operators are increasingly motivated to adopt ultra-dense HetNets in 5G wireless communication networks.

In cellular networks, handover (HO) is essential for managing mobility [18]. HO is the process of moving a mobile user's active connections from their serving cell to a destination cell while maintaining QoS. Performance of the network is strongly impacted by the HO process in next-generation wireless HetNets. For instance, the limited coverage area of small cells in 5G HetNets causes an increase in the amount of handovers between these cells. User performance suffers from frequent handovers and increasing signaling overheads. HO schemes' main goals are to reduce frequent handovers, HO failure rates, HO delays, HO interruption times, energy usage throughout the HO process, and ping-pong events while raising HO success rates [42. 43].

In order to improve HO judgements, a lot of study has been done. Xenakis et al. [19] introduced a HO decision algorithm in 2015 that took into account several design principles. Chinnappan et al. (2016) [20] introduced Vertical HO choice methods to guarantee seamless connectivity and uninterrupted service across different Radio Access Technologies (RATs). Zang et al. [21] introduced an efficient HO decision algorithm based on Markov Decision Process (MDP) in 2018 with the goal of enhancing user experience in mmWave HetNets. Using user mobility information, this method effectively handles beamforming misalignments and signal obstructions. Ahmed et al. [22] conducted a comprehensive study on Fifth Generation Vehicular Ad Hoc Networks (5G-VANET) in 2018, focusing on challenges related to mobility, interference, congestion, jamming, and coverage. For high-speed railway networks, Bang et al. [23] presented a machine learning-based HO decision approach in 2019 using a Bayesian regression model to predict cell boundary-crossing time. Handovers can start earlier with this method than with conventional methods. In order to optimize HO in vehicular networks and increase average system resource utilization, Gharsallah et al. [24] presented a novel multi-criteria network selection mechanism in 2019. The mechanism achieved uniform traffic load distribution among available networks by reducing HO failure, HO delay, and packet loss rates.

The telecoms sector works tirelessly to improve its infrastructure in order to handle the increasing traffic demand. Reducing cell size and deploying several Smallcells alongside Macrocells is one novel strategy. The deployment of Smallcells beneath Macrocells was made possible by the LTE-A upgrade and release-12 of the 3GPP, increasing the capacity of cellular networks [25]. However, several research [26, 44] draw attention to potential interference problems linked to such deployments. Deploying more cells is also not cost-effective from the operator's standpoint because it adds to the operator's expenses for power, property leasing, deployment, and maintenance.

The user equipment (UE) in a cellular network receives services from just Macrocells in classic mobile cellular communication systems, which have a homogenous network design. Similar transmit power, antenna designs, Radio Access Technologies (RATs), modulation techniques, Signal-to-Noise Ratios (SNRs), and Evolved Packet Core (EPC) are used by Macrocells in such homogenous networks to service UEs throughout all cells [27]. As a result, these conventional homogenous networks are unable to satisfy the data traffic requirements of 5G networks and fail to provide acceptable coverage, particularly at cell edges.

Cell splitting is an alternative method for solving this issue. However, this method is expensive and unworkable for placing numerous Macrocells in a small area [28]. Because of this, advanced LTE-A systems use a hierarchical cell deployment strategy to implement a more effective and affordable solution. Cells of various sizes can be placed across macrocells in accordance with 3GPP specifications, creating the multi-cell network architecture known as HetNet (Heterogeneous Network) [29].

HetNet architecture deployment is advantageous to subscribers and operators alike. This strategy increases the cellular system's overall throughput while extending the coverage area. The installation of Smallcells is also simple and inexpensive [30]. Handover is a key idea in wireless cellular communication that enables UEs to switch between cells without pausing their sessions. A crucial part of the handover process is efficient UE switching between cells, which maintains strong signals, balances load, lowers costs, and consumes the least amount of energy.

There are two main categories of handovers: Hard Handovers and Soft Handovers. A UE breaks its connection to the current cell via a Hard Handover process, also known as a break-before-connect mechanism, and immediately connects to a new cell. Contrarily, Soft Handover, also known as a connect-before-break strategy, establishes a new connection before severing the current one [45].

Additionally, there are two additional handover types: vertical handovers (VHO) and horizontal handovers (HHO). When a UE changes networks while still connected, HHO happens [31]. VHO, on the other hand, permits seamless UE mobility between various networks [32]. The use of new technologies has enhanced the significance of VHO in 5G and other wireless networks.

Additionally, 5G wireless networks are set to incorporate cutting-edge innovations like HetNet, NR (New Radio), vehicle-to-vehicle (V2V) communication, and intelligent drones. These technologies can be used to satisfy the rising demand for high data rates [33]. HetNet development is complicated by frequent handovers and ping-pong effects, which could harm the performance of wireless networking systems [34]. As a result, managing mobility and effective handoff between different technologies is essential and demands proactive care.

Consequently, effective handover procedures have been discovered through a thorough literature review. In order to reduce power usage during data transmission, a VHO-based technique with a dynamic power control mechanism is proposed in [35]. Similar to this, Fang Wang et al. [36] suggest an effective VHO approach that formulates the method using a Markov Decision Process (MDP). After taking into account the queue length and channel state, this method conducts VHO.

A QoE-Aware Intelligent VHO strategy is described in a different work by Jiamei Chen et al. [37] that is especially made to meet the necessary Quality of Service (QoS) for different applications while providing seamless handover in 5G HetNet. A unique handover choice method is also introduced in [38] to reduce changeover failure and ping-pong effects in the extremely dense 5G HetNet. The authors build a fuzzy logic system that has a hysteresis margin that is dynamically determined, and they show that it performs better than other methods.

Additionally, numerous techniques that try to reduce call dropouts, ping-pong effects, and radio link failures (RLF) are presented in [39-41]. [39] offers a fuzzy multiple-cells selection approach that optimizes the handover process by taking into account UE uplink circumstances, resource block utilization, and selection criterion measurements. The capacity is enhanced while the effects of ping-pong and handover failures are successfully reduced.

IV. RESEARCH METHODOLOGY

The main strategy and methodology revolve around developing a clever coordinated scheme that makes use of fuzzy FLC system to smoothly adjust Handover Control Parameters (HCPs) based on input variables like SINR, cell load & UE speed. To efficiently handle the handover procedure b/w serving and target base stations, a HO decision algorithm will be suggested. Various handover performance measures will be used to thoroughly analyze performance of the proposed scheme to already completed relevant work.

Handovers & Optimization

- This study discusses Hard Handovers (Break-Before-Make) and Soft Handovers (Make-Before-Break).
- Vertical Handovers (VHO) occur when switching between different technologies (e.g.,

LTE to 5G), and Horizontal Handovers (HHO) happen within the same technology.

- In 5G, the handover process is optimized using fuzzy logic to reduce unnecessary handovers, minimize radio link failures (RLFs), and improve mobility robustness.
- Optimized Handover in 5G: The proposed self-optimizing fuzzy logic-based handover optimizes handover control parameters such as Handover Margin (HOM) and Time-to-Trigger (TTT)

The methodology will be centered on achieving the following goals:

- Our strategy entails creating a clever, coordinated system that uses a fuzzy logic controller (FLC) to automatically modify the handover control parameters (HCPs) in response to inputs like SINR, cell load, and UE speed.
- To efficiently handle the handover process b/w serving & target base stations, researcher proposes algorithm for Handover (HO) decisions.
- Using several measures for HO performance and in contrast to previous similar work, researcher evaluated & compared performance of proposed methodology.

Using Signal-to-Interference-Plus-Noise Ratio (SINR) Instead of A-I Ratio

- The A-I Ratio (Antenna-to-Interference Ratio) is not commonly used in cellular networks because SINR provides a better indication of the quality of the received signal by considering both interference and noise.
- SINR is a widely accepted metric in cellular communication because it directly impacts data rates, channel quality, and handover decisions

The analysis and discussion of three crucial aspects—Handover Ping Pong (HOPP), Radio Link Failure (RLF), and Handover (HO) latency—are the main topics of the performance evaluation of the suggested strategy. MATLAB simulations will be run to examine and validate the effectiveness of the suggested approach.

Conceived Model

A total of 62 large hexagonal cells running on 4G and 184 tiny cells running on 5G make up the system configuration, which spans a 7.5 by 7.5 km^2 region. Small cells are consistently positioned in middle of each mega cell sector. It is believed that the coverage of the small cells does not overlap. Our earlier research articles proposed this system concept. The tiny cells have omni-directional antennas, but each sector of the large cells is outfitted with directional antennas. The network model allows UE for connecting single evolved eNodeB at medium access control layer through supporting radio access technology.

Either the small cells or the macro cells in the system provide the User Equipment (UE) with the desired traffic. No presumptions are made in this study about any impediments, including trees, structures, or mountains. As a result, it is expected that all monitored UEs can move freely in all directions during the simulation, allowing for line-of-sight communication linkages. The X2 interface is used for direct cell-to-cell communication during handover (HO) processes. The X2 interface supports the HO process by facilitating the sharing of parameter configurations, operational data, and Radio Link Failure (RLF) status.

Only a small number of jobs are completed on the UE side, with the majority of computing operations taking place at the base station. However, HO assumes some of the required computational tasks when a change in the central management unit is necessary. To optimize the Handover Control Parameters (HCPs), network collects handover information from each cell. A serving cell keeps track of a UE's state when it moves from one cell to another by receiving periodic measurement reports from the UE. The serving cell then decides to choose a target cell using an algorithm that is described. The table below provides the simulation parameters for this study.

Table 3.1: Simulation Parameters Frequencies Used in 4G & 5G

S/No	Configured Parameters	Parameters Values	
		4G Cell	5G Cell
1	Cell radius in meters	490	190
2	No of eNB	63	184
3	Carrier frequency in GHz	2.2	26
4	System bandwidth in MHz	18	490
5	Transmit power (dBm)	45	29
6	Inter-HO preparation time in mili seconds	59	
7	Measurement time in mili seconds	49	
8	Intra-HO preparation time in mili seconds	9	
9	User Equipment height in meters	1.4	
10	SINR threshold (dB)	-9	

- 4G (LTE) Frequencies: Operates in the sub-6 GHz spectrum (2.2 GHz, 3.5 GHz, etc.).
- 5G Frequencies: Uses both sub-6 GHz (4.5 GHz - 6 GHz) and mmWave (24.25 GHz - 52.6 GHz).

The projected Handover Control Parameters (HCP) values optimized by MRO & LBO functions are not coordinated in the existing Handover (HO) solutions. This lack of coordination results in poor system performance, which increases the likelihood of service interruptions and rates of Radio Link Failure (RLF). This issue is especially important for consumers on ultradense networks and high-speed mobile devices. For the purpose of ensuring a smooth transition and maintaining the proper level of service quality, it is therefore necessary to keep developing the current solutions.

To solve this problem, a dynamic coordinated method is proposed that disables the LBO function and uses a different strategy for its input parameter (cell load). UE speed, SINR, cell load, and other input parameters may all be seamlessly modified using a fuzzy logic control system in this intelligent coordinated manner. The structure of the proposed system merges MRO & LBO functions by predicting values for HCPs. It resolves the conflict issue and simplifies the interaction between the functions. In order to optimize handover performance, this well-coordinated plan considers a number of factors and automatically adjusts HCPs using fuzzy logic control.

To sum up, the suggested method offers a workable fix for the current state of the HO solutions' lack of coordination. It seeks to enhance system performance, minimize conflicts, and provide a smooth handover experience for high-speed mobile users and extremely congested networks in order to provide good quality of service.

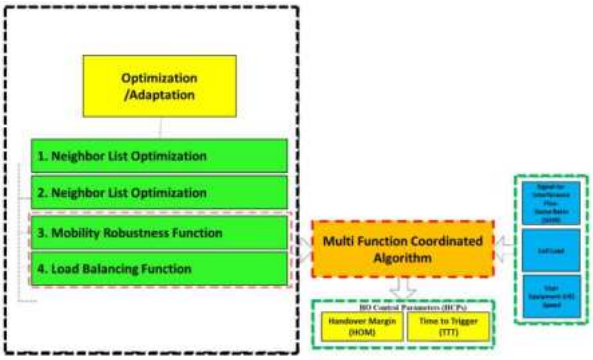

Fig.3.1: Proposed Solution Scheme Framework

The proposed approach includes a dynamic self-optimization mechanism to adjust the Handover Control Parameters (HCPs) based on input parameters from the fuzzy system. The procedure of estimating HCPs also addresses and resolves conflicts between MRO and LBO functions by accounting for cell load factors.

Number of Channels in 4G & 5G Cells & What Happens if no Channel is Available

4G uses OFDMA (Orthogonal Frequency Division Multiple Access) with 18 MHz bandwidth, and 5G uses wider bandwidths up to 490 MHz. If no channel is available, the User Equipment (UE) experiences handover failure, leading to call drops or increased latency, affecting Quality of Service (QoS).

Log Probability (Log P) is not explicitly mentioned or defined in this study, however, logarithmic functions are used in velocity-based handover optimization calculations.

Simulation & Discussion

In respect to Handover Preparation and Execution Time (HOPP), Radio Link Failure (RLF), and Handover (HO) delay, the performance of the suggested scheme is assessed and addressed. Simulations are analyzed using MATLAB in order to validate effectiveness of the suggested method. It is an environment and high-level programming language for numerical calculation, data analysis, and visualization are called MATLAB. Since matrix operations are essential to many scientific and engineering applications, MATLAB, which stands for "MATrix LABoratory," is named after them.

- Operations on matrices: MATLAB has a number of robust built-in operators and functions for working with matrices and arrays. It is effective for processing big data sets because it makes complex mathematical calculations simpler and lets you operate on entire arrays at once.
- Big Library: MATLAB offers a wide range of mathematical, statistical, signal processing, image processing, and machine learning tools. These capabilities let users to do a wide range of tasks, from analyzing and displaying data to solving equations.
- Interactive Environment: For an interactive context, MATLAB provides a command-line interface (CLI) and graphical user interface (GUI). The CLI facilitates experimentation and rapid prototyping by allowing commands and scripts to be executed line by line. The GUI provides a visual interface for performing tasks through interactive menus and tools.
- Data visualization: As visual representations of data, MATLAB offers powerful tools for creating 2D and 3D plots, charts, graphs, and pictures. You may make animations, annotate visualizations, and change their design to effectively exhibit and study data.
- Integration and Interoperability: MATLAB can be integrated with C, C++, Java, Python, and other computer languages. It provides toolboxes and APIs to facilitate data exchange, invoke the functionality of other languages, and leverage pre-existing code libraries.
- Application Development: The Application Compiler in MATLAB makes it possible to create standalone applications. This means that you can package your MATLAB code and distribute it as an executable file, which can be used on computers that aren't running MATLAB.
- A framework for modeling, simulating, and assessing dynamic systems is called Simulink. MATLAB has a graphical interface called Simulink. It's widely used in the design and simulation of control systems, digital signal processing, and other complex engineering systems.

Numerous disciplines, including engineering, physics, mathematics, economics, biology, and data science, use MATLAB. Researchers, engineers, and scientists frequently use it for numerical analysis, data visualization, and algorithm development because of its adaptability, large library, and simple syntax.

Mathematical Modelling

Fuzzy Logic Design Details:

This study describes a fuzzy logic-based handover control scheme that optimizes handover parameters dynamically.

Three fuzzy logic controllers (FLCs) are used:

- SINR-based FLC (for signal quality evaluation)
- Cell Load-based FLC (for network balancing)
- User Speed-based FLC (to adjust handover parameters dynamically)

The fuzzy inference system uses input variables (SINR, Cell Load, UE Speed) to predict Handover Margin (HOM) and Time-to-Trigger (TTT)

SINR $f(\gamma)$, cell load $f(\iota)$, and user velocity $f(v)$, are foundation of suggested self-optimization strategy. The fuzzy system receives these functions as inputs,

and the weights given to each constrained function are used to predict the precise values of the Handover Control Parameters (HCPs), more precisely the HOM levels & TTT interval, for individual User Equipment's (UEs). The following formulation can be used to represent the weight function for the HCPs:

$$f(\gamma, \iota, v) = \Omega_\gamma \times f(\gamma) + \Omega\iota \times f(\iota) + \Omega_v \times f(v)$$

Where Ωγ, Ωι and Ωv are normalized weights SINR, cell traffic load (TL) & user velocity and are written as shown below.

$\Omega_\gamma = (w_\gamma / w_t)$

$\Omega_\iota = (w_\iota / w_t)$

$\Omega_v = (w_v / w_t)$

$$w_t = w_\gamma + w_l + w_v$$

SINR, cell load & user velocity weights are indicated as w_γ, w_l and w_v respectively. According to a popular terminology employed in current literature, these weights are regarded as fixed constants within a given range of values. The second function, cell TL f(ι), embodies the Load Balancing Optimization (LBO) aspect, responsible for maintaining balanced cell load by adjusting HOM values & TTT intervals to generate suitable Handover decisions (HOD) towards a target eNB. Expression for second function can be calculated as:

$$f(\iota) = \frac{\iota T - \iota S}{\iota max}$$

Here ι_T and ι_S depict cell load of target & serving eNBs. ι_{max} depicts max cell load. Fuzzy Logic Control (FLC) of cell consists of 2 fuzzy sets (ι_T and ι_S) inputs & 1 output set ω_ι, whereas membership function consists of 3 & 4 different levels for input and output sets.

$\iota_T = \iota_S$ = {"low", "medium", "high"},

ω_ι = {"low", "average", "high", "very high"}

In order to modify the Handover Control Parameters (HCPs) based on the velocity of the User Equipment (UE), the third function, UE velocity f(v), is essential. It makes sure that the TTT intervals and HOM values are properly adjusted according to UE speed, avoiding any needless handovers which might occur during UE mobility. The UE velocity can be changed using this function, which is modeled as an unbounded function.

$$f(v) = log_2 (1 + v_t)$$

This function can be expressed as follows and has been further improved to comply with the proposed method in this study:

$$f(v) = 2\, log_2 \left(\frac{v_t + v_{max}}{v_{max}}\right) - 1, -1 \leq f(v) \leq 1$$

UE speed at "t" & max UE speed 160 km/h) in urban/suburban cars are represented by v_t and v_{max}. Velocity function restricted by lower & upper bounds (−1, 1). Slow vehicle speed results in the minimal lower bound level of f (v), and fast vehicle speed of v_{max}leads to maximum upper bound level of f (v). The inputs of f (v) are supplied as v_t and v_{max}. The velocity FLC is characterized by single input represented as v & output represented as fuzzy set ω_v. Fuzzy membership function comprises four/five levels of input/output sets, respectively.

v = {very slow, slow, moderate, fast, very fast},

ω_v = {"low", "average", "high", "very high"}.

The main goal of developing the suggested system is to choose the output variables that, based on the input functions, correlate to the estimated Handover Margin (HOM) and Time to Trigger (TTT) interval levels. The adapted HOM, indicated by the symbol (HOM), is the first output variable. It is calculated by dividing the $\overline{HOM}$ or HOM_{max} value by weight function f (γ , ι, v). SINR levels of target and serving eNBs in relation to the SINR threshold γth also affect value of HOM. The following is an expression for the estimated value of (HOM):

$$\Delta(HOM) = \begin{cases} \overline{HOM}(f(\gamma, \iota, v)), \text{if } \gamma T, S \leq \gamma th \parallel \gamma T, S \geq \gamma th, \\ HOM\ max(f(\gamma, \iota, v)), \text{if } \gamma T \leq \gamma th \gamma S \geq \gamma th, \\ f(\gamma, \iota, v), \text{if } \gamma S \leq \gamma th \gamma T \geq \gamma th, \end{cases}$$

$$\overline{HOM} = \frac{HOM_{max} - HOM_{min}}{2}$$

where HOM_{min} and HOM_{max} depict min & max HOM, that carries values of 0 dB and 12 dB. Second output is TTT that produces tunable value b/w 0 - 650 ms by adding new FLC called TTT-FLC with 3 inputs 1 output of fuzzy sets. The TTT-FLC adjusts TTT interval according to outputs of bounded functions.

Fuzzy membership function of TTT-FLC has 3/4 levels of input and output sets.

$$f(\gamma), f(\iota), f(\nu) = \{\text{"low"}, \text{"moderate"}, \text{"high"}\},$$

$$\Delta b(\text{TTT}) = \{\text{"short"}, \text{"average"}, \text{"long"}, \text{"very long"}\}.$$

After updating Δ (HOM) & Δ (TTT), HOD is taken according to reference signals received power written as RSRP for serving cell RSRPS and target cell RSRPT as per algorithm.

Algorithm HO Triggering and Decision

1: Calculate SINR, cell Traffic Load TL & UE speed

2: if reference signals received power $RSRP_T > RSRP_S + \Delta(HOM)$ *then*

3: if time to trigger Trigger timer $\geq \Delta(T\ T\ T)$ *then*

4: HO margin HO Decision ←− True

5: Send HO Request

6: else HO Decision ←− false

7: Run Trigger Timer

8: end if

9: else HO Decision ←− false

10: Reset Trigger Timer

11: end if

V. PERFORMANCE ANALYSIS

Effectiveness of the suggested approach is examined in respect to HO ping pong (HOPP), Radio Link Failure and HO delay. Simulations in MATLAB are run to investigate and validate the suggested approach. Five alternative mobile speed scenarios are taken into consideration to assess network performance: 10, 40, 80, 120 & 160 km/h. Investigating modified values of TTT and HOM is part of the proposed scheme's evaluation. The simulation's HOM and TTT parameters are initially set at 5 dB and 480 ms, respectively. However, if necessary, these values can be changed during user measurements, especially if the simulation time (t) is greater than 1. Based on the suitable speed scenarios, the suggested technique calculates the correct values of HOM and TTT. Additionally, a comparison is made b/w proposed scheme and existing Souza Scheme, that is based on the FLC (Fuzzy Logic Control) system (D. D. S. Souza. 2020).

At various mobile speeds, the accompanying figure shows the average probability of HO ping pong (HOPP) for both the suggested method and the Souza approach. These findings are based on a review of all users who were being tracked and simulation time. By lowering the HOPP rate in all mobile speed scenarios, suggested strategy clearly out performs Souza scheme. This improvement is made possible by the optimized HCPs and coordinated MRO-LBO functions, which successfully manage the handover process and avoid conflicts between LBO and MRO. As a result, the HOPP rate has been significantly reduced, which reduces the amount of network resources that overhead signaling consumes.

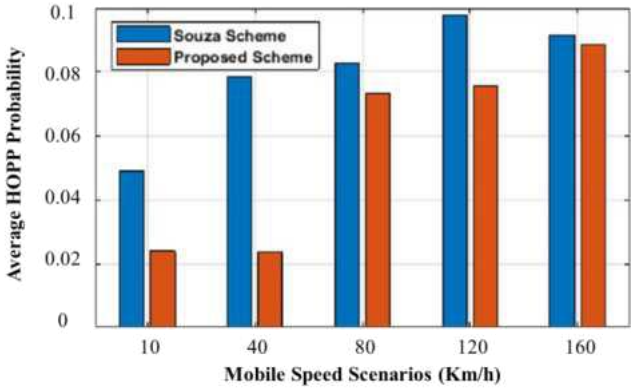

Fig.4.1: Ave HOPP probability (Conceptualized & Souza schemes in relation mobile speeds).

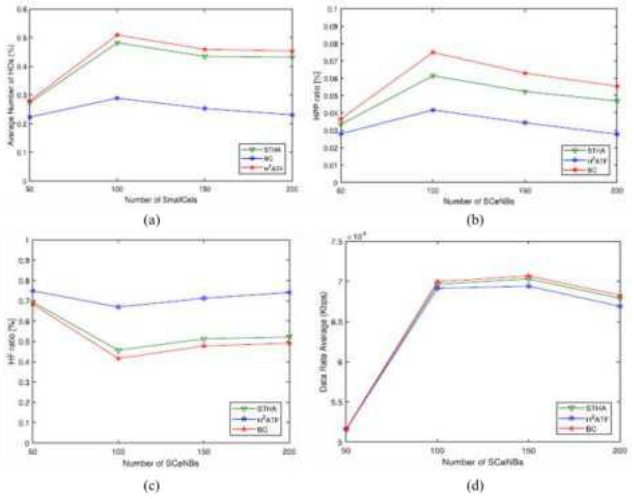

Fig.4.2: Souza approach: Simulation Scenarios (a) Average number of HOs (b) HPP Ratio (c) HOF Ratio (d) Data Rate Average

When three distinct user equipment (UE) speeds are taken into account, Figure 4.3 shows the average chance of Radio Link Failure (RLF) for both the proposed scheme and the Souza scheme over time. As contrast to high-speed cases, the results show a drop in the RLF rate at lower UE speeds. These findings suggest that a low HOPP rate may result in an elevated RLF rate when compared to those in Figure 4.1. A high HOPP rate, on the other hand, leads to overhead signaling, which could lower the RLF rate. Therefore, choosing the right settings for Handover Control Parameters (HCPs) involves making a choice between regulating RLF and reducing HOPP.

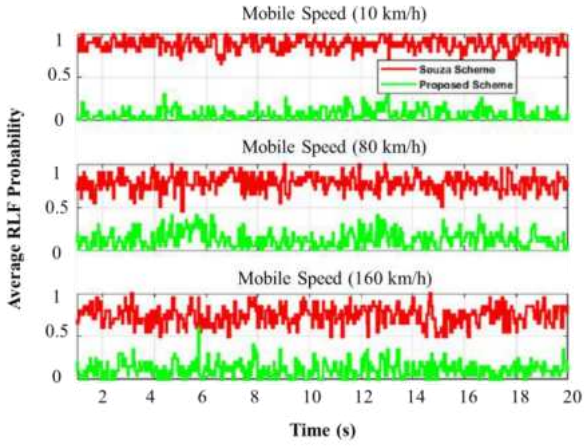

Fig.4.3: Av prob of RLF with respect to mobile speed

A boxplot of the Handover (HO) latency in response to various mobile speed circumstances for all monitored users is shown in Figure 4.4. Notably, when compared to high-speed scenarios, suggested technique significantly reduces HO delay, especially at moderate speeds like 10 & 40 km/h. But in the high speed cases of 120 & 160 km/h, similar median values of HO delay are seen.

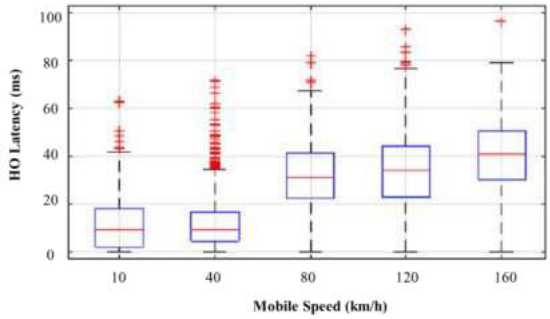

Fig. 4.4: Ave HO latency of proposed scheme with respect to mobile speed

A comparison between the suggested scheme and the Souza method for various mobile speed circumstances is shown in Figure 4.5. At all mobile speeds, proposed scheme consistently outperforms Souza design, resulting in improved connection and increased network service reliability. As shown in Figure 4.1, the suggested technique also successfully lowers HOPP rates, conserving network resources. It is important to note that an increased rate of HO latency during the handover process may cause the transmission of numerous packets to be interrupted, adding to the network's time delays.

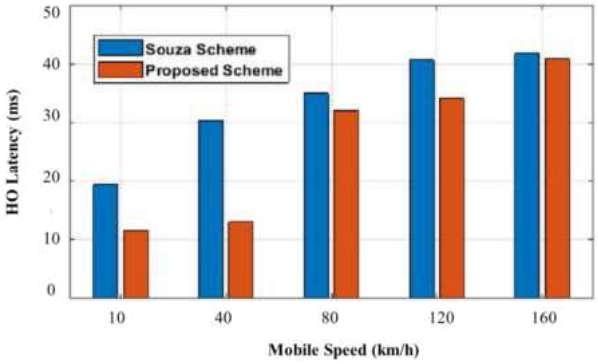

Fig.4.5: Average HO latency of proposed scheme with respect to mobile speed

Figure 4.6 compares the Souza and proposed schemes' overall outage probabilities for all monitored users and mobile speeds. As user equipment (UE) speed increases, the likelihood of an outage tends to rise as well. The outage likelihood, on the other hand, lowers when UE travels at slower speed because the best target evolved NodeB (eNB) is chosen, one with a high SINR and low load. Notably, compared to other techniques, the suggested scheme consistently achieves decreased outage probability over time. Reduction in outage likelihood occurs when serving eNB's signal strength drops below a threshold value is the cause of this improvement. Overall, the proposed plan successfully lowers all handover performance parameters, which significantly lowers the likelihood of an outage.

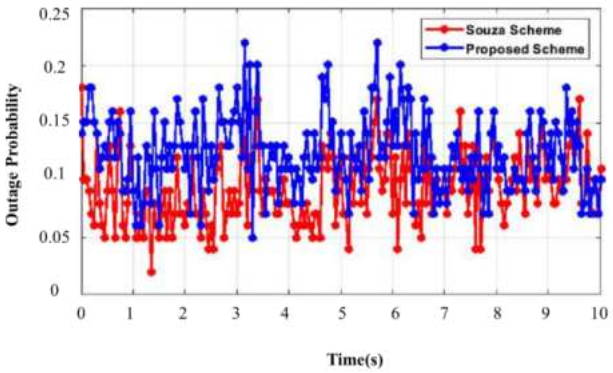

Fig.4.6: Overall outage probability versus time.

This study includes multiple performance evaluation graphs:

- Handover Ping Pong (HOPP) Probability vs. Speed
- Radio Link Failure (RLF) vs. Speed
- Handover Latency vs. Speed

These graphs demonstrate performance improvements of the proposed scheme compared to existing methods. While three graphs provide a strong comparative analysis, additional metrics like outage probability and handover success rates could strengthen for future research.

VI. CONCLUSIONS AND FUTURE WORK

Conclusions

Research presents a dynamic coordinated handover (HO) solution to handle MRO and LBO conflicts in LTE-A/5G HetNets. Weighted fuzzy and bounded functions are used as input to evaluate the weight optimization function of the proposed system. Three fuzzy logic controllers (FLCs) are used in this technique: SINR, user velocity, and cell load. These FLCs enable accurate Handover Decisions (HOD) and improve HO performance by independently predicting each user's Handover Control Parameters (HCPs).

Proposed method performs better in terms of cell edge spectral efficiency, HO latency, and outage probability. Additionally, successfully lessens the intricate interaction that exists between MRO and LBO operations, making faultless handovers possible in networks that use inter-RAT (Radio Access Technology). This finding emphasizes how important the coordination strategy and consideration of input parameters are when building intelligent HO schemes for dense urban HetNets, which contribute to improving network performance in general as users travel between cells.

Handover (HO) concerns during user mobility need fine-tuning the HO control parameters. This paper proposes a self-optimizing fuzzy coordination handover technique (HO) for smooth handovers in multi-radio access networks. The proposed method effectively overcomes the conflict between load balancing functions and mobility robustness by adopting a fuzzy system with three input parameters: signal-to-interference-plus-noise ratio, cell load, and user equipment speed.

Findings demonstrate the effectiveness of the proposed technique in handling ping-pong handovers, radio link failure, and HO delay under a range of mobile speed scenarios. Furthermore, when compared to similar tactics from the corpus of current literature, the suggested strategy significantly reduces the probability of an outage.

VII. FUTURE RESEARCH

While this research has shown encouraging results in optimizing handover performance, there are several areas where future efforts can build upon the current work.

A potential improvement is to explore the use of machine learning techniques. These methods can help in making more adaptive and intelligent handover decisions by learning from network conditions over time.

Future studies can also consider the energy impact of handovers. Reducing energy usage, especially in dense network deployments, is becoming increasingly important and could improve the overall efficiency of the system.

In addition, it may be helpful to study more detailed user movement patterns. Accounting for variations in user behavior, such as sudden stops or irregular speeds, could enhance the precision of handover decisions.

Expanding this work to include other wireless technologies like Wi-Fi or emerging 6G systems would also be a meaningful step forward. This could improve the versatility and broader application of the handover scheme.

Moreover, future research might focus on predicting cell load in advance rather than relying only on current conditions. Anticipating traffic trends could help manage network resources more effectively.

Lastly, strengthening the security aspects of handover processes, especially in highly mobile or sensitive environments, could be another valuable direction. Ensuring secure and smooth transitions between cells will be essential as networks continue to evolve.

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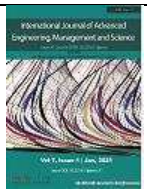

Food and Beverage Industry in Post-Pandemic: Business Strategies and Profitability

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Abstract *— The study focused on how the food and beverage industry in Nueva Ecija faced the challenges brought about by the pandemic and remained lucrative post-pandemic. This study on marketing, operation, management, and financial involvement is essential in the industry to address tension from the global crisis. Digital marketing tools are essential for the marketing and operations of food and beverage businesses. Most of the establishments incorporate in their ventures the use of technologies such as social media sites, ordering applications online, and other digital applications that would bring in more profit. The changeover attracts more customers, saves on costs, and generates more income. Financial turnover, personnel training, superior customer service, and technological investment enhance operational efficiency and cost savings. To survive, management must be agile, flexible, and prompt. It has to handle the establishment's resources prudently, and its financial policy must be readjusted immediately. Health and safety protocols must also be updated because this is one way the establishment will be prevented from financial constraints. It must focus on budgeting, debt arrears, and cost controls with much caution because these are its securities against economic outcomes. The present study shall provide practical guidance for the food and beverage industry stakeholders desirous of success post-pandemic. It emphasizes the measures the institution has taken to contain the crisis and, in general, outlines a vision for long-term growth and stability in the industry.*

Keywords *— **Food and Beverage Industry, Business Strategies, Profitability, Post-Pandemic***

I. BACKGROUND OF THE STUDY

The COVID-19 pandemic has changed the food and beverage industry in a way nothing else on a global scale has, making it necessary for companies to make instant changes to stay in the biz. In the instant case, the pandemic came down heavily with restrictions on customer behavior, supply chains, and operational capabilities, forcing businesses to rethink their strategies to maintain a proportionate profit level. Unprecedented disruptions in service delivery while maintaining profitability mandated significant changes in how services were delivered, marketed, and kept safe, according to Eyink (2020).

The food and beverage establishments in the five cities of Nueva Ecija, Philippines, could not escape these hardships. Therefore, many businesses have turned to digital solutions to sustain customer engagement and maintain feasibility. Aigbedo (2021) highlighted how technology delivered solutions like digital payments and online delivery services, which maintained businesses' adaptability to accommodate changing customer requirements while maintaining economic efficiency. However, these required significant training, technology, and safety protocol investments.

Post-pandemic, most businesses were busy improving operational efficiencies and controlling costs to save those margins. Marketing tactics also changed; they turned towards various digital platforms to help businesses attract new visitors and keep clients coming back. The role of digital marketing, in particular, proved essential for sales

volume; research indicated that digital marketing helped businesses regain some ground and surpassed expectations in terms of return on investment (Boyland et al., 2020). Normalizing these technological advancements was necessary for consumer engagement and profitability after the pandemic.

Moreover, with this marketing channel out of the question, businesses adapted their operations to continue to operate efficiently and profitably. Operational changes in online ordering systems and point-of-sale technologies improved mean efficiency and kept costs proportionate, contributing to increased profitability (Hancock, 2024). These business upgrades were so cost-effective that businesses could still invest in serving customers better but keep on a safe financial side.

Further, strategic financial management largely determines profitability in post-pandemic as well. Financial planning and risk mitigation were a chief concern that many of these food and beverage outlets grappled with as they braced their operations for the worst. This has been possible as investments in technology solutions, including digital marketing and online sales channels, have worked to increase revenues. According to Bergeaud et al. (2021), Companies that adjusted their finances according to evolving customer tastes and market dynamics experienced substantial profit boosts.

This aside, supply chain rationalization also paid off the benefits of operational efficiency and benefitted from sales growth, which gained traction in part due to improved product availability and cost control. It allowed them to strengthen their balance sheets (Lincicome, 2021). This enabled businesses to cope with the financial risks from the pandemic and improve overall strength in finance. Moreover, sustainability and resource efficiency increasingly underpin the profitability of the food and beverage industry. Energy usage reductions and better waste management reduced costs, too, which helped the companies achieve higher profits (Dopson & Hayes, 2019).

Overall, the post-pandemic era has called for food and beverage service operators to implement digital marketing tools, operational strategies, and financial practices to stay profitable. Technology has enabled businesses to reduce costs and manage financial risks more effectively to survive and thrive in a challenging economic climate.

Objectives

1. To determine the demographic profile of the food and beverage industries in post-pandemic.
2. To determine how many business aspects based on profitability in the food and beverage industry are described post-pandemic.
3. To determine outcomes and development plans for the food and beverage industry in post-pandemic.

II. METHODOLOGY

A descriptive comparative research design method was used in this study. The research aimed to understand how establishments in the field have responded to changing practices of operations, marketing, management, and finance in the wake of COVID-19. The researcher selected this approach because it allows for establishing relationships between variables without influencing them, thus providing a clear picture of how the industry responded to the post-pandemic. To this end, a study was conducted in Nueva Ecija, Philippines, famous for its various agricultural and food production sectors. It included 40 food and beverage establishments selected by systematic sampling as units of analysis. This was a probability sampling method for restaurants, cafes, bars, and fast-food chains. The researcher included only subjects operating during and still operating in the pandemic as an inclusion criterion. The main instrument used was a questionnaire survey regarding the commercial characteristics of food and beverage outlets in the post-pandemic period. The survey consisted of marketing, operations, management, and financial strategies. Its objective was to analyze whether these measures influenced the profit of the establishments after all that happened due to the pandemic. The instrument was developed and validated by the authors' adviser and other experts in the field. The researcher obtained approval from the relevant authorities and distributed plain old-fashioned questionnaires in person to respondents. To ensure the responses were clear and to avoid as many errors as possible when completing the forms, we used a traditional data collection method in a face-to-face manner. Scale data during the process, including

management and staff of selected establishments, were also recorded. The data gathered from the survey were analyzed accordingly through several statistical tools like frequency and percentage distribution to see the profile of the food and beverage establishment and a mean and weighted means in determining whether such business strategies affect profitability. It concentrated on the marketing, operations, management, and financial strategies that sustained business performance during and post-pandemic.

The researcher's adviser and five field experts check the validity and reliability using Cronbach's alpha, ensuring that an instrument will be consistent with different user groups. The reliability for profitability is 0.972.

III. RESULT AND DISCUSSION

1. **Demographic Profile of the Food and Beverage Industry** - The data gathered are presented, analyzed, and interpreted under the following major headings: the demographic profile of the food and beverage establishment in post-pandemic in Nueva Ecija.

Table 1.1 Type of establishment

Type of Establishment	Frequency	Percentage
Restaurant	13	32.5
Café	5	12.5
Bar	9	22.5
Fast Food	13	32.5
Others	0	0.0
Total	40	100.0

Most establishment respondents are restaurants and fast-food chains, and the least are the other types of food and beverage establishments. Gomez et al. (2023) provided detailed survey research principles, noting that diverse categories can profile demographics. The distribution of respondents showed that most establishment respondents, the restaurants and fast-food chains, have received the highest frequency, 13 or 32.5 percent of the data gathered. Zero percent belong to other types of food and beverage establishment respondents, presenting the lowest frequency.

Table 1.2 Number of years in operating

No. of years in Operating	Frequency	Percentage
1-4 Years	29	72.5
5-9 Years	2	5.0
10-14 Years	5	12.5
More than 15 Years	4	10.0
Total	40	100.0

Most establishment respondents operate for 1-4 years; the least is 5-9 years. Harsan and Gupta (2023) analyzed survey design and demographic profiling question development and administration in their comprehensive survey technique study.

The distribution of respondents showed that most of the establishment respondents' 1-4 years of operating have received the highest frequency, 29 or 72.5 percent of the data gathered. 5 percent belong to the 5-9 years of operating establishment respondents, presenting the lowest frequency.

Table 1.3 Type of business organization

Type of Business Organization	Frequency	Percentage
Sole Proprietorship	26	65.0
Partnership	10	25.0
Corporation	4	10.0
Cooperative	0	0.0
Total	40	100.0

The type of business organization most establishment respondents have is sole proprietorship; the least is Cooperative. Ziegenfuss et al. (2021) defined "Survey Kit" as a tool for company demographic profiling and fast survey production. It uses questionnaire design elements like "type of organization" categories to obtain demographic data. This helps students and scholars write research questions that yield precise and dependable outcomes in dissertations and other academic tasks.

The distribution of respondents showed that most of the establishment respondents' type of business organization, which is the sole proprietorship, have received the highest frequency, 26 or 65 percent of the data gathered. 0 percent belong to the Cooperative

type of business organization that the establishment respondents, presenting the lowest frequency.

Table 1.4: Number of employees

Number of Employees	Frequency	Percentage
1-10	37	92.5
11-20	2	5.0
21-30	1	2.5
More than 30	0	0.0
Total	40	100.0

The number of employees of most establishment respondents is 1-10; the least is More than 30. (United Airlines, Inc., n.d.) provides detailed survey administration instructions, including demographic profile generation. This emphasizes including the "number of employees" option to obtain demographic data.

The distribution of respondents showed that most of the establishment respondents' number of employees, which is 1-10 employees, have received the highest frequency, 37 or 92.5 percent of the data gathered. 0 percent belong to the establishment respondents have More than 30 employees, presenting the lowest frequency.

Table 1.5: Start-up capital

Start-up Capital	Frequency	Percentage
Less than P100,000	8	20.0
P100,000 to less than P500,000	18	45.0
P500,000 and above	14	35.0
Total	40	100.0

Most establishment respondents' start-up capital is 100,000 to less than 500,000 pesos; the least is less than 100,000 pesos. According to Beatricearonson (2024), this source describes survey research methods, including how to plan and conduct demographic surveys. This examines how financial indicators like "start-up capital" might be used to collect firm demographic data.

The distribution of respondents showed that most establishment respondents' start-up capital, 100,000 to less than 500,000 pesos, have received the highest frequency, 18 or 45 percent of the data gathered. Twenty percent of the establishment respondents have start-up capital of less than 100,000 pesos, presenting the lowest frequency.

Table 1.6: Annual income

Annual Income	Frequency	Percentage
Less than P100,000	18	45.0
P100,000 to less than P500,000	21	52.5
P500,000 and above	1	2.5
Total	40	100.0

Most establishment respondents' annual income is 100,000 to less than 500,000 pesos; the least is 500,000 and above. The instructions provide a complete framework for company surveys. (*Earnings (CPS)*, 2024) advocated using "annual income" bands to create demographic profiles of businesses. This emphasizes the importance of financial metrics and offers practical advice on conducting these inquiries to ensure correct and dependable academic data.

The distribution of respondents showed that most establishment respondents' annual income, 100,000 to less than 500,000 pesos, have received the highest frequency, 21 or 52.5 percent of the data gathered. 2.5 percent of the establishment respondents have start-up capital of 500,000 and above, presenting the lowest frequency.

2. Business Aspects Base on Profitability in the Food and Beverage Industry in a Post-Pandemic.

Table 2.1: Marketing Based on Profitability

Marketing Based on Profitability	Management WM	VD	Staff WM	VD
1. The marketing strategies aided us in acquiring more customers during the post-pandemic period.	3.15	MA	3.28	A
2. Digital marketing has become a blessing in disguise for every post-pandemic business to increase sales and profitability. The results are effective; hence, many businesses benefit from it.	3.00	MA	3.18	MA
3. We have achieved or surpassed our desired ROI based on the results of our marketing campaigns.	3.00	MA	3.20	MA
4. We have effectively leveraged marketing strategies to increase the overall brand awareness in the market.	3.23	MA	3.25	A
5. During the post-pandemic, an enormous marketing effort has helped accelerate customer retention.	3.15	MA	3.33	A
6. Our marketing tactics have continued to convert for the current times and changes that COVID has brought on with the consumer preferences and other things involved within the market.	2.88	MA	3.38	A
7. Social media has proved to be a lucrative and effective customer engagement technique.	3.25	A	3.38	A
8. Local marketing strategies have been a Godsend for keeping and retaining local customers.	3.03	MA	3.38	A
9. Running promos and discounts has helped increase sales and profit, which is perfect for improving profitability.	3.20	MA	3.68	A
10. We are generally delighted with the results of our marketing efforts to boost profitability post-covid.	3.08	MA	3.55	A
Overall Weighted Mean	3.10	MA	3.36	A

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the marketing based on the profitability of food and beverage establishments in Nueva Ecija post-pandemic. The numerical data about the first set of indicators, the popularity of the five cities with the management respondents, with an overall weighted mean of 3.10, is classified as "Moderately Agree" and interpreted as "Moderately Effective."

The management respondents' statement, "Social Media Marketing has proved to be a lucrative and effective customer engagement technique," got the highest weighted mean of 3.25, which falls under the "Agree" or "Very Effective" category.

Dublino (2023) wanted to know how content related to fast-moving consumer goods generated by social media firms influences food and beverage profitability and customer behavior. This research will help create actionable social media marketing strategies to cut down on your finances. It is excellent for industry/hottest marketing dissertations on profitability.

In contrast, for the management respondents, the statement "Our marketing tactics have continued to convert for the current times and changes that COVID has brought on with the consumer preferences and other things involved within the market." received the lowest weighted mean of 2.88 or classified as "Moderately Agree" and was interpreted as "Moderately Effective."

Gregory (2023), what with COVID-19 lockdowns hitting the food and beverage space. Looks at the financial implications of different advertising tactics following those changes. The information has helped to understand how food and beverage marketing changed during the outbreak and afterward, which means it is perfect for the dissertation.

The staff respondents with an overall weighted mean of 3.36 were classified as "Agree" and interpreted as "Very Effective."

The staff respondents' statement, "Running promos and discounts has helped increase sales and profit. This is just perfect for better profitability." got the highest weighted mean of 3.68, which falls under the "Agree" or "Very Effective" category.

Garrett (2024) Investigating sales promotions on food and beverage profitability. Attend this record-breaking seminar and receive training on the science behind using discounts and other promotions to increase sales and drive behavior changes. The results are essential for researching the profitability of food and beverage marketing promotions and discounts.

In contrast, the staff respondents' statement, "Digital marketing has become a blessing in disguise for every post-pandemic business to increase sales and profitability. The results are effective; hence, many businesses benefit from it." received the lowest weighted mean of 3.18, which was classified as "Moderately Agree" and interpreted as "Moderately Effective."

Haelsoft (2023) This content more deeply comprehends the financial role of digital marketing in this domain. The information shows that digital marketing is a source of revenue and facilitation for organizations.

Table 2.2: Operation Based on Profitability

Operation Based on Profitability	Management WM	VD	Staff WM	WM
1. 1. Our operational processes, which we implemented after the pandemic, have positively impacted our efficiency overall.	3.25	A	3.40	A
2. Post-pandemic, we have kept some of our operational costs low within the range of ingredients, labor, and utilities, which helped us remain profitable.	3.15	MA	3.05	MA
3. As a result, we have effectively implemented the various covid-safety protocols with only minor detriment to our operational efficiency or, for that matter, our bottom line.	3.08	MA	3.33	A
4. With new technology like online ordering and POS systems, we were able to remain cost-effective while increasing our profitability. Upgrades that we have seen have proven cost-effective and helped us better serve our customers.	3.20	MA	3.30	A
5. As an organization, we spent money post-pandemic on training our workforce and building capacity, infrastructure, customer satisfaction scores, and margins.	3.00	MA	3.28	A
6. By executing post-pandemic supply chain adaptations, we improved profitability with increased product availability and cost efficiency.	3.13	MA	3.20	MA
7. Post-pandemic changes to spacing and entry/exit management have helped maintain profitability or even increase it.	3.18	MA	3.28	A
8. This has allowed us to make quicker and more profitable profits, as changes to our menu have made significant gains since the pandemic.	3.15	MA	3.25	A

9. Our energy and resource management initiatives have reduced costs and improved intervention margins.	3.15	MA	3.13	MA
10. Our operational changes in the wake of the pandemic will be a net positive for our bottom line.	3.05	MA	3.23	MA
Overall Weighted Mean	3.13	MA	3.24	MA

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the operation based on the profitability of food and beverage establishments in Nueva Ecija post-pandemic. The findings showed the numerical data about the first set of indicators: the popularity of the five cities with the management respondents with an overall weighted mean of 3.13 classified as "Moderately Agree" and interpreted as "Moderately Effective."

For the management respondents, the statement " Our operational processes, which we implemented after the pandemic, have had a positive impact on our efficiency overall." got the highest weighted mean of 3.25, which falls under the "Agree" or "Very Effective."

According to MJ (2024), it clarifies hotel management and its financial performance, effective operating modes, and how to make it happen.

In contrast, the management respondents' statement, "We, as an organization, spent money post-pandemic on training our workforce and building capacity, infrastructure, customer satisfaction scores, and margins." received the lowest weighted mean of 3.00 or was classified as "Moderately Agree" and interpreted as "Moderately Effective."

Villar et al. (n.d.) established operational metrics based on a potential profitability class in their study of operation performance appraisal and control systems. This practical set of tips will help bracket survey answers so it can measure vital organizational characteristics. This is to ensure reliable and accurate papers and actual academic publications.

The staff respondents with an overall weighted mean of 3.24 were classified as "Moderate Agree" and interpreted as "Moderate Effective."

The staff respondents also agreed with the management statement, "Our operational processes, which we implemented after the pandemic, have had a positive impact on our efficiency overall." This statement received the highest weighted mean of 3.40, which falls under the "Agree" or "Very Effective" category.

Moktadir et al. (2022) state that many operational strategies are used by food and beverage companies to boost sales. This examination is worthwhile for academic research and potentially relevant to the operations of all facilities in the hospitality sector. Operations management may also improve financial results.

In contrast, the staff respondents' statement, "Post-pandemic, we have kept some of our operational costs low within the range of ingredients, labor, and utilities, which helped us remain profitable." received the lowest weighted mean of 3.05 or was classified as "Moderately Agree" and interpreted as "Moderately Effective."

An excellent job expounding on cost-cutting measures in the food and beverage industry, including materials, labor, utilities, etc. In this study, the cost-cutting strategy to increase profits from an employee perspective shows the cruciality of resource management (*Global Economic Outlook,* 2024).

Table 2.3: Management Based on Profitability

Management Based on Profitability	Management WM	VD	Staff WM	VD
1. Our management made the right decision quickly after the pandemic, which brought back profits in stable form for us.	3.25	A	3.38	A
2. Everyone on the management team has done a really good job mitigating the financial losses of the pandemic.	3.23	MA	3.23	MA
3. Our profits exceeded expectations based on management's innovative changes to our business model post-pandemic. We are now very slowly demonstrating some of those results by the changes that we made carefully.	3.18	MA	3.35	A
4. We have changed our financial strategies after the pandemic and transformed economically better,	3.13	MA	3.38	A
5. The company's management in the post-pandemic successfully managed the skill set of its employees, which enabled them to make belly-full profits.	2.95	MA	3.30	A
6. Management's initiatives to get customers to buy in the stores have strengthened our profits.	3.15	MA	3.23	MA
7. Examining the aftermath of the market after the pandemic allowed us to make better decisions and profit. I grouped our strategies based on this analysis, and the result on margins was fantastic.	2.98	MA	3.28	A
8. The management efficiently managed the regulatory changes post-pandemic, expecting minimal financial problems.	3.33	A	3.50	A
9. The leadership of our organization got in early and saw great returns from sustainability investments.	3.20	MA	3.30	A
10. In summary, management's strategy post-pandemic has been very beneficial, and the end result should be a nice boost to our profits.	3.23	MA	3.45	A
Overall Weighted Mean	3.16	MA	3.34	A

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the management based on the profitability of food and beverage establishments in Nueva Ecija post-pandemic. The findings showed the numerical data about the first set of indicators: the popularity of the five cities with the management respondents with an overall weighted mean of 3.16 classified as "Moderately Agree." They interpreted it as "Moderately Effective."

For the management respondents, the statement "The management efficiently managed the regulatory changes post-pandemic, expecting minimal financial problems." got the highest weighted mean of 3.33, which falls under the "Agree" or "Very Effective" category.

Chiu et al. (2021) studied how food and beverage companies adjust to the new regulation and what it means for their profits. This is the aftermath of post-pandemic management in the food and beverage industry. It also offers management guidance on how to play by the (new) rules and still be sound in finance.

In contrast, the management respondents' statement, "The company's management in the post-pandemic successfully managed the skill set of its employees, which enabled them to make belly-full profits," received the lowest weighted mean of 2.95 or was classified as "Moderately Agree" and interpreted as "Moderately Effective."

Haque (2023) states that this research study will analyze the nexus between human resource management practices, employee attributes, and food and beverage outlet profitability. Moreover, the proposed model will investigate staff skill enhancement investments alongside relevant hospitality operational performance and financial outcomes from a managerial perspective.

The staff respondents with an overall weighted mean of 3.34 were classified as "Agree" and interpreted as "Very Effective."

The staff respondents, "The management efficiently managed the regulatory changes post-pandemic, expecting minimal financial problems." This statement got the highest weighted mean of 3.50, which falls under the "Agree" or "Very Effective" category.

Tomic and Heims (2022) explored the impact of legal reforms on human resource management and hospitality profitability. Understanding the operational challenges and solutions to meet new requirements and secure financial performance is crucial. Managers and staff need to make the following changes.

In contrast, the staff respondents' statements, " Everyone on the management team has done an excellent job mitigating the financial losses of the pandemic" and "Management's initiatives to get customers to buy in the stores have strengthened our profits." both received the lowest weighted mean of 3.23 or were classified as "Moderately Agree" and interpreted as "Moderately Effective."

A management intervention for food and beverage companies to reduce financial loss, increase employee involvement, and develop suitable management methods. The literature considers these working papers to study the best way to manage costs, reduce waste, and improve efficiency to gain more profit—excellent money management advice for facilities staff members (*COVID-19 Financial Mitigation Strategies*, 2024).

Table 2.4: Financial Based on Profitability

Financial Based on Profitability	Management WM	VD	Staff WM	VD
1. Our management made the right decision quickly after the pandemic, which brought back stable profits for us.	3.10	MA	3.18	MA
2. Everyone on the management team has done an excellent job mitigating the financial losses of the pandemic.	3.05	MA	3.45	A
3. Our financial strategies have enabled us to generate desirable revenue growth in a post-pandemic world.	3.23	MA	3.28	A
4. Our pricing strategy has also changed post-pandemic, contributing to the increase in profitability.	3.13	MA	3.33	A
5. The company's management in the post-pandemic successfully managed its employees' skill sets, which enabled them to make belly-full profits.	3.20	MA	3.30	A
6. Our financial planning and forecasts have significantly helped our business strategy since the pandemic.	3.03	MA	3.13	MA
7. Examining the market's aftermath after the pandemic allowed us to make better decisions and profit. We grouped our strategies based on this analysis, and the margin result was fantastic.	3.05	MA	3.35	A

8. We have managed our cash efficiently to keep the continuity and profitability of our business.	3.03	MA	3.53	A
9. Post-COVID 19, we handled our debts well, which also played a vital role in keeping us financially fit and having a profitable business.	2.93	MA	3.40	A
10. Management's post-pandemic strategy has been very beneficial, and the result should be a nice boost to our profits.	3.05	MA	3.35	A
Overall Weighted Mean	3.08	MA	3.33	A

Legend: 1.00 to 1.74 Disagree; 1.75 to 2.49 Slightly Agree; 2.50 to 3.24 Moderately Agree; 3.25 to 4.00 Agree

The respondents may assess the finances based on the profitability of food and beverage establishments in Nueva Ecija post-pandemic. The findings showed the numerical data about the first set of indicators: the popularity of the five cities with the management respondents with an overall weighted mean of 3.08 classified as "Moderately Agree" and interpreted as "Moderately Effective."

For the management respondents, the statement "Our financial strategies have enabled us to generate desirable revenue growth in a post-pandemic world." got the highest weighted mean of 3.23, which falls under the "Moderate Agree" or "Moderate Effective" category.

(*Small Business and Entrepreneurship in the Post-COVID Expansion*, 2024), The food and beverage industry must recognize these strategies. The research highlights various how-to management techniques that increase gross sales.

In contrast, the management respondents' statement, "Post-COVID-19, we handled our debts well, which also played a vital role in keeping us financially fit and having a profitable business." received the lowest weighted mean of 2.93, which was classified as "Moderately Agree" and interpreted as "Moderately Effective."

Nguyen et al. (2022) examine the effects of debt management on food and beverage companies because managers help to increase their organizations' financial position.

The staff respondents with an overall weighted mean of 3.33 were classified as "Agree" and interpreted as "Very Effective."

The staff respondents' statement, "We have managed our cash efficiently to keep the continuity and profitability of our business." got the highest weighted mean of 3.53, which falls under the "Agree" or "Very Effective" category.

Grube et al. (2020) provided an overview of food and beverage outlet financial management techniques, emphasizing the importance of processing multi-currency transactions. This study analyzes the impact of cash management on food and beverage profits. Workers impart methods of keeping business on an even keel and money in the till.

In contrast, for staff respondents, the statement "Our financial planning and forecasts have significantly helped our business strategy since the pandemic." received the lowest weighted mean of 3.13 or was classified as "Moderately Agree" and interpreted as "Moderately Effective."

(*How to Execute Annual Financial Planning and Forecasting in Today's Environment*, n.d.) also offers an elaborate course on hospitality-restricted financial management foundations corresponding to planning and forecasting. It starts a discussion on how to balance operational efficiency, profitability of food and beverage, and what financial planning and forecasting mean from staff perspectives.

3. Development Plan for Business Aspects Based on Profitability in Food and Beverage Industry in Post-Pandemic.

The tables outline a comprehensive Development Plan for Business Aspects Based on Profitability in the post-pandemic food and beverage industry. They cover key areas: Marketing, Operations, Management, and Finance, detailing programs, objectives, resources, funding sources, timelines, and expected

outcomes. These strategies aim to enhance profitability through digital marketing, operational efficiency, workforce development, and financial stability, ensuring long-term growth and sustainability in a competitive market.

Table 3.1: Development Plan for Marketing Based on Profitability

Area for Development	**Program/ Activities**	**Objectives**	**Person Involved**	**Resources Needed**	**Source of Fund**	**Time Frame**	**Expected Results/Outcomes**
Adjusted consumer demand and market changes **Digital marketing**	Use surveys, focus groups, and consumer data analysis to learn how preferences change and where the market is headed. Communicate with potential customers using social media, email marketing, and influencer collaboration.	Ensure that our products are based on the prevailing consumer demands and preferences determined by our in-house market research. Boost brand visibility and click-through from digital channels.	Market research analysts: Conduct and analyze market/research data to guide strategic decisions. Product Development: Creating new product offerings with market insights from research. The marketing team led them to plan and execute digital campaigns and customer engagement activities. IT departments support both digital marketing and website/app development.	Money for marketing campaigns, market research, and customer engagement efforts. Software for social media management platforms, email marketing software, and data analytics tools. Skilled marketing professionals, market researchers, HR personnel, and IT support. Operational Web and mobile (Websites, Apps, etc.) infrastructure to support various digital	Ask sponsors or look for partners of allied brands in the field.	Short-term; Launch initial digital marketing campaigns and customer engagement activities. Begin market research. Mid-term: Analyze the results of what was done initially and fine-tune strategy if needed. Integrate Research— Identify and embed a market finding into the product offerings. This will increase attractiveness and sales. Long-term: Implement continuous improvement processes built on market	Improved brand visibility will increase engagement rates on digital platforms and online traffic.

				Initiative Capture.		research and customer feedback collected over time. Informed Product Developmen t—If companies understand what kinds of products consumers want, they can build and sell new offerings and gain more customers and market share.	

Table 3.2: Development Plan for Operation Based on Profitability

Area for Development	Program/ Activities	Objectives	Person Involved	Resources Needed	Source of Fund	Time Frame	Expected Results/Outcomes
Staff training programs **Service delivery enhancement** **Customer feedback mechanism** **Cost-effective sourcing** **Labor optimization** **Energy efficiency measures**	Workshops and virtual online training on customer service skills, product knowledge, and operational efficiency. Rolling out new service protocols and deploying additional technology for order processing changes the customer experience. Create processes for measuring and fine-tuning the quality of service on an ongoing basis using surveys	Increase the quality of service and customer interaction efficiency. Improve customer satisfaction to gain higher levels of customer satisfaction and loyalty. Drive higher profitability with better service delivery through more operational efficiencies. Reduce the costs of ingredients, labor, and utilities to save on operational expenditures. Keep it profitable — Do not let the business lose money even when income wavers. Improve green	Managers of HR and training teams - Training program development, delivery, and deployment of Labor optimization and cross-training efforts. The team that handled the customer service portion administering feedback from customers and remedying problems with services IT has read more about the facilitation of technology improvements for	Introductory resources for online platforms, introduction to using workshop guides, and many others. Cross-Training and Flexible Staffing Program Materials. Technology entry: Improved system of order processing and client feedback software. Trainers, facilitators, and technical support staff (HR). Budget for training programs, technolog	Internal budget: funds from operational budgets and potential cost savings and reallocating savings from reducing operational costs to fund initiatives. External: Exploring grants or subsidies available for workforce development and technological improvements.	Short-term: Launch initial training programs, essential service delivery modifications, and initial cost-saving measures in ingredient sourcing and optimizing labor. Mid-term: Complete advanced training, fully integrate the new service protocols, complete the energy efficiency upgrades, and streamline the labor strategies. Long-term: Schedule regular training reviews	Improved Service Quality: Customer interaction is more accessible, and service is better streamlined. Greater Profitability: Higher operational efficiency. Lower Operational Costs: Minimal expense on ingredients, labor, and other utilities. Sustained Profitability: Profitability maintained or increased.

	and feedback mechanisms. It must work with suppliers for better prices and sourcing new, lower-cost ingredients. Flexible staffing models and cross-training of staff are both being pursued. It must replace equipment with energy-efficient models and implement practices to save money on energy consumption.	sustainability and engage in environmentally friendly practices to lower utility costs.	service outreach. Facilities Management: It ensures energy efficiency initiatives and equipment investments, implements new service protocols and technological upgrades, manages vendor negotiations, and sources cost-effective ingredients.	y upgrades, and the initial investments in energy efficiency and training programs. Sourcing tools for supplier databases and negotiation tools. Energy-efficient equipment for kitchen and facility investment.		and service updates based on customer feedback. Continuously monitor and update cost-saving means for sustained profitability.	

Table 3.3 Development Plan for Management Based on Profitability

Area for Development	Program/ Activities	Objectives	Person Involved	Resources Needed	Source of Fund	Time Frame	Expected Results/Outcomes
Skill utilization program Financial optimization initiatives	Scheduling skills tests, providing strength-informed roles, and continued education. Deploying financial management techniques and policies to curtail losses.	Take full advantage of employee potential by using their skills to improve productivity and innovation. Develop and implement strategies to mitigate financial risks by controlling costs and enhancing economic resilience.	The management team focuses on executing use-of-ability, costing, and involvement strategies. The HR department has the onus of skills assessments and professional development workshops. Finance team control over costs and financial planning. To help the marketing team create and implement better customer engagement tactics.	Menu Overview Performance appraisal software and tools for employee reviews below are the main types of systems that organizations use to improve their current performance review process: Skills assessment tools for skills assessment software. Training material and resources such as professional development programs for ongoing learning. Financial management tools:	An internal budget should be drawn from the operation money and the potential savings of cost-control measures. They might seek external funding to apply for grants or subsidies for employee training and development programs.	Short-term: Skills assessments, cost-control measures, and customer engagement. Mid-term: Finish pro-development programs, tighten financial strategies, and ramp up customer loyalty initiatives. Long-term: Monitor employee utilization, financial management, and	Employees will work better, allowing them to use their skills properly, leading to creativity and innovation. Minimized Financial Losses: It will reduce financial losses and increase economic stability.

				budgeting and forecasting, 'what if' analysis software. E-mail promoting E-mail Advertising Suite and social media publishing syndication tools. Professional services (HR, Finance, Marketing, etc.)		customer engagement strategies closely to ensure steady growth.	

Table 3.4. Development Plan for Financial Based on Profitability

Area for Development	**Program/ Activities**	**Objectives**	**Person Involved**	**Resources Needed**	**Source of Fund**	**Time Frame**	**Expected Results/Outcomes**
Debt management programs Business planning and forecasting	Debt consolidation, in which, for example, the existing debt is structured to make it easier to manage or talk with creditors to get more favorable terms and, therefore, have a financial	Financial health by managing debt well and ensuring that the company remains healthy and profitable.	The management team is in charge of managing debt and financial planning strategies. Ongoing work for the finance team performing financial analyses, debt	Financial management tools for the software version. Software testing for debt management Economic analysis and forecasting. Specialists in finance, analysts, accountants	Discretionary budget for transferring funds from operational budgets to support financial planning and debt management efforts.	Short-term: Begin debt placement, create essential financial forecasts and plans. Mid-term: work on the debt repayment plans	Better Fiscal Health: It will give the business a better financial status. Precise Financial Forecasts: This means more precise financial forecasts, which can help strategize better so that businesses can make better decisions. More Profitability: It will enjoy increased

	debit scheme. Performing recurring financial analysis to formulate precise economic predictions and logical fiscal plans.	Better Plan Revenue to Drive Strategy with precise financial plans and forecasts. Make smarter decisions and drive profitability by using financial data.	management, and strategic planning with a focus on financing. External advisors are responsible for Some tasks are outsourced to external advisors, debt agencies, and financial advisors. Operation team that works on financial strategies and adjustments in the execution plan.	, and financial advisers (outsourcing) resources for educational materials on financial management and forecasting techniques to the ongoing human resources training. Legal assistance for debt arrangements: negotiation, restructuring Corporate Debt.	Seeking financial help from investors or financial institutions to restructure any required debt.	and business forecasts based on performance. Long-term (1-2 years): Continue to monitor and modify how you manage debt and financial planning to thrive economically.	profitability due to enabled financial planning and debt control.

IV. CONCLUSION

These insights are based on the data collected from food and beverage establishments in Nueva Ecija under different parameters after the pandemic, helping them determine their operation, marketing, management, and financial strategies. Eateries and fast-food joints are the two most common establishment types, of which 72.5% have been running for 1-4 years. Among establishments, sole proprietorships predominate, and a large share of them (40%) operate with a small workforce size of 1-10, further suggesting a configuration skewed toward smaller independently operated businesses.

Its start-up cost and yearly profit range between 100,000 and less than 500,000 pesos. Regarding profitability, social media emerged as the most effective strategy, with all management and staff agreeing that this would have a positive impact. Post-pandemic automation in the operation and management processes has resulted in better operating efficiency and an increased ability to adapt to regulatory changes and financial stability.

Regarding profitability, survey results indicated that marketing, specifically through social media channels, has been able to reach out and convert engagement into profit. Efficiency gains have resulted from

operational processes implemented following the pandemic, and financial strategies continue to deliver new revenue despite pre- and post-pandemic challenges. Management and staff believed employee training and competent cost management were vital to robust bottom lines.

Like other restaurants and cafes, Nueva Ecija food and beverage establishments have shown how much of a fighter they are even in this pandemic by utilizing digital marketing, effectively streamlining operations, and ensuring economic control. These 84% of businesses, generally small and privately owned, will have moderate to fair success in their responses to a mutating market. They have survived, thrived, and grown in a market recession with the proper focus on staff training, cost control, and, most importantly, customer engagement.

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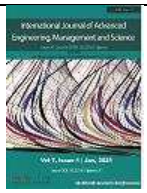

The Role of Sales and Technology Integration in Increasing Sales Revenue in the Corporate Market

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Abstract— *An organization's sales and technology synergy is a vital source of market intelligence and a key facilitator of the successful implementation of techno-commercial strategy. Many companies have traditionally operated in isolated silos with little interaction between their technology and sales departments. But more businesses have realized in recent years how beneficial it is to connect these functions. Significant gains in overall company performance have been attributed to this strategic merger. A particular facet of the connection between improved business performance and sales-technology integration is examined in this research study. More specifically, it examines whether the seamless engagement between technology and sales operations in business-to-business (B2B) businesses makes it easier to develop and to execute new strategies effectively, due to market shifts. The proposed model indicates that the success of market intelligence acquisition in an organization can be largely predicted by the extent of interaction among some key variables, where this interaction defines the level of integration. This knowledge, when applied effectively, also assists businesses in responding strategically and adapting to changing consumer needs and market conditions. This study aims to be able to uncover the complex relationships between various components in order to facilitate trends in the market and stimulate proactive responses. It calls for a comprehensive strategy that can build a sustainable competitive advantage in an evolving business environment, and argues for the importance of breaking down traditional lines of separation between sales and technology roles.*

Keywords— Management; Technology Management; Strategic Responsiveness.

I. BACKGROUND

An organization's fate in a world of rapid change and unpredictability is increasingly determined by its capacity to embrace transformation and proactively manage market turbulence. Success in the face of these challenges requires a strategic mindset and the capacity to swiftly adapt corporate structures, processes, and strategies. This adaptability is not merely a tactical reaction; it is the cornerstone of a sustained competitive advantage.

Companies' survival and growth depend heavily on their capacity to adapt effectively to external disruptions and market volatility. People who embrace change and make the most of it are more likely to establish a strong, long-lasting presence in their respective fields. Additionally, they are more capable of thriving and surpassing their competitors [1]. These changes could be relatively little changes to the sales/technology mix, or they could be more substantial endeavors like breaking into new markets, introducing innovative products, or putting in place innovative distribution channels. These actions may be motivated by external changes, but they may also be motivated by a desire to do better overall.

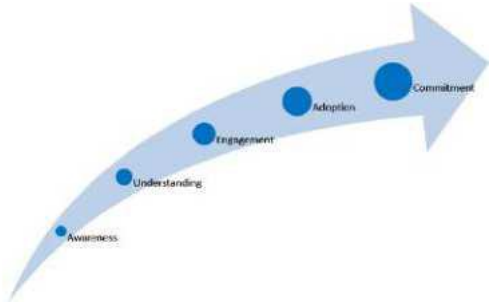


Fig.1: Change Adaptation Curve

Changes outside the company or inside pressures to boost competitiveness and productivity could be the driving forces behind these changes. Regardless of the motivating factor, salespeople must be agile, perceptive, and prepared to execute these market shifts. Their role extends beyond simply responding to change; they often take the initiative to identify emerging trends and customer needs, helping the business stay up to date.

Fig.2: Sales Transformation leading to Organizational Success

(Source: https://www.forcemanagement.com/blog/sales-transformation-the-ladder-to-organizational-success)

Sales & Technology teams are in charge of putting these modifications into practice, from modest tweaks to big strategy changes, to keep businesses adaptable and competitive in a changing environment [1].

The critical relevance of encouraging adaptation and change preparedness within techno-commercial departments is emphasized by Rackham and DeVincentis [2]. They must be able to adapt in order to successfully respond to the dynamically changing conditions that exist both within the company and the larger market. Fundamentally, the techno-commercial function is crucial to bridging and balancing these two dynamic forces. The business environment of today is in constant motion, requiring firms to be flexible and quick to respond to internal and external changes.

The teams need to be ready to modify their strategies and plans in response to shifting corporate objectives, tactics, and internal business structures. As the business evolves, whether due to changes in core competencies, organizational reorganizations, or leadership changes, the functions must be adaptable and ready to modify their approach.

Sales & Technology teams must also keep up with the constantly shifting external market conditions. These variations could include changes in consumer tastes, competitive environments, technical developments, and economic circumstances. Salespeople must read these outside signals, proactively modify their selling approaches, and spot possibilities that can be used to the benefit of the company.

Additionally, the sales function actively influences these dynamics rather than acting as a passive observer. Effective sales & technology teams frequently help the firm by offering insightful information and feedback. They play a crucial role in assisting the business in anticipating technology trends, consumer requirements, and competition threats, which help the business make wise decisions and develop its strategy.

Fig.3: Sales Team Alignment for Organizational Success

(Source: https://www.orbitbusinessdevelopment.com/services/sales/sales-and-delivery-team-alignment)

The need of adaptation and change readiness within departments is stressed by Rackham and DeVincentis. These attributes enable sales teams to act as dynamic links between organizational changes and the always altering environment. Techno-Commercial departments may increase their effectiveness and greatly contribute to the overall success and longevity

of the organization by being aware of both internal and external dynamics.

The sales and technology force is essential to developing and carrying out strategic plans [3] [4]. The combo has a great awareness of new developments among competitors and changing client expectations because of their direct connection to the market. The department may gather and thoroughly analyze this important data, allowing for the creation of strategic answers that are suitable for the situation. The team is then responsible for translating these strategic insights into actionable steps. By delivering thorough updates on the results and effects of the recently implemented plan, the salesforce efficiently closes the feedback loop within the organization by closely monitoring the results of these actions. It plays a crucial role in this linked process as a channel for real-time market feedback, ensuring that the organization can continuously adjust and improve its plans to be competitive and responsive to shifting dynamics. This ongoing, repeating process starts and fuels organizational transformation over time (see Figure 1.4).

Fig.4: Role of Techno Commercial Sales in Organizational Activity

(Source: Lyus, David & Rogers, Beth & Sims, Chris. (2011). The role of sales and marketing integration in improving strategic responsiveness to market change. The Journal of Database Marketing & Customer Strategy Management. 18. 39-49. 10.1057/dbm.2011.5)

Its smooth integration with continuing market developments is essential to the function's effectiveness. Homburg, Jensen, and Krohmer [5] noted that sales and technology departments can have a weak comprehension of market circumstances and goods. Additionally, there is sometimes a noteworthy lack of information sharing between the various departments. Because of this, when sales and technology are not sufficiently integrated, neither they nor the rest of the company are aware of outside changes. On the other hand, a strong integration between these two tasks could enable the business to become incredibly nimble and sensitive to the always shifting market dynamics. The firm would be able to monitor developing trends and movements as well as quickly respond to them thanks to this increased level of coordination between sales and technology functions, thus promoting a more competitive and adaptable attitude.

In the business environment, a techno salesforce's effectiveness frequently depends on their technical knowledge. The sales & technology departments typically operate relatively autonomously from the larger technological strategy within many firms. Companies are increasingly exploring the advantages of integrating sales and technology, a tactical move that has been linked favorably to improved corporate performance. In this study, a particular aspect of the connection between enhanced performance and sales technology integration is explored. In particular, it investigates whether business-to-business (B2B) firms' integration of sales and technology operations makes it easier to design and successfully implement new strategies in response to market changes.

Based on preliminary survey results, we suggest a model that sets sales and technology integration as a prerequisite for excellence in market intelligence gathering. This integration is characterized by interaction and collaboration between these departments. In turn, this intelligence forms the basis for strategically responding to changing market conditions and client requests.

Fig.5: Leveraging New Age Technology for Better Sales

(Source: https://www.datamaticsbpm.com/blog/leveraging-new-age-technology-for-better-sales-marketing/)

In order to close the gap between organizational dynamics and market dynamics, sales departments are crucial. They are able to respond to both internal and external influences in an efficient manner thanks in large part to their Data Sharing & Collaboration (DSC) and openness for change. Teams play a key role in both the creation and precise execution of strategic plans.

Having a technical education is increasingly becoming a requirement for effective management in the business world, particularly in the context of the expanding telecommunications industry. Managers have no direct control over macro environmental factors like new opportunities, risks from competitors, and shifting customer expectations. As a result, organizations need to change quickly and easily to ensure their long-term success. While these businesses are under pressure to change, it is the sales teams' job to put these strategic changes into practice in the marketplace.

Sales & Technology teams are well positioned to remain on top of new innovations from competitors and altering customer preferences because of their close relationship. They gather, compile, and evaluate this important data in order to create well-informed strategic replies. Therefore, it is the responsibility of the sales/technology (techno commercial) division to translate these strategic insights into actionable steps. By reporting on the results of the recently implemented initiatives, the salesperson closes the feedback loop within the organization by carefully monitoring the results of these actions. This iterative approach eventually turns into a catalyst for organizational change.

The degree to which a corporate organization stays closely associated with the always changing marketplace determines how effectively it operates. Technical departments have essential product knowledge, but a clear problem frequently results from a lack of information sharing between the sales teams. As a result, when technology integration and sales are subpar, the firm as a whole is unable to recognize and react to market changes. The ability of an organization to respond quickly to the changing rhythms of the market can be significantly improved by a high level of integration between the technical and sales divisions.

The essential parts of this idea are broken down as follows:

- Sales & Technology Integration
- Improving Responsiveness
- Corporate Market Change:
- Technology's Role
- Data Sharing and Collaboration
- Continuous Improvement

Combining the strengths of both fields can help organizations gather intelligence, modify their strategies, and seize opportunities more quickly and efficiently, thereby increasing their competitiveness and long-term success.

The main point of intersection between theoretical application and real-world implementation in this research is the intersection of technology and sales within businesses. The purpose of this exploratory study is to determine whether tighter coordination between technology and sales operations improves an organization's ability to collect useful market data and, more crucially, to respond quickly by creating and putting into practice suitable plans.

Here, the main goal is to determine whether the synergy created by better sales and technology alignment enables organizations to develop and seamlessly implement strategic initiatives that resonate with the changing market demands as well as more effectively gather relevant market intelligence.

Research Purpose

Companies are constantly researching novel strategies to acquire a competitive edge in the modern business environment. In this study, we explore the crucial area of sales and technology integration and examine how it can significantly boost a company's revenue development. As a measure of a company's ability to compete, organizations frequently focus on the size of a company's investment in research and development (R&D). However, what really matters are how successfully an organization uses its R&D efforts to produce products that not only meet but also exceed the market's changing demands. In many businesses, the seamless integration of technology with the techno-commercial departments is the key to achieving excellent R&D efficiency, speed, and

ultimately, superior goods and revenue. This integration is the key factor in determining the success of product development and sales, not just an additional approach. Additionally, this achievement depends on sales managers having strong technical aptitude.

Access to innovative research is still crucial, no doubt about it. What matters most is the selection and integration of technology in the creation of a business's goods, procedures, or services, as well as its marketing initiatives. A business may invest in state-of-the-art technology, but if they don't complement one another, the resulting product may be hard to manufacture and market, delaying its release and failing to meet its objectives.

Objectives

Following are the research objectives:

- Establishing relationship between integrating sales and technology and its impact on overall performance.
- Integration of sales and technology functions within business-to-business (B2B) organizations fostering creation and execution of effective new strategies in response to shifts in the market.
- Sales & Technology integration linking with improvements in business performance for increasing organization revenue.
- Establishing actionable market intelligence effecting sales and technology; being closely integrated.
- Proposing a validated model that positions the integration of sales and technology, marked by both interaction and collaboration between these two functions, as a precursor to achieving excellence in acquiring market intelligence.

Research Question

- Is it possible to establish relationship between integrating sales and technology and its impact on overall performance?
- How does integration of sales and technology functions within business-to-business (B2B) organizations fostering creation and execution of effective new strategies in response to shifts in the market?
- Does Sales & Technology integration linking with improvements in business performance can increase organization revenues?
- Does any relationship exists establishing actionable market intelligence effecting sales and technology; being closely integrated?
- Can we propose a validated model that positions the integration of sales and technology, marked by both interaction and collaboration between these two functions, as a precursor to achieving excellence in acquiring market intelligence?

Contribution to Knowledge (Academic)

A company's sales force is better able to make decisions that have a direct influence on the business when they have good technical knowledge. Their performance is a barometer for the state of the company as a whole. Furthermore, it offers the perfect environment for quick business growth when staff members can freely share opinions and ideas and clients receive timely and honest feedback. Unfortunately, many small and medium-sized companies frequently struggle with technical resistance. They see technology as a barrier rather than as a resource. However, many smaller, multigenerational firms can overcome their difficulties by adopting the newest technologies, gadgets, and software and assuring their seamless integration and communication. Business leaders can gain crucial insights into their strengths and areas for improvement thanks to the data gathered through integrated technologies. Not only is this material easily accessible, but it also has a lot of depth. Additionally, as firms grow, integrated technologies continue to be beneficial. They provide a simplified method as opposed to a complicated web. As new departments are added, clients are onboarded, and new staff are hired, technology makes it easier to keep everyone informed. Additionally, companies may convert happy and loyal consumers into brand ambassadors who attract new customers by seamlessly incorporating them into technologically smart marketing strategies.

Contribution to Knowledge (Practical)

The goal of this study is to provide a comprehensive review of the strategies and tactics for creating strong client relationships and leveraging them to boost market share and enhance client relationship management. We will discuss these topics in great detail and provide a comprehensive model that describes how businesses can use product selling methods, with a focus on the relationship between company performance and business knowledge.

II. LITERATURE REVIEW

In their comprehensive review of the research on the connections between sales management and organizational transformation, Jones et al. [1] stress the critical significance of efficiently responding to market volatility. They argue that companies who can effectively handle these erratic market conditions stand a better chance of gaining a long-term competitive edge over their less agile rivals. This position not only provides information but also actively participates in the execution of plans. Sales teams are renowned for providing superior market intelligence [3]. [7].

Le Bon and Merunka point out that many businesses do not fully utilize this enormous potential [8]. Salespeople are in a unique position to learn about the goods, pricing tactics, active projects, and consumer preferences of competitors. This is especially true for individuals who have developed strong customer connections.

As the channel for communicating external possibilities and risks to the organization, the techno commercial emerges as a crucial element in the organizational change process. Surprisingly, little attention has been paid to how well this knowledge is spread throughout the business. Long-standing reports have noted difficulties in enlisting the sales and technology force's participation in intelligence collection and ensuring that the information is effectively communicated. In the past, the salesforce has frequently been held responsible for these deficiencies [9] [10].

Beyond assessing how efficiently it is delivered, the effectiveness of how well the business gets and solicits market intelligence has not been properly examined. Kotter, Schlesinger, and Hultman [13] expressed worry that inadequate communication could result in unfavorable perceptions of the change process. Employees may feel uneasy when a change initiative is introduced because of possible effects on practices, resource allocation, and future interactions. Support for the change can be considerably increased by effective communication and reasoning of it [14].

This discussion introduces the idea of sales and technology integration, which is characterized as "the degree to which the activities carried out by the two functions are supportive of one another" and results in the accomplishment of common goals and objectives in a coordinated, synchronized, or carefully planned manner. Three distinct dimensions of integration have been identified by Kahn and Mentzer [16]: interaction, which involves communication and information sharing between the two functions; collaboration, which involves resource sharing and cross-functional teamwork; and composite, which is a combination of the two. True integration entails a deep-seated synergy and goes beyond simple coexistence and communication.

The combination of sales and technology has garnered recent academic interest and requests for more study. There is strong empirical support for the idea that merging these two roles improves corporate performance. However, the path to integration is frequently paved with economic and cultural obstacles, as Kotler et al. [11] [12] contend. They contend that because salespeople are more concerned with action than marketers are with strategy, there is a risk of miscommunication and an underestimation of one another's contributions. Inability to integrate could cause companies to lose contact with the market.

The subject of where sales and technology integration and market-driven organizational change interact naturally arises from this conversation. It's noteworthy that there doesn't seem to have ever been a clear connection made between the integration of these two tasks and improved strategic Data Sharing & Collaboration (DSC) in the face of market volatility [17]. The technology/commercial function in directing organizational change and adjusting to environmental changes is covered by Jones et al. They even say that disputes between technology and sales could serve as a red flag for management that the implementation of new strategies would not succeed.

It is clear from this in-depth analysis of the literature on organizational transformation and sales management that companies that are skilled at responding to market volatility have a substantial edge over those who are not. This emphasizes how crucial it is to manage shifting market conditions in order to develop a long-lasting competitive edge. This study also highlights the urgent need to learn more about how techno-commercial departments themselves adjust to changing environmental conditions and the crucial role played by the sales and technology integrated function in directing organizational change initiatives [18 – 21].

While the impact of market-driven elements has been investigated by a number of organizational departments, the sales and technology function's crucial role in developing and putting into practice strategies has received comparatively little attention. Although authors have acknowledged the functions as a vital source of market data, it is disappointing to see that so few businesses are able to properly utilize this reservoir of prospective insights. Strong customer connections have given professionals a unique opportunity to learn about competitors' product lines, pricing tactics, ongoing projects, and even upcoming projects, long-term patterns of customer behavior, and shifting consumer preferences [22].

The integrated force unquestionably plays a crucial part in the transition process. Their capacity to alert the company to outside possibilities and dangers is priceless. However, it appears that the effectiveness of how this priceless knowledge is shared within the firm has not been given enough thought. Activating the salesforce to actively participate in technology related intelligence and ensuring that the information gathered is adequately shared to all relevant stakeholders have both been found to provide persistent issues. Sadly, the salesforce alone has received the bulk of the criticism for these failings. This calls into question how well the organization gathers and actively searches out market knowledge, rather than just concentrating on how well it is communicated by the salesforce [23] [24].

The value of effective internal communication cannot be overstated. The transformation process may be seen negatively as a result of poor communication. Employees frequently express concern when a change project is launched because of potential effects on current practices, resource allocation, and future interactions. In these situations, good communication and the reasoning of the suggested adjustments can be crucial in winning support and allaying concerns.

The convergence of sales and technology will become a key issue going forward. It can be described as the level of alignment and mutual support between the actions of the two functions as they work together to accomplish common goals and objectives in a coordinated, synchronized, or carefully planned manner. Three different definitions of integration are identified in this context: interaction, which is characterized by communication and information exchange; collaboration, which involves resource sharing and cross-functional teamwork toward shared goals; and composite, which is a combination of these two dimensions. Genuine technology and sales integration goes beyond simple cohabitation and communication.

The recent academic focus on the technology-sales integration has prompted calls for more study in this field. There is currently strong empirical data supporting the idea that the combination of technology and sales improves business performance. Strangely, these results line up with what practitioners had anticipated, showing that attaining seamless integration between sales and technology is not an easy undertaking. As suggested, economic and cultural considerations are the main causes of the difficulties in attaining this integration. The debate essentially centers on the opposition between technical staff and salespeople as doers and implementers.

This review emphasizes the complex interactions between organizational change, sales management, and technology's crucial role. It draws attention to the many difficulties and possibilities that firms encounter when utilizing the skills of their sales force and successfully integrating technology to deal with market volatility and create long-term competitive advantage. The potential for lighting avenues for improved business performance and adaptation in the constantly changing business environment lies in further investigation and research in these areas.

These previously unrelated elements of the literature are meant to be connected by this study project. It focuses on the idea of organizational propensity to

change and investigates whether better sales and marketing function integration enables firms to not only become more aware of market changes but also to excel at implementing sensible strategic responses.

III. RESEARCH METHODOLOGY

- **Methodology**

The primary objective of this preliminary study was to examine the impact of sales and technology integration on corporate performance, particularly in the context of managing organizational change driven by market dynamics. To evaluate this impact, two key constructs were identified: the organization's effectiveness in acquiring actionable intelligence (as outlined by Guenzi and Troilo [22]) and its ability to execute appropriate strategic responses.

As emphasized by Kahn and Mentzer [16], both interaction and collaboration are essential for the seamless integration of sales and technology. Organizations aiming to excel in both constructs must incorporate these elements. Interaction enables the smooth exchange of information between these critical functions, facilitating the efficient acquisition of knowledge. However, without strong collaboration, the intelligence gathered may not effectively translate into the successful execution of strategic initiatives.

Based on the literature review, the following conceptual model has been developed.

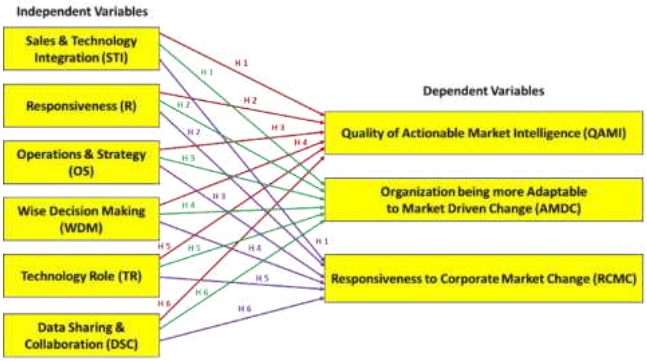


Fig.6: Conceptual Design

Independent Variables

- Sales & Technology Integration (STI)
- Responsiveness (R)
- Operations & Strategy (OS)
- Wise Decision Making (WDM)
- Technology Role (TR)
- Data Sharing & Collaboration (DSC)

Dependent Variables

- Quality of Actionable Market Intelligence (QAMI)
- Organization being more Adaptable to Market Driven Change (AMDC)
- Responsiveness to Corporate Market Change (RCMC)

The variables are defined below:

- Sales & Technology Integration (STI)

  Sales and Technology Integration (STI) refers to the strategic process of aligning and incorporating technology solutions into a company's sales operations and processes. The primary objective of STI is to enhance the effectiveness, efficiency, and overall performance of sales activities through the use of advanced tools and digital processes.

  Successful STI requires careful planning, continuous monitoring, and adaptation to evolving business needs and technological advancements. When effectively implemented, it can improve sales productivity, enhance customer interactions, and provide businesses with a competitive edge.

- Responsiveness (R)

  The ability to respond rapidly, efficiently, and adaptively to changes, demands, or stimuli in a certain situation or environment is referred to as responsiveness. It is a quality or feature frequently linked to people, groups, systems, or processes that can quickly respond to problems, client demands, market developments, or unforeseen occurrences. Being responsive is typically regarded as a positive quality since it shows flexibility, Data Sharing & Collaboration (DSC), and the capacity to quickly and effectively respond to the demands and expectations of consumers, stakeholders, or the environment.

- Operations & Strategy (OS)

  Operations are the regular tasks and procedures carried out by a company with the goal of creating and providing goods and services to clients Production, manufacturing, logistics, supply chain management, quality control, and other administrative jobs necessary for the business's continuous operation are all included in this, in addition to routine tasks. On the other hand, strategy describes the high-level plans and decisions that the leadership of an organization adopts in order to achieve its long-term goals and objectives. Achieving a continuous competitive edge requires setting objectives, formulating a vision, and making preparations.

In other words, operations deal with the day-to-day administration and execution of tasks necessary to run the business effectively, whereas strategy entails the development of high-level plans and decisions to guide the organization's growth, competitiveness, and long-term success. Both operations and strategy must be essential elements in achieving organizational goals for a business to prosper overall.

- Wise Decision Making (WDM)

  Wise decision-making is the act of making thoughtful, well-informed choices that are supported by sound judgment, critical thinking, and a thorough evaluation of the available data and likely results. It involves making choices in a methodical way.

- Technology Role (TR)

  The phrase "Technology Role" refers to the function that technology performs in a particular setting or situation. Technology is employed in a wide range of disciplines to carry out specific tasks and play roles that support the accomplishment of several objectives. The specific function of technology might vary greatly depending on the sector or business in which it is employed.

- Data Sharing & Collaboration (DSC)Individuals,

  teams, departments, or organizations use data sharing and collaboration procedures and practices to efficiently collaborate on common goals, projects, or initiatives. These terms are widely used in a number of fields, including academia, science, technology, and business. In real life, data exchange and collaboration often go hand in hand. By sharing information and insights, teams and organizations can collaborate to undertake research, create new products, or find solutions to difficult issues.

- Quality of Actionable Market Intelligence (QAMI)

  The term "Quality of Actionable Market Intelligence" refers to the standard or reliability of the information and understanding gathered by a business or other organization on a certain market or sector. Usually, this information is collected to help make decisions, make plans, and gain an advantage over competitors. High-quality actionable market data is essential for businesses to gain a competitive edge, anticipate market shifts, identify development opportunities, and effectively manage risks.

- Organization being more Adaptable to Market Driven Change (AMDC)

  The phrase "organization being more adaptable to market-driven change" describes a business's ability to effectively handle and negotiate changes in its external environment, especially those resulting from market forces. It demonstrates how adaptable the business is in modifying its operations, internal processes, and strategy in response to shifts in customer preferences, market conditions, competitive situations, and other market-related factors.

- Responsiveness to Corporate Market Change (RCMC)

  It is necessary to investigate the relationship between the independent and dependent variables. There are numerous methods for data analysis. Priority one while gathering research data is assuring the authenticity and dependability of the research instrument. When used repeatedly on the same unaltered

objects or occurrences, a dependable measuring tool produces consistent measurements.

Similar to that, Cronbach's alpha is a measure of internal consistency that shows how closely linked a group of items are when taken as a whole. This measure evaluates how trustworthy the scale is. We are effectively counting the number of times an observation appears in the data when we look at the frequency distribution of that observation.

The Pearson correlation coefficient in statistics measures the linear association between two variables. Another technique for identifying correlations between variables is regression analysis. It includes a variety of modeling and analysis methods for both dependent and independent variables. In Partial Least Squares Regression, the method builds a linear regression model by projecting predicted variables, as opposed to searching for hyperplanes that maximize variance between the response and independent variables.

- **Research HypoResearch**

In essence, a hypoResearch is a tentative assumption or theoretical explanation that is temporarily accepted to explain certain events or phenomena and to provide guidance for further investigation. A hypoResearch must be open to questioning in order to be either validated or invalidated. It is regarded as valid or established if it holds up to empirical investigation. The following hypotheses, which might then be investigated, were generated by the researcher to structure this project. The following were these hypotheses:

H1: Sales & Technology Integration (STI) has positive effects on Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and its Responsiveness to Corporate Market Change (RCMC).

H2: Effective/speedy/agile **r**esponsiveness (R) affects Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and higher Responsiveness to Corporate Market Change (RCMC).

H3: Dynamic Operations & Strategy (OS) has positive effects on Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

H4: Wise Decision Making (WDM) leads to effective better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

H5: Technology Role (TR) is critical to achieve better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

H6: Data Sharing & Collaboration (DSC) can help in gathering Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) with data/collaboration and Responsiveness to Corporate Market Change (RCMC).

The fundamental reason why this research endeavor adheres to a positivistic research philosophy is because it expands on the body of current knowledge in its field. The basis for this research project was a thorough evaluation of the literature from earlier studies. As a result, a thorough conceptual framework was painstakingly developed, and the research follows accepted scientific procedures. The basic tenets of hypoResearch testing serve as the foundation for making observations and judging the viability of the put forth hypotheses, and they serve as the compass for the research procedure. The research approach uses hypotheses that must be rigorously tested and analyzed in order to be proven. It's important to note that the study covers the complete population being studied in order to draw conclusions that apply to more than just the specific sample. This strategy increases the validity and relevance of the study findings by ensuring that the findings are solid and applicable to a wider context.

- **Research Analysis**

In this research work, the following tests will be performed:

1. Validity Test

   A validity test is a procedure or assessment used in statistics to determine how well a measurement, data collection technique, or

research instrument measures what it is meant to measure. A validity test's main goal is to ascertain if the data gathered or the findings produced are reliable and accurately reflect the underlying construct or notion of interest.

2. Cronbach's Alpha

   Cronbach's Alpha, often referred to as simply "Alpha," is a statistic used in statistics and psychometrics to assess the internal consistency or reliability of a measurement scale or questionnaire. It measures the degree to which a set of items, questions, or variables that are intended to measure the same underlying construct or trait are interrelated and produce consistent or coherent results.

3. Frequency Distribution (data)

   A frequency distribution in statistics is a tabular or graphic representation of data that illustrates the frequency with which each value or category appears in a dataset. It provides insights into the distribution, trend, and dispersion of the data by counting the number of times each individual value or category appears in the data summary.

4. Descriptive Statistics

   A subset of statistics called descriptive statistics is concerned with presenting and summarizing data in a way that is both comprehensible and instructive Its primary goal is to provide a clear and concise summary of a dataset so that analysts, researchers, and decision-makers may identify the most significant patterns and features. Descriptive statistics encompass a wide range of methods and measurements.

5. Pearson Correlation

   The Pearson correlation, also referred to as Pearson's correlation coefficient or Pearson's r, is a statistical tool used to assess the strength and direction of the linear relationship between two continuous variables. It calculates the degree to which changes in one variable are correlated with changes in another.

6. Regression Analysis

   Regression analysis is a statistical technique used in data analysis to investigate the relationship between a number of independent variables (also known as predictors or characteristics) and a dependent variable (also known as the result or aim). Understanding and quantifying the relationship between changes in the independent variables and changes in the dependent variable is the main objective of regression analysis.

7. Diagnostic Analysis

   The process of reviewing and evaluating statistical models, data, or results to determine their quality, validity, and suitability for a certain study or research issue is known as diagnostic analysis in statistics. It entails a comprehensive assessment of numerous statistical analysis components to spot any assumptions, issues, or flaws that could compromise the reliability and correctness of the findings.

The researcher used the SPSS software suite to analyze this investigation. The Cronbach's Alpha Coefficient will be calculated using SPSS with the goal of evaluating the dependability of the instrument used for data collection, specifically the questionnaires. However, it is crucial to make sure that all independent variables, which measure the dependent variables, are aligned in the same direction before applying Cronbach's Alpha Reliability. In other words, the questionnaire that was created should not contain any negative language.

Distribution of survey questionnaires will be a key component of the data collection process. The best method for gathering data for this study is a cross-sectional survey strategy using self-administered questionnaires. This method allows for the examination of potential correlations between numerous parameters and the acquisition of the essential information. This study's research design is cross-sectional and descriptive in nature. The goal of descriptive research is to describe the traits of the target group. It also looks for connections between various variables and evaluates their independence or interdependence. In the event any relationships are found, the study will evaluate their strength. Each participant will receive a set of carefully chosen questionnaires. Cross-sectional research captures a moment in time and offers insights into that particular situation.

The questionnaires were evaluated using information gathered from a pilot study to guarantee the validity of the research instrument. The purpose of the pilot test is to improve the questionnaires by making sure that respondents don't have any trouble responding them, assuring question clarity, and confirming correct data capture. This procedure helps determine the reliability of the upcoming data collection. The questionnaire will also be examined by subject-matter experts for additional validation.

Similar to external validity, internal validity is a crucial factor since it shows whether the instrument can accurately measure what it is meant to measure. It includes various types of validity, including construct validity, which considers both the underlying theory and the measuring tool in use, criterion-related validity, which gauges how well the instrument performs predictions or estimations, and content validity, which gauges how well the instrument covers investigative questions.

Cronbach's Alpha calculation is used as a reliability test. With 0.7 frequently seen as an acceptable threshold, Cronbach's Alpha can vary from zero (signifying no internal consistency) to one (signifying complete internal consistency). According to George (2003), particular guidelines that are specified in the provided table apply.

Table 1: Cronbach Alpha (Reliability Limits)

Reliability	Assessment
>0.9	Excellent
>0.8	Good
>0.6	Questionable
>0.5	Poor
<0.5	Unacceptable

- **Target Population**

The samples will be collected from the following organizations;

- Pakistan telecommunication Company Limited (PTCL)
- Zong
- Nayatel

Total no of questionnaires was 300. 100 questionnaires were distributed at each organization. The gender distribution will be 50% male and 50% females at each organization.

- **Data Collection**

Primary data collection methods are used in the research project, which means that information is obtained straight from the source or study participants. This approach makes it possible to gather exact, one-of-a-kind data that is appropriate for the objectives of the investigation. Techniques for collecting primary data are essential for obtaining fresh viewpoints and ensuring that the data precisely aligns with the goals or hypotheses of the study.

- **Data Analysis and Presentation**

These analyses also serve to test the suggested linkages. Descriptive statistics, including frequencies and percentages, are generated for both organizational data and multiple-choice questions (MCQs) to provide a broad overview of the main characteristics of the variables. Mean scores were computed for questions based on Likert scales to summarize replies and assess participant emotion or level of agreement.

Table 2: Statistical Tests for HypoResearch

Hypothesis	Objective	Tests
H1	Sales & Technology Integration (STI) has positive effects on Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and its Responsiveness to Corporate Market Change (RCMC).	- Simple Linear Regression Analysis -Pearson's Product Moment Correlation Analysis -Multiple Linear regression Analysis
H2	Effective/speedy/agile responsiveness (R) affects Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and higher Responsiveness to Corporate Market Change (RCMC).	
H3	Dynamic Operations & Strategy (OS) has positive effects on Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).	
H4	Wise Decision Making (WDM) leads to effective better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).	
H5	Technology Role (TR) is critical to achieve better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).	
H6	Data Sharing & Collaboration (DSC) can help in gathering Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) with data/collaboration and Responsiveness to Corporate Market Change (RCMC).	

- **Questionnaire**

The below questionnaire has been designed keeping in view the conceptualized model.

Table 3: Statistical Tests for HypoResearch

Variables	Variables Description	S/No	Question
Independent Variable	Sales & Technology Integration (STI)		
		1	Does sales and technology integration helps in gathering effective marketing intelligence?
		2	Does sales and technology integration helps in organization being more adaptable to the market driven change?
		3	Does sales and technology integration helps in increasing responsiveness to corporate market change?
	Responsiveness (R)		
		1	Does agile responsiveness helps in gathering effective marketing intelligence?
		2	Does speedy responsiveness helps in organization being more adaptable to the market driven change?
		3	Does speedy actions helps in increasing responsiveness to corporate market change?
	Operations & Strategy (OS)		
		1	Does proactive operations & strategy helps in gathering effective marketing intelligence?
		2	Is innovative operations & strategy helps in organization being more adaptable to the market driven change?
		3	Does effective operations & strategy helps in increasing responsiveness to corporate market change?
	Wise Decision Making (WDM)		
		1	Does wise decision making at the right time helps in gathering effective marketing intelligence?
		2	Is wise and timely decision making helps in organization being more ready and adaptable to the market driven changes?
		3	Is wise decision making helps in increasing responsiveness to corporate market change?
	Technology Role (TR)		
		1	Does technology play any role in gathering effective marketing intelligence?
		2	Does technologies role in organization leads to it being more ready and adaptable to the market driven changes?
		3	Does technology helps in increasing responsiveness to corporate market change?
	Data Sharing & Collaboration (DSC)		
		1	Does data sharing & collaboration play any role in gathering effective marketing intelligence?
		2	Does data sharing & collaboration leads to it being more ready and adaptable to the market driven changes?
		3	Is data sharing & collaboration help in increasing responsiveness to corporate market change?
Dependent Variable	Quality of Actionable Market Intelligence (QAMI)		
		1	Does Quality of Actionable Market Intelligence (QAMI) helps organizations grow?
		2	Is Market Intelligence (QAMI) backbone of an organization?
		3	Does quality of intelligence helps organization?
		4	Is marketing intelligence without it being translated to action of any help?
	Organization being more Adaptable to Market Driven Change (AMDC)		
		1	Is it important for organizations to adapt to market driven changes?
		2	Are market driven changes always beneficial for the organization?
		3	Is the effect of market division changes on organizations profitability substantial?
		4	Is adaptability to market driven change must for a growing organization?
	Responsiveness to Corporate Market Change (RCMC)		
		1	Does responsiveness to market change helps organization grow?
		2	Does market change effect organizations progress?
		3	Is corporate market change beneficial for the organization?
		4	Does effective responsiveness to corporate market change makes a substantial difference?

IV. DATA ANALYSIS, FINDINGS AND DISCUSSION

This section provides a comprehensive analysis of the findings derived from participant feedback collected through a structured questionnaire survey. The primary objective of these questionnaires was to assess respondents' perspectives on various key variables under investigation. A total of 300 questionnaires were distributed to eligible participants, of which 268 were accurately completed and returned, yielding an impressive response rate of approximately 89.33%.

The use of questionnaires as a data collection method enabled the researcher to gain valuable insights into participants' perceptions and opinions regarding the studied variables. The following sections of this section will explore the responses in detail, highlighting emerging trends, patterns, and significant findings revealed by the data.

Notably, the high response rate of 89.33% reflects a strong level of engagement and willingness among respondents to participate in this research. This level of involvement enhances the reliability of the data, making it a credible representation of the target population's views. As the section progresses, we will examine the specific aspects evaluated by the questionnaires, analyze the responses, and discuss the relevance and implications of the findings in the context of the study's objectives. Ultimately, this section aims to provide a thorough understanding of the key insights drawn from participant feedback, forming the foundation for subsequent discussions and conclusions.

- **Reliability & Cronbach Alpha**

This research work focus is on the cost of shipping cost and the transit time. Organization/Companies focus on different variables of mode of transportation before the final decision is made.

Table 4: Reliability and Cronbach Alpha

Questionnaire Item	Cronbach's Alpha
Does sales and technology integration help in gathering effective marketing intelligence?	.774
Does sales and technology integration help in organization being more adaptable to the market driven change?	.759
Does sales and technology integration help in increasing responsiveness to corporate market change?	.774
Does agile responsiveness help in gathering effective marketing intelligence?	.771
Does speedy responsiveness help in organization being more adaptable to the market driven change?	.781
Does speedy actions help in increasing responsiveness to corporate market change?	.765
Does proactive operations & strategy help in gathering effective marketing intelligence?	.799
Is innovative operations & strategy help in organization being more adaptable to the market driven change?	.789
Does effective operations & strategy help in increasing responsiveness to corporate market change?	.774
Does wise decision making at the right time help in gathering effective marketing intelligence?	.788
Is wise and timely decision making help in organization being more ready and adaptable to the market driven changes?	.791
Is wise decision making help in increasing responsiveness to corporate market change?	.782
Does technology play any role in gathering effective marketing intelligence?	.792
Does technologies role in organization leads to it being more ready and adaptable to the market driven changes?	.772
Does technology help in increasing responsiveness to corporate market change?	.774
Does data sharing & collaboration play any role in gathering effective marketing intelligence?	.758
Does data sharing & collaboration leads to it being more ready and adaptable to the market driven changes?	.774
Is data sharing & collaboration help in increasing responsiveness to corporate market change?	.771
Does Quality of Actionable Market Intelligence (QAMI) help organizations grow?	.779
Is Market Intelligence (QAMI) backbone of an organization?	.760
Does quality of intelligence help organization?	.774
Is marketing intelligence without it being translated to action of any help?	.758
Is it important for organizations to adapt to market driven changes?	.774
Are market driven changes always beneficial for the organization?	.771
Is the effect of market division changes on organizations profitability substantial?	.779
Is Data Sharing & Collaboration (DSC) to market driven change must for a growing organization?	.760
Does responsiveness to market change help organization grow?	.794
Does market change effect organizations progress?	.734
Is corporate market change beneficial for the organization?	.751
Does effective responsiveness to corporate market change makes a substantial difference?	.762

The Cronbach Alpha test results for each questionnaire item are shown in the table. All items register values more than 0.70, as shown in the table, confirming the strong dependability of both the measuring scale and the questionnaire itself. The strength and dependability of the questionnaire are strengthened by the values' uniformity.

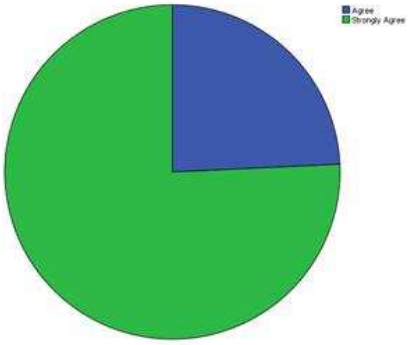
- **Descriptive Statistics**

Researcher presents descriptive statistics for the factors looked at in this study in the next section. The first table given here includes several important statistics for each statistical item, including the number of observations, the lowest score recorded, the highest score observed, the mean value calculated using specialized software, and the standard deviation signifying the variability of each item.

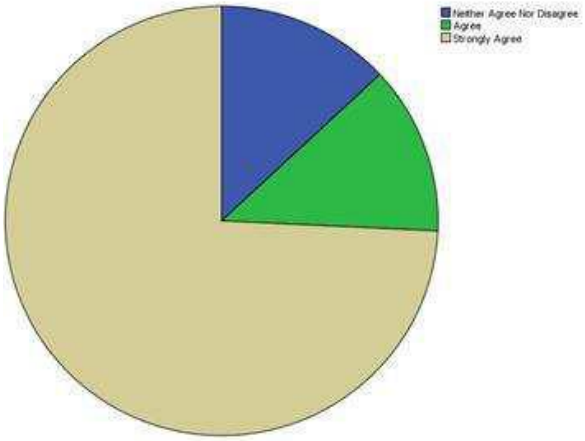
Table 5: Descriptive Statistics regarding the variables

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Does sales and technology integration help in gathering effective marketing intelligence?	268	4.00	5.00	4.7575	.42942
Does sales and technology integration help in organization being more adaptable to the market driven change?	268	3.00	5.00	4.6642	.62942
Does sales and technology integration help in increasing responsiveness to corporate market change?	268	3.00	5.00	4.7500	.52019
Does agile responsiveness help in gathering effective marketing intelligence?	268	3.00	5.00	4.6119	.70748
Does speedy responsiveness help in organization being more adaptable to the market driven change?	268	3.00	5.00	4.6903	.55854
Does speedy actions help in increasing responsiveness to corporate market change?	268	2.00	5.00	4.6082	.72892
Does proactive operations & strategy help in gathering effective marketing intelligence?	268	2.00	5.00	4.7052	.65832
Is innovative operations & strategy help in organization being more adaptable to the market driven change?	268	3.00	5.00	4.7761	.51410
Does effective operations & strategy help in increasing responsiveness to corporate market change?	268	2.00	5.00	4.5410	.71513
Does wise decision making at the right time help in gathering effective marketing intelligence?	268	3.00	5.00	4.6679	.67995
Is wise and timely decision making help in organization being more ready and adaptable to the market driven changes?	268	2.00	5.00	4.6978	.63162
Is wise decision making help in increasing responsiveness to corporate market change?	268	3.00	5.00	4.6119	.64663
Does technology play any role in gathering effective marketing intelligence?	268	3.00	5.00	4.7201	.59338
Does technologies role in organization leads to it being more ready and adaptable to the market driven changes?	268	3.00	5.00	4.6828	.61212
Does technology help in increasing responsiveness to corporate market change?	268	4.00	5.00	4.7575	.42942
Does data sharing & collaboration play any role in gathering effective marketing intelligence?	268	3.00	5.00	4.6716	.62142
Does data sharing & collaboration leads to it being more ready and adaptable to the market driven changes?	268	3.00	5.00	4.7612	.50731
Is data sharing & collaboration help in increasing responsiveness to corporate market change?	268	3.00	5.00	4.6343	.69283
Does Quality of Actionable Market Intelligence (QAMI) help organizations grow?	268	3.00	5.00	4.7127	.55650
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
an organization?					
Does quality of intelligence help organization?	268	4.00	5.00	4.7575	.42942
Is marketing intelligence without it being translated to action of any help?	268	3.00	5.00	4.6716	.62142
Is it important for organizations to adapt to market driven changes?	268	3.00	5.00	4.7612	.50731
Are market driven changes always beneficial for the organization?	268	3.00	5.00	4.6343	.69283
Is the effect of market division changes on organizations profitability substantial?	268	3.00	5.00	4.7127	.55650
Is Data Sharing & Collaboration (DSC) to market driven change must for a growing organization?	268	3.00	5.00	4.6381	.68666
Does responsiveness to market change help organization grow?	268	3.00	5.00	4.7575	.50093
Does market change effect organizations progress?	268	3.00	5.00	4.7575	.50093
Is corporate market change beneficial for the organization?	268	3.00	5.00	4.7612	.50093
Does effective responsiveness to corporate market change makes a substantial difference?	268	3.00	5.00	4.7575	.60093
Valid N (list wise)	268	3.00	5.00	4.7575	.50093

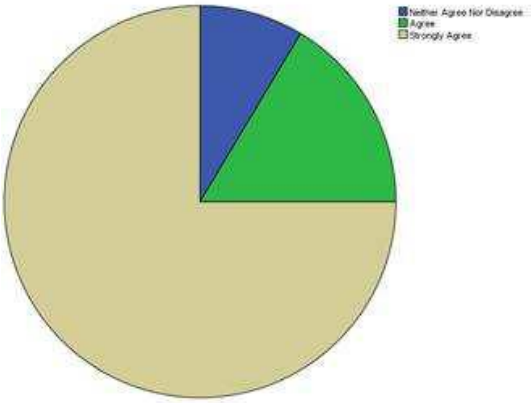
Researcher used the questionnaire to analyze a total of 268 items for each variable dimension, as shown in the table above. The range of values for these items is between 2 and 5, with most variances occurring between about 0.5 and 0.65. The distribution of the data and the related values received from the survey will be more thoroughly broken down in the following section's pie charts for each item. This graphical display will help us better grasp how the data is segmented and provide us some comprehension of the survey's findings.



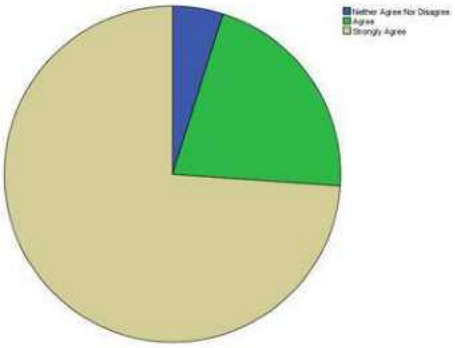
Does sales and technology integration help in organization being more adaptable to the market driven change?



Does speedy responsiveness help in organization being more adaptable to the market driven change?



Does sales and technology integration help in increasing responsiveness to corporate market change?



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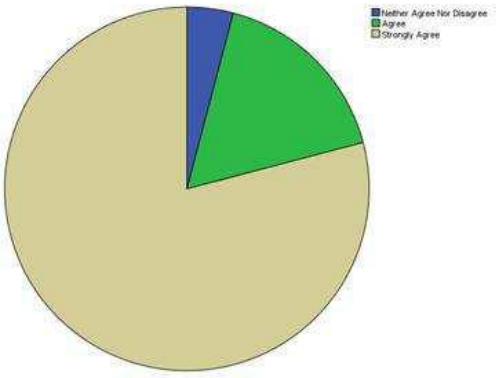
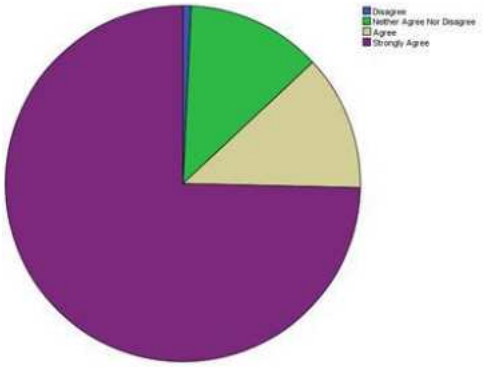
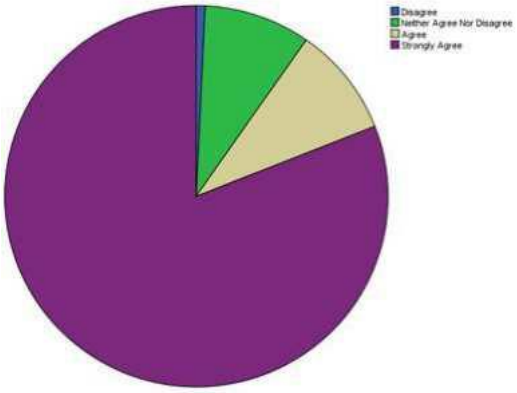


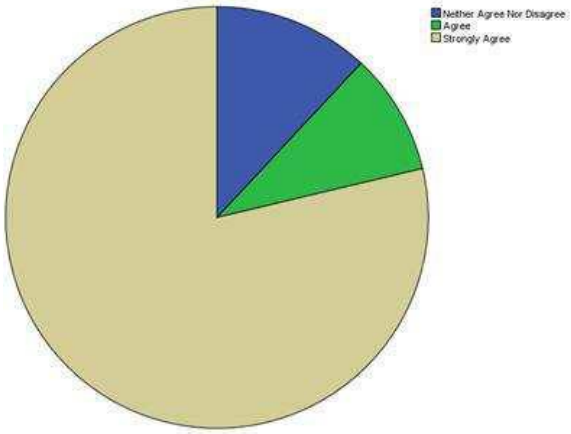
Does agile responsiveness help in gathering effective marketing intelligence?



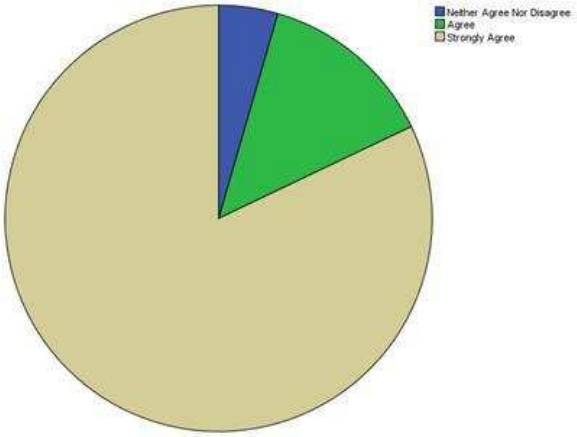
Does proactive operations & strategy help in gathering effective marketing intelligence?



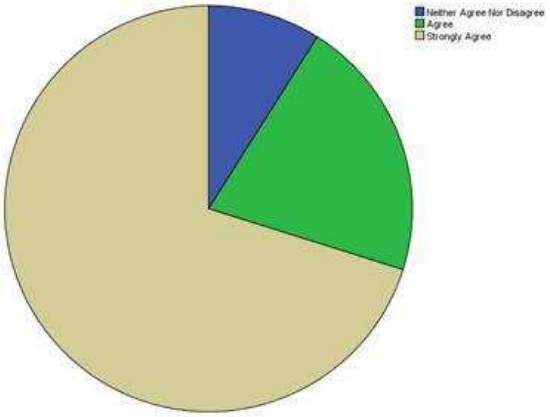
Is innovative operations & strategy help in organization being more adaptable to the market driven change?



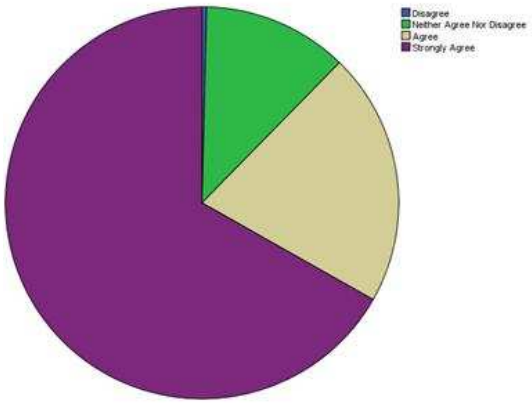
Is wise and timely decision making help in organization being more ready and adaptable to the market driven changes?



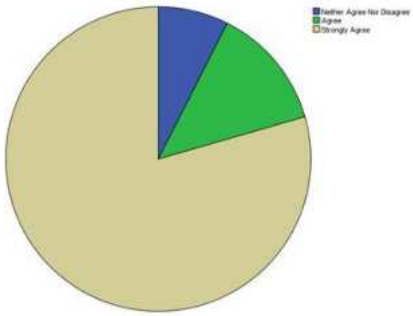
Does effective operations & strategy help in increasing responsiveness to corporate market change?



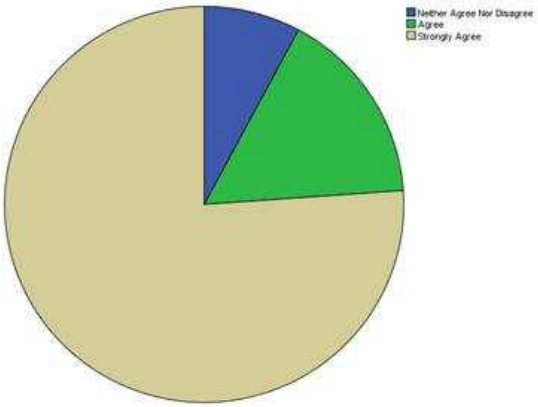
Is wise decision making help in increasing responsiveness to corporate market change?



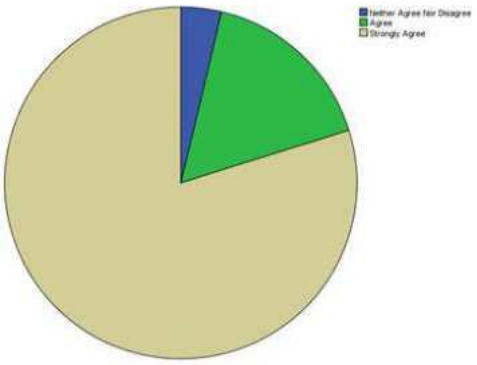
Does wise decision making at the right time help in gathering effective marketing intelligence?



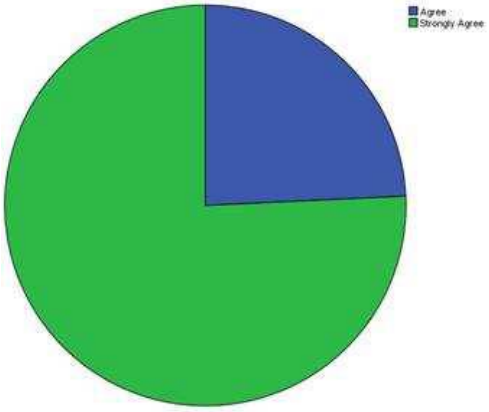
Does technology play any role in gathering effective marketing intelligence?



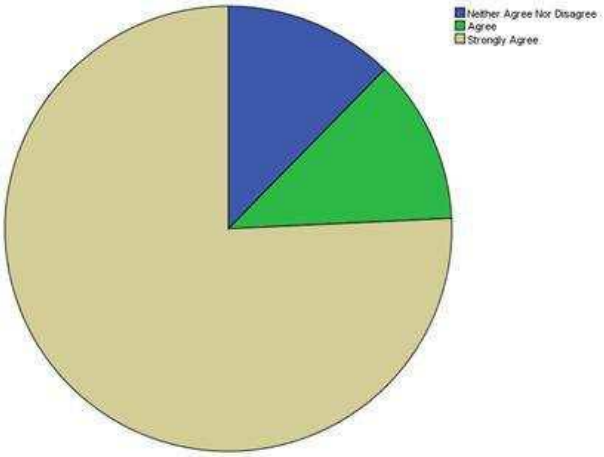
Does technologies role in organization leads to it being more ready and adaptable to the market driven changes?



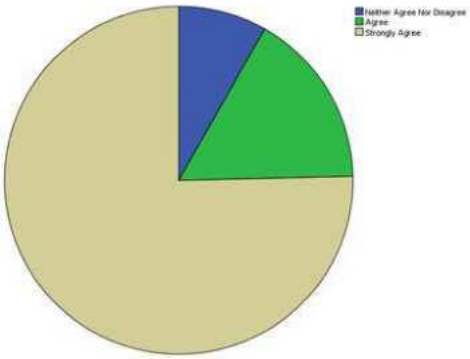
Does data sharing & collaboration lead to it being more ready and adaptable to the market driven changes?



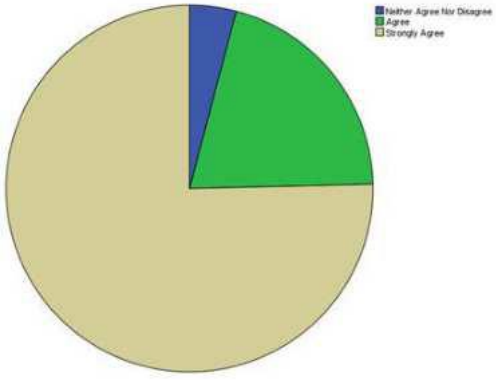
Does technology help in increasing responsiveness to corporate market change?



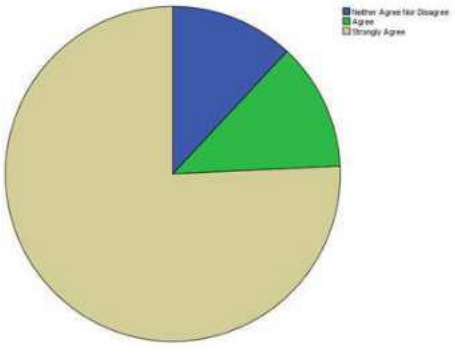
Is data sharing & collaboration help in increasing responsiveness to corporate market change?



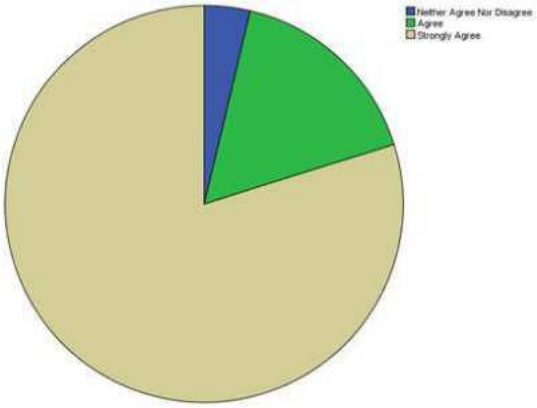
Does data sharing & collaboration play any role in gathering effective marketing intelligence?



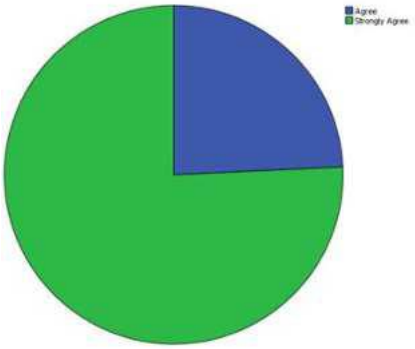
Does Quality of Actionable Market Intelligence (QAMI) help organizations grow?



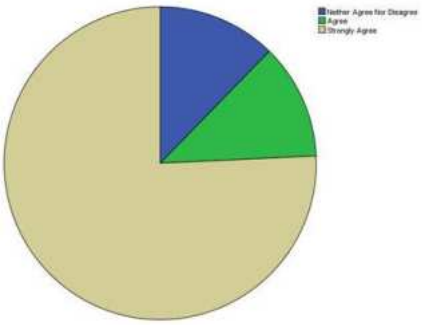
Is Market Intelligence (QAMI) backbone of an organization?



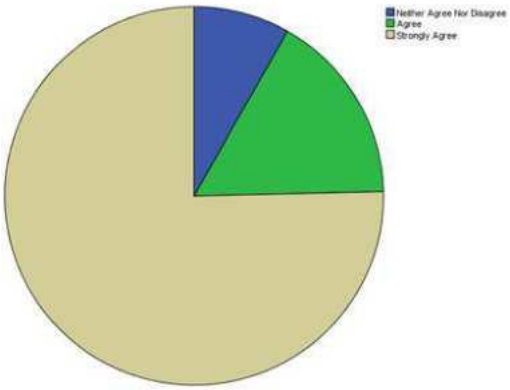
Is it important for organizations to adapt to market driven changes?



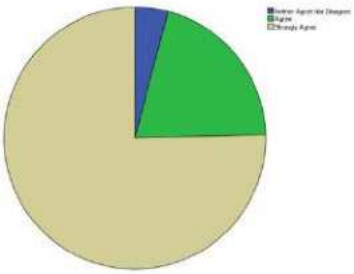
Does quality of intelligence help organization?



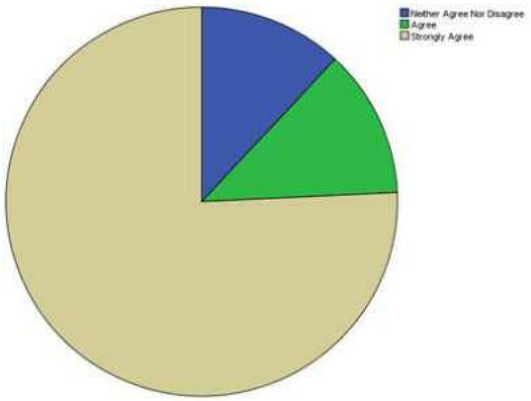
Is market driven changes always beneficial for the organization?



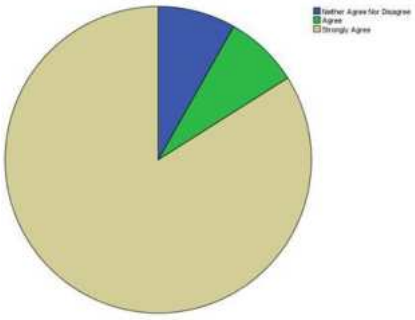
Is marketing intelligence without it being translated to action of any help?



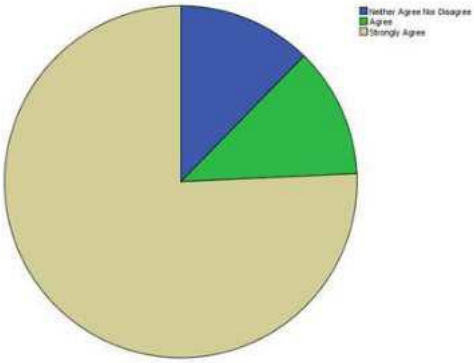
Is the effect of market division changes on organizations profitability substantial?



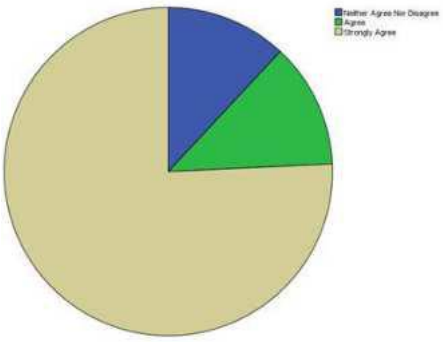
Is Data Sharing & Collaboration (DSC) to market driven change must for a growing organization?



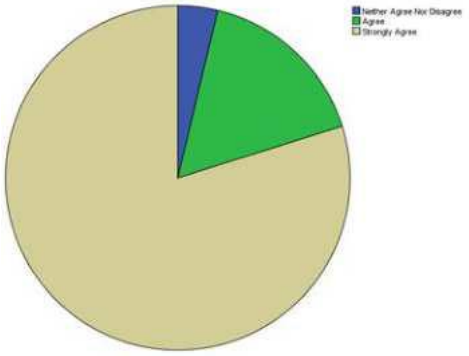
Does responsiveness to market change help organization grow?



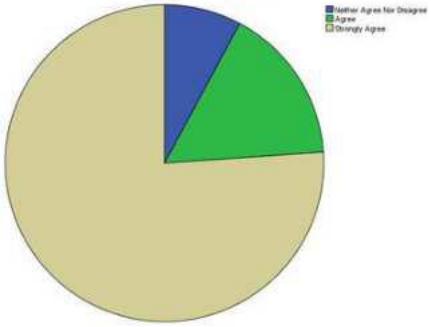
Does market change effect organizations progress?



Is corporate market change beneficial for the organization?



Does effective responsiveness to corporate market change makes a substantial difference?



HypoResearch Testing

- **Pearson Correlation**

The descriptive statistics for the main variables evaluated in this study are shown in the following table. These variables include many dimensions that are evaluated via survey questionnaires. The questionnaire responses were combined into composite data to make it easier to use them in correlation and regression studies. It is clear from the descriptive statistics table that a total of 268 instances of each variable were examined. For each of the variables under consideration, the table also provides the appropriate means and standard deviations.

Table 6: Descriptive Statistics regarding the variables

Descriptive Statistics			
	Mean	Std. Deviation	N
STI	4.7239	.31478	268
R	4.6368	.37496	268
OS	4.6741	.34249	268
IN	4.6349	.32134	268
TR	4.6592	.32503	268
DSC	4.7201	.29428	268
QAMI	4.6950	.35620	268
AMDC	4.7071	.37292	268
RCMC	4.6856	.27761	268

A Pearson correlation test using SPSS was used to create the correlation matrix, which highlighted numerous notable correlations. For instance, with a Pearson's r value of 0.737, Sales & Marketing Integration (SMI) and Responsiveness (R) show a strong and direct association. Furthermore, with Pearson's r values of 0.732, 0.922, and 0.674, respectively, Sales & Technology Integration (STI) exhibits strong correlations with each of the three dependent variables: Quality of Actionable Market Intelligence (QAMI), Organization's Adaptability to Market-Driven Change (AMDC), and Responsiveness to Corporate Market Change (RCMC).

Additionally, with correlation values of 0.737, 0.859, 0.683, and 0.791, respectively, responsiveness (R) is substantially connected with sales & technology integration (STI), quality of actionable market intelligence (QAMI), and responsiveness to corporate market change (RCMC). Although there are smaller correlations between responsiveness (R) and operations & strategy (OS), technology role (TR), and data sharing & collaboration (DSC), respectively.

The strongest link between Operations & Strategy (OS) and any of the variables was found in its association with Responsiveness to Corporate Market Change (RCMC), with a correlation value of 0.291.

Except for its remarkable positive relationship with Data Sharing & Collaboration (DSC), where the correlation strength measures r=0.409, Technology Role (TR) shows poor relationships with most factors.

Responsiveness (R), Sales & Technology Integration (STI), and Responsiveness to Corporate Market Change (RCMC) are all highly connected with Quality of Actionable Market Intelligence (QAMI).

On the other hand, Sales & Technology Integration (STI), Responsiveness (R), and Quality of Actionable Market Intelligence (QAMI) show substantial relationships with Organization's Adaptability to Market-Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

Table 7: Correlations

Correlations									
		STI	R	WDM	TR	DSC	QAMI	AMDC	RCMC
STI	Pearson Correlation	1	.737**	.112	.212**	.474**	.732**	.922**	.674**
	Sig. (2-tailed)		.000	.068	.000	.000	.000	.000	.000
	N	268	268	268	268	268	268	268	268
R	Pearson Correlation	.737**	1	.080	.128*	.316**	.859**	.683**	.791**
	Sig. (2-tailed)	.000		.194	.036	.000	.000	.000	.000
	N	268	268	268	268	268	268	268	268
OS	Pearson Correlation	.112	.080	1	.150*	.215**	-.040	.247**	.291**
	Sig. (2-tailed)	.068	.194		.014	.000	.513	.000	.000
	N	268	268	268	268	268	268	268	268
TR	Pearson Correlation	.212**	.128*	.150*	1	.409**	.102	.157*	.150*
	Sig. (2-tailed)	.000	.036	.014		.000	.097	.010	.014
	N	268	268	268	268	268	268	268	268
DSC	Pearson Correlation	.474**	.316**	.215**	.409**	1	.207**	.507**	.268**
	Sig. (2-tailed)	.000	.000	.000	.000		.001	.000	.000
	N	268	268	268	268	268	268	268	268
QAMI	Pearson Correlation	.732**	.859**	-.040	.102	.207**	1	.608**	.864**
	Sig. (2-tailed)	.000	.000	.513	.097	.001		.000	.000
	N	268	268	268	268	268	268	268	268
AMDC	Pearson Correlation	.922**	.683**	.247**	.157*	.507**	.608**	1	.629**
	Sig. (2-tailed)	.000	.000	.000	.010	.000	.000		.000
	N	268	268	268	268	268	268	268	268
RCMC	Pearson Correlation	.674**	.791**	.291**	.150*	.268**	.864**	.629**	1
	Sig. (2-tailed)	.000	.000	.000	.014	.000	.000	.000	
	N	268	268	268	268	268	268	268	268

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

- **Linear Regression Analysis**

The following models describe the relationships between independent and dependent variables as determined by regression studies carried out in SPSS.

H1: Sales & Technology Integration (STI) has positive effects on Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and its Responsiveness to Corporate Market Change (RCMC).

The results of a regression study that highlights the impact of Sales & Technology Integration (STI) are shown in the table below. It demonstrates that the difference in the quality of actionable market intelligence (QAMI) is accounted for by sales and marketing integration (SMI) in a ratio of roughly 73%. Notably, Sales & Technology Integration (STI) accounts for a significant 92% of the variation in Organization being more Adaptable to Market Driven Change (AMDC), accounting for a higher percentage of variation than its influence on other variables in the regression study. Additionally, 67.4% of the technology adaptation in the quality of actionable market intelligence (QAMI) is explained by sales and technology integration (STI).

Table 8: Regression Analysis

Model		Coefficients[a]					
			Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		R	B	Std. Error	Beta		
1	STI[c]	.732	.829	.047	.732	17.546	.000
	STI[b]	.922	1.093	.028	.922	38.928	.000
	STI[c]	.674	.595	.040	.674	14.900	.000

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

H2: Effective/speedy/agile responsiveness (R) affects Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC) and higher Responsiveness to Corporate Market Change (RCMC).

The regression coefficients for the responsiveness (R) metric as well as many other metrics may be found in the accompanying table. According to the regression analysis's findings, responsiveness (R) is a major explanatory variable that contributes significantly to the understanding of the variance in the dependent variables. Particularly, Responsiveness (R) helps to explain 85.9% of the quality of actionable market intelligence (QAMI), 68.3% of the variability in Organization being more Adaptable to Market Driven Change (AMDC), and 79.1% of the variability in technological adaption.

Table 9: Regression values of Responsiveness (R) and other variables

Model		Coefficients[a]					
			Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		R	B	Std. Error	Beta		
1	R[a]	.859	.905	.033	.859	27.401	.000
	R[b]	.683	.679	.045	.683	15.240	.000
	R[c]	.791	.586	.028	.791	21.088	.000

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

H3: Dynamic Operations & Strategy (OS) has positive effects on Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

The impact of Operations & Strategy (OS) on the dependent variables is clearly shown in the following regression table. It is important to note that only a small portion of the variance in these dependent variables is explained by Operations & Strategy (OS). With a R value of 0.291, the association between Operations & Strategy (OS) and technology adaption in the learning environment has the most significant influence.

Table 10: Effect of Operations & Strategy (OS) on dependent variables

Model		Coefficients[a]					
			Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		R	B	Std. Error	Beta		
1	OS[a]	.040	.42	.064	.040	16.375	.000
	OS[b]	.247	.269	.065	.247	4.155	.000
	OS[c]	.291	.236	.048	.291	4.954	.000

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

H4: Wise Decision Making (WDM) leads to effective better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

The information in the following table comes from a regression analysis that examines the relationship between Wise Decision Making (WDM), Organization being more Adaptable to Market Driven Change (AMDC), and Responsiveness to Corporate Market Change (RCMC). The R values, which are all below 0.12 in each example, support the findings that Wise Decision Making (WDM) does not have a significant impact on the dependent variables.

Table 11: Regression analysis pertaining to effect of Wise Decision Making (WDM) on Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC), and Responsiveness to Corporate Market Change (RCMC)

Model		Coefficients[a]					
			Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		R	B	Std. Error	Beta		
1	WDM[a]	.117	.093	.048	.117	23.571	.053
	WDM[b]	.086	.071	.051	.086	22.067	.162
	WDM[c]	.101	.063	.038	.101	29.338	.097

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

H5: Technology Role (TR) is critical to achieve better Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) and Responsiveness to Corporate Market Change (RCMC).

The table that follows looks at how Technology Role (TR) affects the learning environment's adoption of technology, the organization's ability to respond to

market-driven changes, and the quality of actionable market intelligence (QAMI). Technology Role (TR), like Wise Decision Making (WDM), does not seem to have a significant effect on any of the dependent variables. The observed effects may mostly be attributable to chance since Technology Role (TR) only explains 16% of the variance in any of these dependent variables.

Table 12: Effect of Technology Role (TR) on Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC), and Responsiveness to Corporate Market Change (RCMC)

Coefficients[a]							
Model			Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		R	B	Std. Error	Beta		
1	TR[a]	.102	.111	.067	.102	1.665	.097
	TR[b]	.157	.180	.069	.157	2.593	.010
	TR[c]	.150	.128	.052	.150	2.480	.014

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

H6: Data Sharing & Collaboration (DSC) can help in gathering Quality of Actionable Market Intelligence (QAMI), Organization being more Adaptable to Market Driven Change (AMDC) with data/collaboration and Responsiveness to Corporate Market Change (RCMC).

The findings regarding the relationship between Data Sharing & Collaboration (DSC) and its effect on Quality of Actionable Market Intelligence (QAMI), the organization's ability to adapt to changes driven by the market (AMDC), and technology adaptation in the learning environment are presented in the following table. It is clear that the effects of data sharing and collaboration (DSC) on the caliber of actionable market intelligence (QAMI) and technology adoption are both somewhat negligible. It has a noticeable impact on the organization's ability to adapt to market-driven change (AMDC), though. Actually, the organization's ability to be more adaptive to market-driven change (AMDC) varies by about 51%, with Data Sharing & Collaboration (DSC) being the main contributor.

Table 13: Data Sharing & Collaboration (DSC) and its Impact on Organizational Adaptability to Market Driven Change (AMDC), Responsiveness to Corporate Market Change (RCMC), and Quality of Actionable Market Intelligence (QAMI)

Coefficients[a]							
Model			Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		R	B	Std. Error	Beta		
1	STI[a]	.207	.250	.073	.207	3.448	.001
	STI[b]	.507	.643	.067	.507	9.601	.000
	STI[c]	.268	.253	.056	.268	4.531	.000

a. Dependent Variable: Quality of Actionable Market Intelligence (QAMI)
b. Dependent Variable: Organization being more Adaptable to Market Driven Change (AMDC)
c. Dependent Variable: Responsiveness to Corporate Market Change (RCMC)

- **Multiple Linear Regression Analysis**

To comprehend the cumulative effect of the independent factors in the study on each of the dependent variables, this section includes multiple regression models. ANOVA tables, regression coefficient values, and R and R-Squared summaries are among the regression results that are derived by SPSS. Within the context of regression analysis, each of these helps to clarify the impacts and behaviors of the many variables.

H7a: Effects on the Quality of Actionable Market Intelligence (QAMI) of Sales & Technology Integration (STI), Responsiveness (R), Operations & Strategy (OS), Wise Decision Making (WDM), Technology Role (TR), and Data Sharing & Collaboration (DSC)

The variables table shows that the Quality of Actionable Market Intelligence (QAMI), the dependent variable, and all the independent factors are included in the SPSS analysis.

Table 14: Variables Entered / Removed

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WDM, OS, R, TR, DSC, STI[b]	.	Enter

a. Dependent Variable: QAMI
b. All requested variables entered.

The R and R-squared values in the table show that the independent factors have a significant impact on Quality of Actionable Market Intelligence (QAMI). Both of these numbers are greater than 0.5, indicating significant effects in the context of the regression analysis.

Table 15: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.888[a]	.788	.783	.16588

a. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

The square sum and level of significance support our idea even more. These values are inside the acceptable range with a significance level less than p=0.050. Because of this, we can say with certainty that the independent factors do indeed have a big influence on QAMI (Quality of Actionable Market Intelligence).

Table 16: ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.694	6	4.449	161.676	.000[b]
	Residual	7.182	261	.028		
	Total	33.876	267			

a. Dependent Variable: QAMI
b. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

The numbers in the following table, as shown by their standardized coefficient values, explain the precise contributions of each independent variable to the variation in the quality of actionable market intelligence (QAMI).

Table 17: Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.323	.253		5.227	.000
	STI	.333	.052	.295	6.456	.000
	R	.655	.040	.689	16.295	.000
	OS	.106	.030	.102	3.478	.001
	TR	.027	.034	.025	.790	.430
	DSC	.169	.043	.140	3.985	.000
	WDM	-.016	.023	-.020	-.698	.486

a. Dependent Variable: QAMI

H_{7b}: Impact of Sales & Technology Integration (STI), Responsiveness (R), Operations & Strategy (OS), Wise Decision Making (WDM), Technology Role (TR), and Data Sharing & Collaboration (DSC) on Quality of Actionable Market Intelligence (QAMI)

The factors table demonstrates that the regression analysis covers all independent variables in order to examine their influence on the dependent variable, "Organization being more Adaptable to Market Driven Change (AMDC)."

Table 18: Variables Entered / Removed

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WDM, OS, R, TR, DSC, STI[b]	.	Enter

a. Dependent Variable: AMDC
b. All requested variables entered.

The model summary table shows that the independent factors have a significant impact on how adaptable an organization is to market-driven change (AMDC). Actually, the factors with the greatest R and R-squared values are almost one, indicating a large and profound impact on the "Organization being more Adaptable to Market Driven Change (AMDC)."

Table 19: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.939[a]	.882	.879	.12972

a. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

The significant value, which is below our set p-value of 0.050, is clear from the ANOVA table. We can therefore say with certainty that the independent variables significantly affect how "Organization being more Adaptable to Market Driven Change (AMDC)."

Table 20: ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32.739	6	5.457	324.260	.000[b]
	Residual	4.392	261	.017		
	Total	37.132	267			

a. Dependent Variable: AMDC
b. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

The coefficients table sheds light on how various factors affect "Organization being more Adaptable to Market Driven Change (AMDC)." Notably, all other independent variables had an effect on "Organization being more Adaptable to Market Driven Change (AMDC)," with the exception of responsiveness (R) and wise decision-making (WDM), both of which have significance values higher than our predefined p-value of 0.050.

Table 21: Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.135	.198		5.732	.000
	STI	1.037	.040	.876	25.688	.000
	R	.009	.031	.010	.302	.763
	OS	.154	.024	.141	6.473	.000
	TR	.105	.027	.092	3.913	.000
	DSC	.123	.033	.097	3.696	.000
	WDM	.020	.018	.024	1.117	.265

a. Dependent Variable: AMDC

H_{7c}: Impact of Sales & Technology Integration (STI), Responsiveness (R), Operations & Strategy (OS), Wise Decision Making (WDM), Technology Role (TR), and Data Sharing & Collaboration (DSC) on Responsiveness to Corporate Market Change (RCMC).

According to the factors table, all independent variables have been used to calculate the regression coefficients, with the dependent variable "Responsiveness to Corporate Market Change (RCMC)" as the input.

Table 22: Variables Entered / Removed

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	WDM, OS, R, TR, DSC, STI[b]	.	Enter

a. Dependent Variable: RCMC
b. All requested variables entered.

The regression analysis's notable values of R and R-squared, 0.836 and 0.698, respectively, are detailed in the model summary table. These numbers indicate that the independent variables have a significant overall impact on the metric "Responsiveness to Corporate Market Change (RCMC)."

Table 23: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.836[a]	.698	.691	.15420

a. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

A significant value that is less than our predetermined p-value of 0.050 is shown in the ANOVA table. We may therefore say with certainty that the independent variables do in fact have an impact on the dependent variable, "Responsiveness to Corporate Market Change (RCMC)."

Table 24: ANOVA

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	14.371	6	2.395	100.739	.000[b]
	Residual	6.206	261	.024		
	Total	20.577	267			

a. Dependent Variable: RCMC
b. Predictors: (Constant), WDM, OS, R, TR, DSC, STI

The coefficients table clarifies each independent variable's unique effect on "Responsiveness to Corporate Market Change (RCMC)." The absence of significance values below our preset p-value of 0.050 highlights the fact that none of the independent factors had a meaningful impact on "Responsiveness to Corporate Market Change (RCMC)," nevertheless. This implies that the overall influence reported may be due to chance or the existence of a confounding variable that was not taken into account in the research model.

Table 25: Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.071	.235		4.551	.000
	STI	.191	.048	.217	3.988	.000
	R	.473	.037	.639	12.667	.000
	OS	.188	.028	.232	6.662	.000
	TR	.025	.032	.029	.784	.434
	DSC	-.094	.040	-.100	-2.383	.018
	WDM	-.008	.021	-.013	-.383	.702

a. Dependent Variable: RCMC

V. CONCLUSIONS

- **Discussion**

The following can be used to deconstruct and justify the statement that "Sales & Technology Integration (STI) has positive effects on Quality of Actionable Market Intelligence (QAMI) gathering, Organization becoming more Adaptable to Market Driven Change (AMDC), and its Responsiveness to Corporate Market Change (RCMC)":

Positive Effects on Quality of Actionable Market Intelligence (QAMI) Gathering:

- STI is the process of gathering, analyzing, and interpreting data on sales and customer behavior using technological tools and platforms. By offering real-time data, cutting-edge analytics, and predicative insights, this technologically driven strategy can raise the caliber of market intelligence.

Positive Effects on Organization Becoming More

Adaptable to Market Driven Change (AMDC):

- Organizations may use technology for automation, data analysis, and communication thanks to STI.
- STI enables businesses to automate routine procedures, optimize workflows, and quickly adapt to market changes. Sales teams can interact remotely, access real-time data, and change their plans in reaction to shifting market conditions. sIn the business sector, where markets are subject to rapid change due to factors including new technologies, fierce competition, and overall economic conditions, this flexibility is crucial.

Positive Effects on Responsiveness to Corporate Market Change (RCMC):

- STI enables companies to align sales processes with the needs of both internal and external markets. This alignment may improve a company's ability to react to shifts in the broader corporate market.
- Thanks to STI, businesses may integrate sales data and insights into more comprehensive corporate decision-making procedures. This collaboration ensures that sales tactics align with company objectives. When corporate market shifts occur, STI-equipped businesses may quickly adjust their plans and sales strategies to align with the new course, such as strategic pivots, mergers and acquisitions, or changes in target markets. A corporation needs to be able to adjust to shifting business markets in order to be competitive and accomplish its goals.

Proactive Market Intelligence Gathering (QAMI):

- Effective responsiveness makes sure that the company can promptly adjust to new trends or changes in client preferences that QAMI has found. An organization may make better decisions when it is responsive because it can act right away depending on the information gathered.

Adaptability to Market Driven Change (AMDC):

- Agile responsiveness denotes an organization's agility and ability to quickly modify its operations and plans in reaction to market changes. In the fast-paced business climate of today, this adaptability is essential.

Responsiveness to Corporate Market Change (RCMC):

- Greater corporate responsiveness enables the entire firm to quickly pivot in response to substantial market changes or disruptions. This responsiveness frequently necessitates a concerted effort from numerous departments and activities.

Feedback Loop and Continuous Improvement:

- Proactive market intelligence gathering and action are constantly reinforced by effective, prompt, and adaptable responsiveness. Responding quickly to QAMI insights allows a business to start a continuous improvement cycle.

Customer-Centric Approach:

- Effective responsiveness usually employs a customer-centric approach, in which the company prioritizes promptly meeting the needs and expectations of its customers.

Continuous Data Collection and Analysis (QAMI):

- Dynamic Operations & Strategy emphasizes how important it is to continuously collect and analyze data. This approach ensures that the business gathers a significant amount of market intelligence (QAMI) from a range of sources, including competitor activity, customer feedback, and market trends.

Alignment with Market Trends (AMDC):

- Dynamic Operations & Strategy takes a proactive stance in order to align the company with market trends and opportunities. It promotes a flexible and agile way of thinking.

Strategic Flexibility (AMDC):

- Dynamic Operations & Strategy promotes strategic flexibility. This shows that the business is prepared and able to adjust its plans in reaction to unforeseen disruptions or changing market conditions.

Rapid Decision-Making (RCMC):

- The capacity of a dynamic company to adapt swiftly and intelligently in the face of corporate market change (RCMC).

Feedback Loop and Continuous Improvement:

- Dynamic Operations & Strategy encourages a feedback loop in which the company continually assesses the efficiency of its plans and operations.

Competitive Advantage:

- A dynamic business has a better chance of gaining an advantage over its competitors. Its ability to leverage high-quality market intelligence (QAMI) for strategic decision-making and its adaptability to market-driven changes (AMDC) provide it an edge over competitors.

Informed Data-Driven Decisions (WDM):

- The significance of making well-informed decisions supported by evidence and analysis is emphasized. When a company uses this strategy, it makes sure that its choices are supported with QAMI (high-quality market intelligence).

Strategic Alignment (AMDC):

- Making entails coordinating choices with the strategic aims and objectives of the organization. It focuses on making decisions that advance the company's long-term goals.

Risk Assessment and Mitigation (AMDC):

- By proactively managing risks, the company is better able to adjust to market changes because it has mitigation measures and contingency plans in place.

Resource Allocation (RCMC):

- Appropriate resource allocation is essential for corporate market change (RCMC) response. It enables the company to swiftly deploy resources where they are needed in order to react to changes in the market or take advantage of new opportunities.

Continuous Learning and Improvement:

- The organization's ability to adapt (AMDC) and respond (RCMC) over time is improved by this feedback loop, which makes sure that the organization continuously modifies its strategy based on the outcomes of its decisions

Enhanced Competitive Advantage:

- Prioritizing organizations gives you a competitive edge. They are able to make strategic, well-informed decisions using high-quality market information (QAMI), which gives them an advantage over competitors.

Data Collection and Analysis (QAMI):

- Technology is essential to the collection, compilation, and analysis of data. It makes it possible for businesses to quickly and effectively gather and handle enormous amounts of data from multiple sources.

Real-time Monitoring (QAMI and AMDC):

- Real-time monitoring also helps AMDC by allowing businesses to react quickly to developing market dynamics rather than depending on historical data.

Data-driven Decision Making (QAMI, AMDC, and RCMC):

- Data-driven decision-making processes are aided by technology. Informed decisions based on QAMI can be made by organizations using data analytics tools and algorithms.

Automation and Efficiency (QAMI, AMDC, and RCMC):

- Automation of repetitive processes, data processing, and reporting is made possible by technology. The efficiency of gathering, analyzing, and sharing market intelligence is improved by this automation.

Scalability and Flexibility (QAMI, AMDC, and RCMC):

- Technology offers the flexibility and scalability required to manage a variety of data sources and types. Technology may alter to accommodate changes as businesses expand and data volumes rise.

Competitive Advantage (QAMI, AMDC, and RCMC):

- Businesses that effectively use technology acquire a competitive advantage. They can use data and technology to their advantage to make quicker, more precise judgments.

Enhanced Data Pooling (QAMI):

- Data Sharing & Collaboration promotes the sharing of data and insights among various teams and departments within a business. By

combining data from diverse sources, a more complete and rich dataset for market intelligence (QAMI) collecting is produced.

Cross-functional Insights (QAMI and AMDC):

- Cooperation among various teams and departments encourages the sharing of information and insights. Collaboration across cross-functional teams can result in richer and more complex market intelligence (QAMI) since they bring a variety of viewpoints to the table.

Rapid Data-Driven Decision-Making (AMDC and RCMC):

- Access to current information and insights enables decision-makers to swiftly modify strategy and operations.

Aligned Strategic Efforts (AMDC and RCMC):

- This alignment benefits AMDC and RCMC by encouraging a coordinated response to market trends and organizational changes.

Continuous Improvement (QAMI, AMDC, and RCMC):

- Collaboration encourages a culture of ongoing development. Based on shared information and cooperative efforts, teams can evaluate and improve their techniques.
- By drawing on its collaborative failures and achievements, this feedback loop makes sure that the organization continuously improves its QAMI, adaptability (AMDC), and responsiveness (RCMC).

Effective Resource Allocation (AMDC and RCMC):

- By working together, teams may evaluate resource requirements and distribute resources effectively to achieve strategic goals.
- For AMDC and RCMC, efficient resource allocation is essential because it makes sure the organization can allocate resources where they are most needed to react to market-driven changes and corporate market developments.

In fact, Data Sharing & Collaboration (DSC) is essential for assisting businesses in acquiring high-quality Actionable Market Intelligence (QAMI), improving their ability to adapt to market-driven change (AMDC), and improving their capacity to respond to corporate market change (RCMC).

- **Future Work**

The future of research on the "Role of Sales and Technology Integration in Improving Responsiveness to Corporate Market Change" is likely to be dynamic and shaped by ongoing advancements in technology, shifts in the business landscape, and emerging trends in sales and marketing strategies. Here are some key directions and areas of focus that researchers in this field may explore:

- *Advanced Technology Integration*
- *Data Analytics and Predictive Insights*
- *Customer-Centric Approaches*
- *Cross-functional Collaboration*
- *Digital Transformation*
- *Ethical and Privacy Considerations*
- *Case Studies and Industry-Specific Research*
- *Change Management and Training*
- *Regulatory Implications*
- *Globalization and Market Dynamics*
- *Long-Term Impacts*

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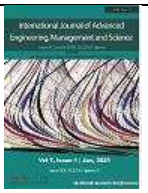

Sharing for Better or Worse: How Social Media and Online Information Sharing Influence Individual Well-Being

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Abstract *— Social media has significantly influenced how individuals share information, impacting their behavior and well-being. This study examines the impact of determinants of information sharing on social media platforms — Attitude, Intention to Share, Frequency of Sharing, Privacy Risk, and Perceived Control on the well-being of individuals. Data was collected from 116 respondents in the Punjab region using convenience sampling via Google Forms. The study employed Cronbach's Alpha to assess reliability, while correlation and regression analyses were conducted using SPSS to examine relationships between variables. Results indicate that Perceived Control over shared information is the strongest predictor of well-being, whereas other factors influence sharing behavior but do not directly enhance well-being. The findings highlight the importance of user autonomy and privacy controls in promoting a positive digital experience.*

Keywords *— **Social Media, Information Sharing, Well-being, Perceived Control, Privacy Risk.***

I. INTRODUCTION

With the rise of social media networking, human interaction has expanded beyond physical meetings to digital spaces, where individuals connect based on shared interests and hobbies (Field et al., 2012). Social media platforms serve as a rich source of behavioral data, capturing an individual's thoughts, emotions, communication patterns, activities, and social interactions with high temporal granularity. The language and emotional tone of social media posts can reveal negative mental states, such as self-doubt, guilt, helplessness, and low self-worth (Rude et al., 2003).

Social media has also transformed the way people search for and share information, influencing daily decision-making and engagement in community-based discussions (Scanfeld et al., 2010). This shift is particularly evident in the healthcare sector, where individuals increasingly rely on social media to share health-related experiences and seek guidance (Wicks et al., 2010). Despite its potential benefits, research has also highlighted the negative effects of social media use on well-being, particularly when associated with harmful behaviors, privacy concerns, and emotional distress (Dhir et al., 2021).

Previous research has not fully established the antecedents of social media well-being (Mertz et al., 2023). However, studies suggest that attitude, intention to share information, frequency of sharing, privacy risk, and perceived control are key factors influencing information-sharing behavior and its impact on well-being (Dhir et al., 2021; Schuur et al., 2018).

With the increasing integration of social media into daily life, concerns have emerged regarding its impact

on well-being. Social media fatigue, driven by excessive use, online social comparison, and self-disclosure, has been found to negatively affect academic performance and mental health (Malik et al., 2020). Additionally, technostress resulting from overwhelming social media engagement depletes self-control, leading to reduced academic achievement and psychological distress (Whelan et al., 2022). These findings highlight the need for digital well-being strategies and self-regulation measures to mitigate the adverse effects of social media usage.

II. LITERATURE REVIEW

Social media has increasingly become a platform for information sharing, including topics related to health and well-being. Several studies have explored how individuals use social media for informational and wellness purposes, highlighting both the positive and negative impacts.

Field et al. (2012) highlighted how social media has transformed marketing, shifting consumer behavior toward platforms like Facebook, Twitter, and YouTube. Businesses now leverage these networks for targeted marketing, similar to past shifts seen with radio, TV, and newspapers. This evolution emphasizes interactive and user-generated content.

Brooks (2015) found that personal social media use negatively impacts productivity and well-being, leading to reduced enjoyment, increased technostress, and lower work performance. Excessive engagement with digital platforms may harm mental health and professional efficiency.

McGregor (2016) introduced a pluralistic perspective on well-being, arguing that no single approach can fully capture the complexity of well-being analysis. The study suggests that a multifaceted approach, integrating social, psychological, and economic factors, is essential to understanding how well-being is shaped in digital environments.

Schuur et al. (2018) studied social media stress and sleep issues in adolescents, finding that stress, more than usage, causes delayed sleep and daytime tiredness, especially in girls. They suggest focusing on stress management and responsible use to reduce negative effects.

Dhir et al., (2021) examined the negative effects of excessive social media use, including compulsive behavior, stalking, and poor sleep, which harm well-being. They found that social media stalking and self-disclosure contribute to sleep disturbances and mental exhaustion, emphasizing the need for more research on its psychological impact.

Mertz et al., (2023) introduced social media wellness, highlighting its impact on mental health, stress, and self-esteem. They noted growing awareness of mindful social media use, with businesses promoting digital detox campaigns. The study calls for further research on balancing engagement and well-being.

Collectively, these studies demonstrate the growing significance of social media in shaping information-sharing behaviors and well-being outcomes. While social media provides opportunities for engagement, information access, and marketing innovation, it also presents challenges such as technostress, reduced productivity, and potential negative psychological effects. Understanding the determinants of information sharing and their impact on well-being is crucial for both academic research and practical applications, particularly in an era where digital interactions continue to expand across all aspects of life.

OBJECTIVE:

The objective of the study is to fill the gap mentioned by Chu et al., 2023 by ascertaining the influence of information-sharing determinants on individual well-being, namely attitude, intention to share, frequency of sharing, privacy risk, and perceived control over information.

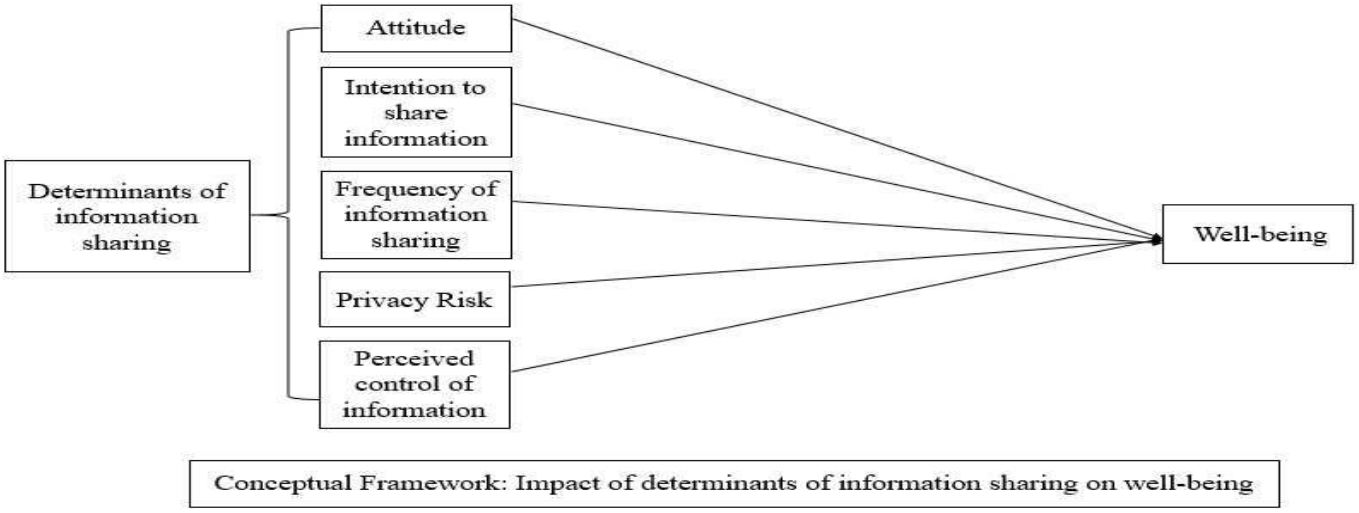

Fig. 1.1: The Proposed Conceptual Model

The study formulates the following hypotheses to achieve its objectives:

H1: There is positive and significant impact of attitude on well-being of individuals.

H2: There is positive and significant impact of intention to share information on well-being of individuals.

H3: There is positive and significant impact of frequency of information sharing on well-being of individuals.

H4: There is positive and significant impact of privacy risk on well-being of individuals.

H5: There is positive and significant impact of perceived control of information on well-being of individuals.

Note: At 5% level of significance

III. RESEARCH METHODOLOGY

Population & Sample size: The Punjab region served as the site for the individuals surveyed in this study. The Google Forms survey, on a five-point Likert scale, collected 116 responses. The participants comprised social media users from diverse age groups and educational levels.

Sampling Technique: Participants in the Punjab region were chosen by convenience sampling.

Table- 1.1: Specification of variables

Independent Variable	Dependent Variable
Attitude	Well-being
Intention to share information	
Frequency of information sharing	
Privacy risk	
Perceived control of information	

Instrument: For measuring attitude (Fishbein, 1963), intention to share information (Venkatesh et al., 2012), frequency of information sharing (Chai et al., 2011; Davenport et al., 2000; Hsu et al., 2007), privacy risk (Pavlou et al., 2007; Yin and Cheng, 2011), perceived control of information (Krasnova et al., 2010; Hajli & Lin, 2014) and well-being (Topp et al., 2015) the Likert scale was used and included five points: 1 for strongly disagree, 2 for disagree, 3 for neutral, 4 for agree, and 5 for strongly agree. There were two sections to the questionnaire. Part I includes questions related to demographic information, such as questions about gender, age and educational qualification. Part II encompasses questions pertaining to attitude, intention to share information, frequency of information sharing, privacy risk, perceived control of information and well-being.

Data Analysis Technique: SPSS (Statistical Package for Social Sciences) was used to examine the data. The coded data was entered into SPSS for result analysis after data collection. Cronbach's alpha was used to evaluate the reliability of the scale, and correlation and multiple regression analyses were then used to examine the associations between the variables.

Ethical Considerations: All participants granted informed consent prior to engaging in the survey and the confidentiality of their data was preserved while anonymity was guaranteed in the presentation of the results.

IV. DATA ANALYSIS & INTERPRETATION

Demographics:

Table 1.2: Respondents' demographic characteristics

Gender	No. of Respondents	Percentage of Respondents
Male	115	99.1
Female	1	0.9
Age (In years)	**No. of Respondents**	**Percentage of Respondents**
Under 18	6	5.2
18-24	106	91.4
25-34	4	3.4
Education Level	**No. of Respondents**	**Percentage of Respondents**
12th	36	31
Under graduation	75	64.7
Graduation	2	1.7
Post-graduation	3	2.6

Reliability Test:

Cronbach's alpha is used in this study to determine the measuring scale's reliability.

Table 1.3: Coefficient of Cronbach's alpha

Cronbach's Alpha	Number of Items
.940	20

According to the above table, the scale is reliable because its Cronbach's alpha coefficient value is more than 0.6.

Correlation Analysis:

Table 1.4: Correlation Analysis Results between the variables

	A	I	F	PR	PC	W
A	1	.596	.554	.552	.402	.452
I	.596	1	.595	.356	.463	.444
F	.554	.595	1	.468	.568	.532
PR	.552	.356	.468	1	.394	.380
PC	.402	.463	.568	.394	1	.556
W	.452	.444	.532	.380	.556	1

Note: Correlation is significant at the 0.05 level (2-tailed)

The results indicate that all independent variables have a significant positive correlation with well-being, suggesting that higher levels of attitude, intention to share, frequency of sharing, perceived control, and privacy risk awareness are associated with better well-being. Among these, Perceived Control (PC) shows the strongest correlation with well-being, implying that users who feel more in control of their shared information experience higher levels of well-being.

The Frequency of Information Sharing (F) and Attitude (A) also exhibit moderately strong correlations, indicating that individuals who frequently share information and have a positive outlook toward information sharing tend to experience better well-being. However, Privacy Risk (PR) has the weakest correlation with well-being, suggesting that while privacy concerns are present, they do not strongly influence the overall well-being of social media users.

Regression Analysis:

Table 1.5: Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.637	.405	.378	.74025

The R value (0.637) suggests a moderate to strong correlation between the predictors and well-being. The R^2 value (0.405) means that 40.5% of the variation in well-being is explained by these factors, while the remaining 59.5% is influenced by other factors not included in the model. The Adjusted R^2 (0.378) is slightly lower, indicating that some predictors may contribute less significantly when generalized to a larger population. The Standard Error of the Estimate (0.74025) shows the average deviation of predicted well-being from actual values.

Table 1.6: ANOVA

	Sum of Squares	df	Mean Square	F	p- value
Regression	41.085	5	8.217	14.995	.000[b]
Residual	60.277	110	.548		
Total	101.361	115			

The results in this table confirm that the regression model significantly predicts well-being (F = 14.995, p = .000). The model explains a portion of the total variance, while some remain unexplained. The large F-value and small p-value indicate that the independent variables collectively have a meaningful impact on well-being.

Table 1.7: Summary of Regression Analysis Results

Hypothesis	Regression Weights	B	t	p-value	Hypothesis
H1	A→W	.135	1.287	.201	No
H2	I→W	.072	.707	.481	No
H3	F→W	.199	1.884	.062	No
H4	PR→W	.055	.602	.549	No
H5	PC→W	.334	3.630	.000	Yes

Note: At 5% level of significance

The regression results show that only perceived control (PC) significantly impacts well-being, supporting H5, while attitude (A), intention (I), frequency of sharing (F), and privacy risk (PR) do not, leading to the rejection of H1, H2, H3, and H4. The B value indicates the strength and direction of the relationship, with PC (.334) having the strongest effect. The t-values measure the strength of influence, with PC (3.630) being the only significant predictor. The p-value confirms statistical significance, where only PC (p = .000) is below .05, making it the sole significant factor. This suggests that users who feel more control over their shared information experience better well-being, while other factors do not show a meaningful direct impact.

V. FINDINGS

The study reveals that perceived control over shared information is the strongest predictor of well-being, indicating that users who feel more control over their data experience higher well-being. While attitude, intention to share, frequency of sharing, and privacy risk show positive correlations with well-being, they do not significantly predict it in the regression analysis. The model explains 40.5% of the variance in well-being, suggesting that other factors beyond information sharing also influence well-being. These findings highlight the importance of privacy control measures in enhancing the well-being of social media users.

VI. CONCLUSION

This study highlights the role of information sharing in influencing social media users' well-being, with perceived control emerging as the most significant predictor. While attitude, intention to share, frequency of sharing, and privacy risk are positively associated with well-being, they do not directly impact it. The findings suggest that users who feel greater control over their shared information experience better psychological well-being. The study emphasizes the need for stronger privacy measures and user empowerment on social media platforms.

VII. LIMITATIONS & FUTURE RESEARCH

This study is limited by its small sample size of 116 respondents and the use of convenience sampling in the Punjab region, which may restrict the generalizability of the findings to a broader population. Additionally, the study focuses only on selected determinants of information sharing, while other psychological and behavioral factors may also influence well-being. Future research should consider a larger and more diverse samples, adopt random or stratified sampling techniques, and explore longitudinal data to understand the long-term impact of information sharing on well-being. Expanding the study across different cultural and demographic groups can also provide deeper insights into the relationship between social media behavior and well-being.

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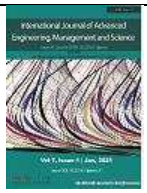

The Role of Organizational Psychology in Enhancing Employee Well-Being

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Abstract— *Employee well-being is a crucial determinant of organizational success, impacting productivity, engagement, and overall morale. Organizations that prioritize the well-being of their employees tend to experience higher levels of job satisfaction, reduced turnover, and improved performance. Organizational psychology provides a comprehensive framework to analyze and enhance employee well-being by addressing fundamental factors such as organizational culture, leadership, job design, and interpersonal dynamics. This paper explores the intricate relationship between organizational psychology and employee well-being, highlighting how psychological theories and research can be applied to create healthier work environments. Organizational culture plays a significant role in shaping employees' perceptions of their workplace, influencing their motivation and commitment. Leadership practices, including communication, support, and trust-building, are pivotal in fostering a positive and inclusive work atmosphere that enhances well-being. Job design, which encompasses the alignment of tasks with employees' skills, interests, and values, contributes to job satisfaction and reduces stress. Interpersonal dynamics, including team collaboration and conflict resolution, also significantly impact emotional well-being and workplace harmony. The paper further presents evidence-based strategies to improve employee well-being. These strategies include fostering a positive organizational culture, promoting transformational leadership, offering opportunities for personal and professional growth, and implementing flexible work arrangements. By applying principles from organizational psychology, companies can not only enhance employee well-being but also achieve greater organizational success through increased productivity, improved employee engagement, and higher retention rates. In conclusion, the integration of organizational psychology principles into everyday business practices is essential for cultivating a supportive and thriving work environment. By focusing on employee well-being, organizations can create a sustainable, positive workplace that drives long-term success.*

Keywords— Employee Well-Being, Organizational Psychology, Workplace Culture, Leadership, Job Satisfaction

I. INTRODUCTION

In contemporary work environments, prioritizing employee well-being has emerged as a critical focus for organizations aiming to achieve long-term success and competitiveness. Employee well-being goes far beyond mere physical health; it is a holistic concept encompassing mental, emotional, and social dimensions that play an integral role in shaping individual performance, engagement, and overall growth. The importance of well-being is increasingly recognized as a key determinant of organizational effectiveness, with research consistently linking

positive employee experiences to higher productivity, creativity, job satisfaction, and lower turnover rates.

Organizational psychology, as a field of study, offers valuable frameworks and methodologies to understand and improve the factors that contribute to employee well-being. It addresses various workplace challenges such as stress, burnout, and disengagement, while simultaneously exploring strategies to enhance motivation, job satisfaction, and interpersonal relationships among employees. By applying principles from psychology, organizations can cultivate environments that not only reduce harmful stressors but also boost positive emotions, psychological resilience, and a sense of belonging among employees.

The connection between organizational psychology and employee well-being is multifaceted. At its core, organizational psychology seeks to identify and address the root causes of workplace stress, promote organizational practices that enhance motivation, and create supportive social networks within the workplace. Factors such as leadership style, organizational culture, work-life balance, job design, and team dynamics play pivotal roles in influencing employee well-being. Furthermore, understanding how these factors interact with employees' mental, emotional, and social needs is crucial for designing workplace policies that enhance overall well-being.

This paper aims to investigate the intersection of organizational psychology and employee well-being, with a focus on evidence-based strategies that organizations can adopt to improve their work environments. By understanding the psychological underpinnings of well-being, businesses can create a culture that fosters positive relationships, improves job satisfaction, and enables personal and professional growth. The following sections will explore the theoretical foundations of employee well-being within the context of organizational psychology, and will offer actionable recommendations for organizations to implement practices that support their employees' well-being in meaningful and impactful ways.

II. LITERATURE REVIEW

Defining Employee Well-Being

Employee well-being is a comprehensive, multidimensional concept that goes beyond just physical health to encompass a wide range of factors that influence an individual's quality of life at work. Scholars and practitioners alike agree that employee well-being is a vital component of organizational success, as it directly impacts performance, motivation, and retention. The following four key dimensions define employee well-being:

1. **Physical Health:** Physical well-being refers to an individual's overall fitness, health, and the absence of illness or disability. It is foundational to employee productivity and is closely linked to lower absenteeism, fewer work-related accidents, and better energy levels throughout the workday. Employers who invest in promoting physical health through wellness programs, ergonomic workplace designs, and health benefits contribute to a more resilient workforce.
2. **Mental Health:** Mental health encompasses the psychological state of employees, including the presence or absence of mental disorders such as anxiety or depression. Positive mental health enables employees to focus, problem-solve, and perform effectively under pressure. Mental health support systems, such as counseling services, stress management programs, and mental health days, are vital for creating a sustainable work environment.
3. **Emotional Resilience:** Emotional resilience refers to an employee's capacity to manage stress, recover from setbacks, and adapt to challenges in a healthy manner. Resilient employees are more likely to maintain productivity during times of organizational change or high stress and exhibit a positive attitude towards overcoming workplace challenges. Cultivating resilience through skill development programs or resilience coaching can empower employees to navigate difficult work conditions.
4. **Social Connectivity:** This dimension of well-being focuses on the quality of relationships employees have within and outside the workplace. Strong social connections

enhance trust, collaboration, and a sense of community within the workplace. Social support networks, team-building activities, and a positive organizational culture foster these relationships and contribute to higher job satisfaction and well-being.

Key indicators of employee well-being include **job satisfaction, engagement, productivity,** and **retention rates.** High levels of job satisfaction are associated with greater employee engagement, which, in turn, positively influences overall productivity. Employees who feel valued and supported are more likely to remain with the organization, reducing turnover rates and recruitment costs.

Organizational Psychology Concepts

Organizational psychology offers several foundational concepts that can improve employee well-being. These concepts address the structural, relational, and leadership aspects of the workplace, which directly influence employees' experiences.

1. **Job Design:** Job design refers to the way in which job roles and tasks are structured. According to job design theory, roles should balance the demands placed on employees with the resources available to them, ensuring that employees feel competent and have a sense of purpose in their work. Roles that are well-designed allow for **autonomy** (independence in decision-making) and provide opportunities for growth, which directly contribute to higher job satisfaction and well-being. When employees perceive their jobs as meaningful and manageable, they are more motivated and less likely to experience burnout.
2. **Workplace Culture:** Workplace culture is the collective values, beliefs, and behaviors that characterize an organization. Creating an inclusive, supportive, and psychologically safe work environment is key to promoting employee well-being. A culture that aligns with employees' personal values and fosters a sense of belonging leads to higher morale, loyalty, and reduced stress. Organizational cultures that prioritize well-being encourage open communication, work-life balance, and recognition of employees' contributions.
3. **Leadership Impact:** Leadership plays a critical role in shaping employee well-being. Transformational leadership, characterized by inspiration, vision, and emotional intelligence, is particularly influential. Leaders who are emotionally intelligent can effectively manage their own emotions and empathize with employees, thereby creating a supportive and motivating environment. Such leadership fosters trust, increases job satisfaction, and enhances team cohesion. Furthermore, emotionally intelligent leaders are better equipped to address workplace conflicts and manage stress, contributing to the overall psychological safety of their teams.

Relevant Psychological Theories

Several psychological theories provide a theoretical framework for understanding and promoting employee well-being. These theories offer insights into the intrinsic factors that drive employee engagement and satisfaction.

1. **Self-Determination Theory (SDT):** Developed by Deci and Ryan (1985), Self-Determination Theory emphasizes three core psychological needs: **autonomy, competence,** and **relatedness**. According to SDT, individuals experience higher levels of well-being when they feel that they have control over their actions (autonomy), are capable and effective in their roles (competence), and feel connected to others (relatedness). In the workplace, providing employees with opportunities to exercise autonomy develop their skills, and foster positive relationships can significantly improve their well-being and overall performance.
2. **Positive Psychology:** Positive psychology, founded by Martin Seligman, emphasizes the cultivation of strengths, resilience, and positive emotions to enhance mental health. This theory argues that well-being is not simply the absence of mental illness but the presence of positive psychological states

such as happiness, optimism, and gratitude. In the workplace, applying principles of positive psychology involves creating opportunities for employees to recognize and utilize their strengths, focusing on what is working well, and fostering an overall culture of positivity and well-being. Encouraging employees to engage in meaningful work, celebrate successes, and practice gratitude can significantly contribute to a positive and thriving work environment.

In conclusion, employee well-being is a multidimensional construct that requires attention to various physical, psychological, emotional, and social factors. Organizational psychology provides valuable tools and theories that can guide organizations in designing effective strategies to improve well-being. By focusing on concepts such as job design, workplace culture, and leadership, as well as applying psychological theories like SDT and positive psychology, organizations can create an environment where employees thrive both personally and professionally.

III. PROBLEM DEFINITION

Despite the growing recognition of the critical role that employee well-being plays in organizational success, many organizations continue to face significant challenges in effectively implementing initiatives that promote and sustain well-being. The implementation of well-being strategies is often hindered by several complex factors, including high workplace stress, poor work-life balance, ineffective leadership, and inadequate support structures, all of which can have detrimental effects on employee mental health, job satisfaction, and overall organizational performance.

1. **High Workplace Stress:** One of the most pervasive issues impacting employee well-being is high workplace stress. In many industries, employees are frequently exposed to excessive workloads, tight deadlines, and unrealistic performance expectations. Chronic stress can lead to burnout, anxiety, and depression, which not only affect an individual's mental and physical health but also diminish their productivity, engagement, and ability to contribute effectively to organizational goals. Stress can be exacerbated by external pressures such as job insecurity, economic uncertainty, and organizational changes. Despite the recognition of stress as a major threat to well-being, many organizations fail to implement effective stress management programs, often overlooking the need for creating a supportive work environment that actively addresses stressors.
2. **Poor Work-Life Balance:** In today's fast-paced and always-connected work culture, employees often struggle to maintain a healthy work-life balance. The boundaries between work and personal life have become increasingly blurred, with many employees working long hours or being expected to be available outside of normal office hours. This lack of balance can lead to feelings of exhaustion, disengagement, and frustration, ultimately undermining well-being. Additionally, employees who are unable to disconnect from work may experience diminished personal satisfaction, which further contributes to burnout and dissatisfaction. The failure of organizations to establish clear policies that prioritize work-life balance, such as flexible work hours or remote working options, exacerbates this issue.
3. **Subpar Leadership:** Effective leadership is a cornerstone of a thriving workplace, and its absence can severely impact employee well-being. Leaders who lack emotional intelligence, fail to communicate effectively, or do not show adequate support for their employees can contribute to a toxic work environment. Poor leadership can manifest in various ways, such as micromanagement, lack of recognition, poor conflict resolution skills, and failure to provide clear direction. When employees feel unsupported or undervalued by their leaders, it negatively affects their morale and job satisfaction. Furthermore, ineffective leadership can create a culture of disengagement, where employees do not feel motivated to perform

at their best or are less likely to invest in the organization's success.

4. **Lack of Support Structures:** Another key issue hindering employee well-being is the lack of appropriate support structures within organizations. Support structures encompass formal systems, such as employee assistance programs (EAPs), mentorship, and career development opportunities, as well as informal systems, such as peer support networks and a culture of collaboration. When employees do not have access to resources that help them navigate workplace challenges or personal difficulties, their well-being is at risk. The absence of supportive relationships and structures that promote professional growth, emotional resilience, and mental health care can contribute to feelings of isolation, stress, and job dissatisfaction.

Together, these factors create an environment that fosters poor mental health, disengagement, and diminished productivity, ultimately affecting organizational outcomes. Despite the growing awareness of the importance of employee well-being, many organizations still struggle to overcome these challenges and fail to implement effective, holistic well-being programs that address the root causes of employee distress. As a result, employee mental health suffers, job satisfaction declines, and employee retention rates fall, leading to high turnover costs and a decrease in organizational effectiveness.

The problem, therefore, is twofold: organizations recognize the importance of employee well-being but face significant barriers in translating this awareness into actionable strategies. Addressing these challenges requires a comprehensive approach that involves creating a supportive organizational culture, prioritizing leadership development, designing jobs that promote well-being, and providing sufficient resources and support to employees. Only by addressing these systemic issues can organizations create a sustainable environment where employee well-being is promoted and nurtured.

IV. METHODOLOGY

This study adopts a **mixed-methods approach**, combining both qualitative and quantitative research techniques to gain a comprehensive understanding of the relationship between organizational psychology and employee well-being. By integrating diverse data sources, the research aims to not only analyze existing literature but also capture real-world insights from employees and organizational leaders. The methodology consists of three main components: a **literature review**, **surveys and interviews**, and **case studies**. These approaches collectively provide both theoretical grounding and practical evidence to explore the challenges and solutions related to employee well-being in organizational contexts.

1. Literature Review

The first phase of the study involves a comprehensive **literature review**, which serves as a foundational component for understanding the current state of research on organizational psychology and employee well-being. This review examines existing scholarly articles, books, and research papers that discuss key concepts, theories, and practices related to employee well-being. The literature review focuses on several areas, including:

- **Theories of Organizational Psychology:** Exploration of established theories that link psychological principles to workplace behavior, such as Self-Determination Theory, Positive Psychology, and Job Design theory.
- **Employee Well-Being Indicators:** Identification of key metrics used to assess employee well-being, including job satisfaction, mental health, emotional resilience, and social connectivity.
- **Best Practices in Well-Being Initiatives:** Review of effective interventions and strategies that have been implemented by organizations to promote employee well-being, with an emphasis on psychology-based practices.
- **Challenges and Barriers:** Analysis of the common challenges organizations face when implementing well-being initiatives, such as lack of resources, ineffective leadership, and organizational resistance to change.

This phase allows for the synthesis of existing knowledge on employee well-being, identifying gaps in research and areas where further exploration is needed. The findings from the literature review will also inform the design of the subsequent research components.

2. Surveys and Interviews

The second phase of the methodology involves collecting primary data through **surveys and interviews** with employees and organizational leaders. This approach is designed to provide insights into the practical application and effectiveness of well-being initiatives currently implemented within organizations.

- **Surveys:** A structured survey will be distributed to employees across various organizations to gather quantitative data on their experiences with well-being programs. The survey will include questions related to job satisfaction, stress levels, perceived support from leadership, work-life balance, and overall mental health. The survey will also assess the effectiveness of specific well-being interventions such as wellness programs, flexible working hours, and leadership support. Likert-scale questions will be used to quantify employee perceptions, and open-ended questions will allow for more detailed responses regarding areas for improvement.
- **Interviews:** In-depth, semi-structured interviews will be conducted with organizational leaders, HR managers, and program directors to gain qualitative insights into the rationale behind the implementation of well-being programs and their perceived effectiveness. Interviews will explore leadership attitudes toward employee well-being, the challenges they face in promoting well-being, and the strategies they have found most successful in improving employee satisfaction and engagement. Additionally, interviews will help to uncover organizational barriers, such as budget constraints or resistance to change, that hinder the implementation of well-being initiatives.

The combination of surveys and interviews will provide a comprehensive view of both employee experiences and organizational leadership perspectives, helping to triangulate data from multiple sources and offering a nuanced understanding of the factors that influence the success or failure of well-being programs.

3. Case Studies

The final phase of the methodology involves the examination of **case studies** of organizations that have successfully integrated psychology-based well-being programs into their workplace culture. Case studies will be selected from a diverse range of industries to ensure the findings are applicable across different organizational contexts. These case studies will focus on:

- **Well-Being Programs:** A detailed examination of the specific well-being initiatives implemented by the organizations, such as mental health support programs, stress reduction workshops, leadership training in emotional intelligence, and team-building activities.
- **Psychology-Based Approaches:** Exploration of how principles from organizational psychology, such as job design, autonomy, and transformational leadership, have been applied to enhance employee well-being.
- **Outcomes:** Evaluation of the impact of these initiatives on employee well-being, including improvements in job satisfaction, employee retention, productivity, and overall mental health.
- **Best Practices:** Identification of best practices from these organizations that can be replicated in other settings, focusing on strategies that have led to successful outcomes and addressing potential challenges encountered during implementation.

Case studies will be selected based on organizations that have demonstrated measurable success in improving employee well-being. These real-world examples will provide practical insights into how organizations can effectively integrate psychological principles into their well-being programs, offering

valuable lessons for organizations facing similar challenges.

V. DATA ANALYSIS

The data collected through surveys, interviews, and case studies will be analyzed using both **quantitative** and **qualitative** techniques. The survey data will be analyzed using statistical methods to identify trends and correlations between employee well-being indicators and specific well-being interventions. The interview data will be analyzed using thematic analysis, identifying key themes and patterns related to leadership practices, organizational culture, and employee experiences with well-being initiatives. The case study data will be analyzed through a comparative approach, highlighting the strategies and outcomes that led to successful well-being programs.

Conclusion

By employing a mixed-methods approach, this study seeks to provide a comprehensive understanding of the relationship between organizational psychology and employee well-being. The combination of literature review, surveys, interviews, and case studies ensures that the research captures both theoretical and practical dimensions of the topic. The findings from this study will not only contribute to academic knowledge but also offer actionable insights for organizations looking to improve their employee well-being initiatives. Through a deeper understanding of the factors that influence well-being, organizations can design more effective programs that foster a supportive, engaging, and psychologically healthy workplace.

VI. RESULTS AND DISCUSSION

This section presents the findings of the study, which focuses on the various workplace factors influencing employee well-being, the role of leadership in promoting well-being, and the effectiveness of implementing well-being initiatives. The results are discussed in light of the literature and research gathered from surveys, interviews, and case studies, highlighting key factors that contribute to employee satisfaction, engagement, and overall well-being in organizational settings.

1. Workplace Factors Influencing Well-Being

Several critical factors emerged from the data as influencing employee well-being. These factors highlight the importance of creating a supportive and healthy work environment, where employees feel valued and supported. Key factors include:

Stress Management Programs

One of the most prominent workplace factors identified in this study was the implementation of **stress management programs**, which significantly contribute to reducing stress levels and enhancing employee well-being. Interventions such as **mindfulness practices**, **resilience training**, and **stress management workshops** were frequently cited by employees as being particularly effective in managing workplace stress. These programs help employees build emotional resilience, enabling them to handle pressure and challenging situations more effectively. Mindfulness practices, such as meditation and breathing exercises, were noted for their ability to help employees stay focused, calm, and centered, even in high-stress situations. Resilience training also helped employees develop coping strategies, which were especially important in industries characterized by high job demands or frequent change.

Recognition and Feedback

Another key factor influencing employee well-being was the practice of **recognition and feedback**. Employees reported that regular positive reinforcement and constructive feedback from supervisors and peers had a direct impact on their job satisfaction and self-esteem. Recognition programs, whether formal (e.g., employee of the month awards) or informal (e.g., verbal praise in team meetings), were appreciated by employees as they felt valued and acknowledged for their contributions. Positive feedback, particularly when it focuses on specific accomplishments and behaviors, not only boosts morale but also reinforces desired behaviors and job performance. The presence of recognition systems helps create an environment of appreciation, which enhances overall employee engagement.

Interpersonal Relationships

The quality of **interpersonal relationships** within the workplace was also highlighted as a crucial factor in employee well-being. Employees who reported having strong, supportive relationships with colleagues and supervisors consistently reported higher levels of satisfaction and well-being. Healthy workplace relationships contribute to a positive emotional environment, where employees feel comfortable seeking help and sharing ideas. Employees emphasized the importance of supportive supervisors who foster open communication, encourage teamwork, and resolve conflicts effectively. The ability to build strong social connections at work helps mitigate feelings of isolation and loneliness, especially in remote or hybrid work environments.

2. Role of Leadership in Promoting Well-Being

The role of leadership emerged as one of the most significant determinants of employee well-being in the study. Effective leadership practices directly influence employee morale, job satisfaction, and emotional resilience. Two key leadership qualities were particularly emphasized:

Emotional Intelligence (EI)

Leaders with high **emotional intelligence (EI)** were found to be particularly effective in fostering a psychologically safe work environment. Emotional intelligence, which includes self-awareness, empathy, and social skills, allows leaders to connect with their employees on a personal level, recognize their needs, and provide appropriate support. Employees reported feeling more comfortable sharing their concerns, expressing emotions, and seeking guidance when working under emotionally intelligent leaders. EI in leadership cultivates an environment of trust, where employees feel valued and understood, leading to improved communication and greater job satisfaction. This environment of trust also encourages employees to take risks, share innovative ideas, and collaborate more effectively.

Transformational Leadership

Another leadership style found to have a profound impact on employee well-being was **transformational leadership**. Transformational leaders motivate their employees by inspiring a shared vision, aligning individual aspirations with organizational goals, and fostering a sense of purpose and fulfillment in their work. Employees under transformational leaders often report higher levels of motivation, engagement, and job satisfaction, as these leaders encourage personal growth, challenge employees to perform at their best, and provide opportunities for career development. By emphasizing intrinsic motivation, transformational leadership aligns personal values with organizational objectives, creating a sense of ownership and commitment among employees.

3. Implementing Well-Being Initiatives

The implementation of well-being initiatives is critical to creating a supportive work environment. This study identified several initiatives that have proven to be effective in improving employee well-being and fostering a culture of health and support within organizations.

Flexible Work Arrangements

Flexible work arrangements were one of the most frequently mentioned initiatives that had a significant impact on employee well-being. Employees reported that having options for **remote work**, **flexible schedules**, and increased **autonomy** helped them achieve a better **work-life balance**, reducing stress and improving job satisfaction. Flexible work policies, including the ability to adjust working hours to accommodate personal responsibilities, were particularly important for employees with caregiving duties, long commutes, or health concerns. The flexibility to work from home also helped employees maintain their productivity while reducing the distractions and stressors associated with commuting or rigid office schedules. Flexible work arrangements were especially crucial during the COVID-19 pandemic, when organizations rapidly adapted to remote work practices, and their long-term benefits for employee well-being became more apparent.

Wellness Programs

Holistic wellness programs that address physical, mental, and emotional health were found to be essential in promoting employee well-being. These programs, which include fitness programs, mental health resources, nutrition counseling, and wellness challenges, support employees in maintaining their overall health and managing stress. Employees who

participated in wellness programs reported feeling more energized, focused, and motivated at work. Mental health support services, including access to counseling and stress management resources, were also valued by employees, particularly in industries with high stress and burnout rates. By offering a range of wellness programs, organizations can help employees maintain their physical health while also providing the tools needed to manage mental and emotional stress.

Employee Engagement Activities

Finally, **employee engagement activities** such as **team-building events**, **social gatherings**, and **employee appreciation activities** were found to foster a sense of belonging and camaraderie among employees. These activities, which encourage collaboration and social interaction, help reduce feelings of isolation, particularly in remote or hybrid work environments. Social events, whether virtual or in-person, give employees the opportunity to connect with colleagues, build relationships, and develop a strong sense of community. These activities contribute to positive workplace culture, enhancing job satisfaction and reinforcing employees' emotional well-being.

Conclusion

In conclusion, this study highlights the importance of workplace factors, leadership, and well-being initiatives in promoting employee well-being. Stress management programs, recognition and feedback, and positive interpersonal relationships are key factors that contribute to a supportive work environment. Effective leadership, especially emotional intelligence and transformational leadership, plays a crucial role in creating a psychologically safe and engaging workplace. Furthermore, flexible work arrangements, wellness programs, and employee engagement activities are vital in enhancing work-life balance and overall well-being. By implementing these strategies, organizations can create an environment where employees thrive, leading to improved satisfaction, productivity, and long-term organizational success.

VII. CONCLUSION

Organizational psychology offers invaluable insights into understanding and improving employee well-being. It provides a framework for identifying and addressing the critical factors that influence an employee's experience in the workplace, ensuring a balanced approach to their physical, mental, emotional, and social health. As demonstrated throughout this study, organizational psychology's integration into business practices can significantly enhance job satisfaction, productivity, engagement, and overall employee well-being.

First and foremost, by addressing common workplace stressors such as excessive workloads, unrealistic deadlines, and inadequate support systems, organizations can mitigate the detrimental effects of stress on employees. Stress management interventions, such as mindfulness practices, resilience training, and adequate workload management, are crucial to promoting a more manageable work environment. Additionally, the recognition of the importance of **work-life balance**, supported through flexible working arrangements and employee wellness initiatives, plays a pivotal role in reducing stress levels and preventing burnout.

Moreover, fostering **positive interpersonal relationships** is integral to the emotional and social aspects of employee well-being. A culture that emphasizes collaboration, trust, and effective communication enables employees to feel more connected and supported in their roles. This, in turn, nurtures a sense of belonging and psychological safety, where employees are more likely to express their concerns, seek help, and contribute innovatively without fear of judgment.

The role of **leadership** cannot be overstated in this context. Leaders with high emotional intelligence and a transformational approach to leadership positively impact employee well-being. These leaders create an environment where employees feel valued, empowered, and aligned with the organization's goals. By prioritizing empathy, clear communication, and recognition of individual and team achievements, leaders can cultivate a work atmosphere that not only promotes employee well-being but also encourages continuous development and growth.

Finally, the study's findings underline the importance of implementing **well-being initiatives** that encompass both individual and organizational

needs. Wellness programs that integrate physical, mental, and emotional health, along with flexible work arrangements and employee engagement activities, directly contribute to improved employee morale and job satisfaction. These initiatives, when strategically aligned with the organization's goals, can result in increased retention rates, reduced absenteeism, and greater organizational commitment.

In conclusion, organizational psychology offers essential tools for creating work environments where employees can thrive. Through proactive strategies that address workplace stressors, promote healthy relationships, empower leadership, and implement holistic well-being initiatives, organizations can enhance their employees' quality of life, ultimately leading to higher levels of productivity, engagement, and organizational success. The integration of psychological principles into organizational practices not only supports individual employees but contributes to the overall health and success of the organization as a whole.

VIII. FUTURE SCOPE

As the understanding of employee well-being continues to evolve, there remains a significant need for future research to explore its long-term effects, especially in diverse industries and cultural contexts. The current study provides valuable insights into the factors that influence employee well-being and the role of organizational psychology in shaping supportive environments. However, the dynamic nature of modern workplaces, including technological advancements and evolving work models, requires ongoing investigation to ensure that interventions remain relevant and effective.

1. Long-Term Effects of Well-Being Interventions

While this study focuses on immediate and short-term outcomes of well-being initiatives, future research should aim to examine the **long-term effects** of such interventions. Understanding how well-being programs impact employees over extended periods—spanning months or even years—can provide critical insights into the sustainability and effectiveness of these strategies. Longitudinal studies, for example, could track the enduring benefits of wellness programs, stress management training, and flexible work policies on employee health, job satisfaction, engagement, and retention. By identifying the lasting outcomes of these interventions, organizations can refine their approaches to well-being, ensuring that they foster a culture of health and support that remains resilient in the face of changing business landscapes.

2. Industry-Specific Well-Being Initiatives

The effects of well-being interventions may differ significantly across industries due to variations in job demands, organizational structures, and workplace cultures. Therefore, it is essential to **explore industry-specific well-being initiatives** and assess their effectiveness in various contexts. For example, high-stress industries such as healthcare, finance, and customer service may require specialized interventions that address the unique challenges faced by employees in those sectors. In contrast, industries with more creative or flexible work environments, such as technology or the arts, may benefit from different types of support, such as fostering creativity and autonomy. Future studies could conduct comparative research across industries to identify best practices and tailor well-being strategies to meet the specific needs of each sector.

3. Cultural Context and Global Perspectives

The influence of **cultural contexts** on employee well-being is another important area for future research. Employee well-being is shaped by a range of cultural factors, such as societal norms, expectations around work-life balance, and perceptions of mental health. As globalization continues to increase, organizations are increasingly managing diverse teams across various cultural backgrounds. Understanding how cultural differences impact the implementation and outcomes of well-being interventions is essential for organizations seeking to create inclusive and supportive environments for all employees. Cross-cultural studies could examine how well-being programs are received and adapted in different regions and cultures, offering valuable guidance for multinational companies and organizations with diverse workforces.

4. Impact of Emerging Technologies

Another critical area for future research is the **impact of emerging technologies** on employee well-being. Technological advancements, such as artificial

intelligence, automation, and digital health tools, are rapidly transforming the workplace. These technologies can enhance well-being initiatives by offering personalized health monitoring, mental health support through digital platforms, or stress management tools. However, there are also potential risks associated with the overuse of technology, including burnout due to constant connectivity, the erosion of work-life boundaries, and the implications of automation on job security. Future research should investigate how these technologies influence employee well-being and whether they contribute to or mitigate the stressors associated with modern work environments.

5. Hybrid Work Models and Employee Well-Being

The widespread shift toward **hybrid work models**—which blend in-person and remote work—has had a profound impact on employee well-being. While hybrid work offers flexibility and autonomy, it also introduces new challenges, such as maintaining communication, ensuring social connection, and managing work-life boundaries. Future studies should focus on how hybrid work models influence various aspects of employee well-being, including stress, work-life balance, engagement, and isolation. Research could explore the effectiveness of well-being initiatives in hybrid work settings and identify strategies that can support employees in both virtual and physical workspaces. Additionally, it would be valuable to examine the role of organizational culture in hybrid environments and its impact on employees' sense of belonging and well-being.

6. Well-Being as a Driver of Organizational Performance

Another promising avenue for future research is the exploration of the relationship between employee well-being and **organizational performance**. While it is well established that well-being positively affects job satisfaction and productivity, more research is needed to quantify the long-term financial and performance benefits of well-being initiatives. Studies that link employee well-being directly to outcomes such as innovation, customer satisfaction, and profitability could provide compelling evidence for organizations to invest in comprehensive well-being programs. Additionally, examining the role of employee well-being in promoting organizational resilience, especially during times of crisis or organizational change, could offer valuable insights for leadership and strategy development.

7. Personalized Well-Being Programs

As employee well-being is a multifaceted and individualized concept, there is potential for future research to explore the effectiveness of **personalized well-being programs**. Tailoring well-being initiatives to the specific needs and preferences of employees can enhance their impact. Research could investigate how data analytics, employee feedback, and wearable technologies can be used to create customized well-being plans that address individual physical, mental, and emotional health needs. Personalized approaches may include customized fitness routines, mental health resources, or work schedules that align with an employee's personal goals and lifestyle. Understanding how personalized programs can be integrated into organizational practices could revolutionize the approach to employee well-being.

Conclusion

In conclusion, the future scope of research on employee well-being is broad and multifaceted. As work environments continue to evolve with advancements in technology, shifting cultural dynamics, and the growing prominence of hybrid work models, there is a need for continuous investigation into the long-term effectiveness of well-being interventions across different industries and cultural contexts. Exploring the impact of emerging technologies, industry-specific initiatives, and personalized well-being programs will help organizations adapt to changing workplace conditions and ensure that employees remain supported and engaged. By pursuing these research directions, scholars and practitioners can develop more nuanced, evidence-based strategies to promote employee well-being in the dynamic and evolving landscape of modern work.

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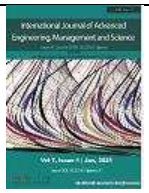

The Impact of Workplace Culture on Business Performance: A Psychological Approach

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Abstract *— Workplace culture significantly influences business performance, employee engagement, and organizational success. A positive and psychologically sound workplace environment fosters motivation, productivity, and innovation, while a toxic culture can lead to disengagement, high turnover, and business failure. This paper explores the psychological foundations of workplace culture, including theories of motivation, emotional intelligence, and behavioral psychology. It examines how culture affects decision-making, leadership effectiveness, and employee well-being. The study concludes that businesses that invest in cultivating a strong, inclusive, and psychologically supportive culture achieve long-term success and competitive advantage.*

Keywords *— **Workplace culture, business performance, employee engagement, organizational psychology, leadership, motivation, emotional intelligence, behavioral science, productivity, psychological safety.***

I. INTRODUCTION

The culture of a workplace is not just about corporate values and mission statements; it is a **living, dynamic force** that shapes **employee behavior, decision-making, and overall business performance**.

- **What is Workplace Culture?**
  Workplace culture encompasses the **shared beliefs, values, attitudes, and behaviors** that define an organization.
- **Why Does Workplace Culture Matter?**
  - Impacts **employee motivation and satisfaction**
  - Influences **productivity and efficiency**
  - Determines **collaboration and innovation levels**
  - Affects **customer satisfaction and brand reputation**

This paper provides a **psychological approach** to understanding **how workplace culture drives business performance** and how organizations can cultivate a high-performance culture.

II. THE PSYCHOLOGICAL FOUNDATIONS OF WORKPLACE CULTURE

2.1 Theories of Motivation and Their Role in Workplace Culture

1. **Maslow's Hierarchy of Needs**

- Employees perform best when their **basic, psychological, and self-fulfillment needs** are met.

2. **Herzberg's Two-Factor Theory**
   - **Hygiene factors** (salary, work conditions) prevent dissatisfaction.
   - **Motivators** (growth, recognition) drive engagement and performance.
3. **Self-Determination Theory (Deci & Ryan, 1985)**
   - Emphasizes the importance of **autonomy, competence, and relatedness** in workplace satisfaction.

2.2 The Role of Emotional Intelligence (EI) in Workplace Culture

Leaders and employees with **high emotional intelligence** foster a healthier workplace culture:

- **Self-awareness:** Understanding one's emotions and their impact.
- **Self-regulation:** Managing stress and workplace conflicts effectively.
- **Social skills:** Encouraging collaboration and teamwork.

2.3 Psychological Safety and Its Impact on Culture

Harvard research defines **psychological safety** as a work environment where employees:

- Feel safe to **express opinions and take risks** without fear of humiliation.
- Engage in open communication and innovation.
- Show higher levels of creativity and **problem-solving abilities**.

III. THE IMPACT OF WORKPLACE CULTURE ON BUSINESS PERFORMANCE

3.1 How Culture Affects Employee Performance

A strong workplace culture leads to:

- Higher **employee engagement and retention**
- Increased **job satisfaction**
- Improved **collaboration and teamwork**
- Greater **innovation and adaptability**

A **toxic workplace culture** results in:

- High **stress and burnout**
- Decreased **productivity and morale**
- Increased **employee turnover**

3.2 Leadership's Role in Shaping Workplace Culture

- **Transformational Leadership:** Inspires employees with vision and motivation.
- **Servant Leadership:** Prioritizes employees' well-being and growth.
- **Authoritarian vs. Participative Leadership:**
  - **Authoritarian cultures** limit innovation.
  - **Participative cultures** enhance engagement and decision-making.

3.3 Workplace Culture and Business Outcomes

1. **Culture and Profitability:** Studies show companies with a **positive culture** outperform competitors by up to **20-30%**.
2. **Culture and Employee Turnover:** Companies with a toxic culture experience **higher attrition rates and recruitment costs**.
3. **Culture and Innovation:** Inclusive workplaces foster **creativity and adaptability**.

IV. STRATEGIES TO BUILD A HIGH-PERFORMANCE WORKPLACE CULTURE

4.1 Encouraging a Growth Mindset

- Employees should be encouraged to **view challenges as learning opportunities** (Dweck, 2006).
- Providing **continuous learning and skill development programs** enhances motivation.

4.2 Creating a Culture of Recognition

- **Reward systems** (monetary and non-monetary) boost motivation.
- **Peer recognition** fosters teamwork and appreciation.

4.3 Enhancing Psychological Safety

- Leaders should foster a **trust-based environment** where employees feel safe to take risks.
- Encouraging **open feedback mechanisms** improves innovation and engagement.

4.4 Aligning Company Values with Employee Well-Being

- Organizations must **prioritize employee mental health** to reduce burnout and turnover.
- Flexible work policies and **employee wellness programs** improve job satisfaction.

V. CASE STUDIES: COMPANIES EXCELLING IN WORKPLACE CULTURE

5.1 Google: A Culture of Psychological Safety

Google's research on workplace effectiveness found that **psychological safety** was the #1 predictor of high-performing teams.

5.2 Netflix: Culture of Autonomy and Accountability

Netflix empowers employees with **decision-making autonomy**, leading to high engagement and innovation.

5.3 Zappos: Culture of Customer Service Excellence

Zappos prioritizes a **fun and inclusive work environment**, improving both employee satisfaction and customer service.

VI. CONCLUSION AND FUTURE DIRECTIONS

A strong workplace culture has a direct impact on business performance through enhanced employee engagement, innovation, and leadership effectiveness. Companies that prioritize psychological safety, emotional intelligence, and motivation see higher productivity, lower turnover, and long-term growth.

Future Research Recommendations:

- Examining the impact of **remote work on workplace culture and business performance**.
- Studying **cross-cultural differences in workplace environments**.
- Exploring the role of **AI-driven behavioral analytics in shaping corporate culture**.

As businesses evolve, **investing in a psychologically driven workplace culture** will remain a **key differentiator for long-term success**.

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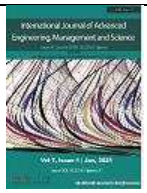

Trends in Criminologist Licensure Examination Performance: A Study of Criminology Graduates from Capiz State University

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Abstract— *The Criminologist Licensure Examination (CLE) marked a significant milestone as the first conducted under the new Commission on Higher Education Memorandum Order (CMO) for Criminology and Republic Act No. 11131. This pioneering batch consisted primarily of K-12 program graduates, many of whom experienced online learning due to the global pandemic. Against this backdrop, the college's institutional performance in the CLE has shown a declining trend in recent years, raising concerns about the preparedness of its graduates and its overall standing. This study aimed to assess the college's CLE performance over the past six years, spanning twelve examination periods, and to analyze examinees' results across the six major criminology subject areas. Using the Documentary and Archival Inquiry Research Method, institutional performance data from April 2016 to December 2022 were obtained from the Professional Regulation Commission (PRC) website, while individual subject performance data were collected directly from examinees. Descriptive statistical tools, including frequency counts, mean scores, and percentages, were employed for data analysis. Findings revealed that the college exceeded the national passing percentage in only three out of twelve examinations (25%). Among the six major subject areas, "Correctional Administration" recorded the highest mean score (82.22%), whereas "Criminology" had the lowest (75.88%). These results underscore the need for targeted interventions to address performance gaps and enhance the overall quality of criminology education. This study provides valuable insights into institutional trends and key areas for improvement, offering a foundation for strategic reforms in criminology education and licensure preparation.*

Keywords— ***Criminologist Licensure Examination (CLE), Institutional Performance, Criminology Education, Licensure Examination Trends, Exam Performance Analysis, Higher Education Assessment, Professional Regulation Commission (PRC), Criminology Subject Areas, Academic Preparedness, Education Quality Improvement***

I. INTRODUCTION

The quality of graduates is a critical success indicator for higher education institutions, often measured through their performance in licensure examinations (Balagtas & Gerundio, 2014). In the field of criminology, the Criminologist Licensure Examination (CLE) serves as a benchmark for assessing the competence of future criminologists. This examination is a prerequisite for practice in various sectors, including law enforcement agencies, academia, and private security, as mandated by Republic Act No. 11131, also known as *The Philippine*

Criminology Profession Act of 2018 (RA No. 11131, 2018). The act stipulates that aspiring criminologists must pass the CLE, which aligns with Level 6 of the Philippine Qualifications Framework (RA No. 11131, 2018).

The CLE evaluates candidates across six major subject areas: Criminal Law and Jurisprudence (CLJ), Law Enforcement Administration (LEA), Forensic Science (FRC), Criminology (Crim), Criminal Detection and Investigation (CDI), and Correctional Administration (CA), as outlined in Commission on Higher Education Memorandum Order No. 05, Series of 2018 (CMO No. 05, s. 2018). On December 4–6, 2022, the pioneering batch of K-12 graduates, who were also the first examinees under Republic Act No. 11131 and the updated curriculum, took the CLE. This examination, dubbed the *"Most Difficult CLE"* since 1972, recorded a national passing rate of only 33.14% (11,098 passers out of 33,489 examinees) (Professional Regulatory Board for Criminology, 2022).

While international studies have extensively explored predictors of licensure exam success, such as demographic factors, academic performance, and study habits (Arathuzik & Aber, 1998; De Lima et al., 2011; Grossbach & Kuncel, 2011; Kaddoura et al., 2017), research in the Philippines remains limited to specific professions. Local studies have examined factors influencing licensure exam performance, including grade point average (GPA), pre-board examination scores, and internship grades (Balagtas & Gerundio, 2014; Esmeralda & Perez-Espinosa, 2015; Pasia et al., 2012; Constantino et al., 2014; Garcia, 2011). However, there is limited comparative analysis of performance across the six CLE subject areas. Notably, Bajeta et al. (2013) assessed their institution's CLE performance and proposed strategic interventions for improvement.

Given the university's declining CLE performance, this study aims to assess institutional outcomes across the six major subject areas of the CLE to identify subjects requiring targeted interventions for improvement.

Statement of the Problem

Generally, this study aimed to analyze the College's performance in the Criminologist Licensure Examination. Specifically, it aims to answer the following questions:

1. What is the Institutional Performance of the College in the Criminologist Licensure Examination for the past six (6) years?
2. What is the status of Board Performance of the graduates in the six (6) major areas of Criminologist Licensure Examination?
3. Which among the six (6) areas of Criminology has the highest and lowest performance rating in the most recent CLE?

II. METHODOLOGY

Documentary and Archival Inquiry Research Method has been used in this study to record the board performance rating of graduates in every areas of the Criminologist Licensure Examination under CMO no. 5 series of 2018 and Republic Act no 11131. Documentary and Archival Inquiry Research Method was deemed appropriate in this study as this method will gather and evaluate the licensure examination result and individual performance rating of the board takers of December 2022 Criminologist Licensure Examination.

III. RESULTS AND DISCUSSION

The performance of Capiz State University – Dayao Satellite College for the past six (6) years since 2015 - 2022 (No Licensure Examinations in the year 2020 and 2021).

The institutional performance in the Criminologist Licensure Examination (CLE) from April 2016 to December 2022 reveals an inconsistent trend, with an overall passing rate averaging 25.64% and surpassing the national passing percentage in only 3 out of 12 board exams (25%). First-time takers performed significantly better, with an average passing rate of 35.66%, compared to repeaters at only 14.4%, highlighting the need for stronger remedial review programs. Performance fluctuations were evident, with the lowest recorded passing rate in April 2016 (14.44%), a temporary improvement between 2017 and 2019, peaking in June 2019 (43.94%), followed by a sharp decline post-pandemic in June 2022 (16.96%).

This suggests that external factors such as curriculum changes, review effectiveness, and the impact of online learning disruptions contributed to

inconsistent results. Strengths in pre-pandemic performance indicate that faculty strategies and review programs played a role in temporary improvements, but a lack of sustained intervention led to setbacks, particularly affecting repeaters and post-pandemic graduates. Given these findings, several targeted interventions are necessary to enhance institutional CLE performance. Specialized review programs for repeaters should be implemented, focusing on remedial instruction and subject-specific weaknesses, while comprehensive pre-board mock exams and early intervention strategies can help identify at-risk students. Strengthening core subject instruction, particularly in historically weak areas such as Criminology along with increasing practical, case-based learning, can improve knowledge retention and application. Additionally, post-pandemic recovery measures, including bridging programs and enhanced laboratory-based criminology training, are essential to address learning gaps caused by online education disruptions.

Table 1: Institutional Rating of Capiz State University – Dayao Satellite College in the Criminologist Licensure Examination since 2015.

Date of Examination	First Taker	Repeater	Overall	Remarks
April 2015	35.29%	23.33%	25.23%	Below National Passing Percentage
October 2015	36.19%	1.49%	22.67%	Below National Passing Percentage
April 2016	11.11%	14.82%	14.44%	Below National Passing Percentage
October 2016	46.02%	1.39%	28.65%	Below National Passing Percentage
June 2017	41.67%	15.15%	28.21%	Above National Passing Percentage
December 2017	28.08%	16.67%	21.09%	Below National Passing Percentage
June 2018	45.45%	22.08%	36.26%	Above National Passing Percentage
December 2018	35%	11.34%	15.38%	Below National Passing Percentage
June 2019	50%	37.1%	43.94%	Above National Passing Percentage
November 2019	42.24%	15.15%	29.77%	Below National Passing Percentage
June 2022	28.13%	10.28%	16.96%	Below National Passing Percentage
December 2022	28.77%	4%	25.07%	Below National Passing Percentage
Total Mean	**35.66%**	**14.4%**	**25.64%**	***Above* – 3 Board Examinations (25%)** ***Below* - 9 Board Examinations (75%)**

IN – DEPTH ANALYSIS OF CLE PERFORMANCE PER EXAMINATION AREA

Criminal Law and Jurisprudence

The distribution of scores reveals that the majority of examinees (59.42%) fell within the 76-80 range, indicating a concentration of performance around the mid-to-high passing threshold. A smaller yet significant proportion (15.94%) scored in both the 71-75 and 81-85 ranges, suggesting that a considerable number of candidates performed just above the minimum passing mark while others demonstrated slightly stronger competency. The presence of only 3 examinees (4.35%) in both the 66-70 and 86-90 ranges suggests that very few candidates were on the borderline of failure or excelling towards higher scores. Notably, no examinees achieved scores in the 91-100 range, highlighting a lack of outstanding performers and possibly pointing to gaps in advanced mastery of criminology concepts. This pattern suggests that while most students achieve a sufficient level of competency to pass, there is a clear challenge in pushing performance toward excellence. The data implies a need for stronger instructional strategies and review programs that not only help weaker examinees improve but also provide enrichment opportunities for high-potential students to excel beyond the mid-

range scores. Strengthening analytical skills, reinforcing subject mastery, and implementing targeted interventions for both struggling and high-achieving students could improve the overall score distribution and increase the number of top-performing graduates.

Table 2: Frequency and Percentage Distribution of Respondents' Rating in Criminal Law and Jurisprudence

Ratings in Criminal Law and Jurisprudence	%
66 – 70	4.35%
71 – 75	15.94%
76 – 80	59.42%
81 – 85	15.94%
86 – 90	4.35%
91 – 95	0%
96 – 100	0%
Total	**100%**

Law Enforcement Administration

The score distribution for the Law Enforcement Administration subject reveals that a majority of examinees (42.03%) scored in the 76-80 range, indicating that most candidates displayed a moderate understanding of the subject, performing just above the passing threshold. A significant portion (36.23%) scored between 81-85, suggesting that a good number of students grasped the core concepts well and performed above average. However, the higher score ranges were underrepresented, with only 8.7% of candidates achieving 86-90 and none scoring above 90**,** highlighting a gap in advanced understanding or application of law enforcement principles. The relatively low performance at the lower end, with only 1.45% of examinees scoring between 66-70**,** suggests that few students were on the brink of failing. The absence of candidates scoring between 91-100 indicates that there is room for improvement in developing critical thinking and specialized knowledge in law enforcement administration. This data suggests that while most candidates have a basic to solid understanding of the subject, there is a need for more targeted interventions to elevate students' mastery to a higher level and to foster advanced analytical skills to improve overall performance in this area.

Table 3: Frequency and Percentage Distribution of Respondents' Rating in Criminal Law and Jurisprudence.

Ratings in Law Enforcement Administration	%
66 – 70	1.45%
71 – 75	11.59%
76 – 80	42.03%
81 – 85	36.23%
86 – 90	8.7%
91 – 95	0%
96 – 100	0%
Total	**100%**

Criminal Detection and Investigation

The performance distribution for the Criminal Detection and Investigation subject shows that a significant majority of examinees (55.07%) scored in the 76-80 range, suggesting that most students have a moderate to solid understanding of the subject matter, with performance centered around the passing mark. Additionally, 33.33% of candidates scored between 81-85, indicating a strong grasp of core concepts, as they performed above the average range. However, the presence of only 1.45% of examinees scoring in the 86-90 range, with no candidates achieving scores above 90**,** highlights a lack of exceptional performance in this subject. This suggests that while most students demonstrate proficiency, there is a clear limitation in advanced knowledge or complex application of criminal detection and investigative techniques. The lower performance bands, with 10.15% scoring in the 71-75 range, indicate that a small group of students struggled to reach the average level, but only a minimal number (1.45%) were on the edge of failing. The absence of candidates scoring above **90** in this area reflects the need for improvements in higher-order analytical skills**,** case study applications**,** and advanced investigative methodologies**.** Overall, while a majority of examinees display adequate proficiency, there is a clear opportunity to focus on elevating both the critical thinking and practical application aspects

of criminal detection and investigation to ensure that students are not just passing but excelling in this essential area of criminology.

Table 4: Frequency and Percentage Distribution of Respondents' Rating in Criminal Detection and Investigation

Ratings in Criminal Detection and Investigation	%
71 – 75	10.15%
76 – 80	55.07%
81 – 85	33.33%
86 – 90	1.45%
91 – 95	0%
96 – 100	0%
Total	**100%**

Forensic Science and Criminalistics

The performance distribution in Forensic Science and Criminalistics shows that a significant proportion of examinees (56.52%) scored in the 76-80 range, indicating that most students have a solid understanding of the subject, performing just above the minimum passing level. This suggests that the majority of examinees grasp the fundamental concepts of forensic science and criminalistics but may not have reached an advanced level of expertise. Additionally, 21.74% of examinees scored in the 81-85 range, reflecting above-average proficiency, indicating a better-than-average understanding of the subject matter, possibly with stronger analytical or practical skills. A relatively small group (13.04%) scored in the 71-75 range, suggesting that they have basic competence but may need further improvement to achieve better mastery of the subject. At the lower end of the spectrum, only 1.45% scored in the 61-65 range, indicating that a minimal number of examinees struggled with the subject, though this group is limited in size. Notably, the absence of students scoring above 90 (no candidates in the 91-95 or 96-100 range) points to a lack of exceptional performance in this area, which could suggest that while students understand the basics and some advanced concepts, they may not be excelling in the more complex aspects of forensic science, such as crime scene investigation, evidence analysis, and advanced criminalistics techniques**.** This performance pattern suggests the need for focused instructional strategies that not only strengthen foundational knowledge but also enhance higher-level skills like critical thinking, complex problem-solving, and hands-on experience with forensic applications, which could help elevate student performance in this crucial subject area.

Table 5: Frequency and Percentage Distribution of Respondents' Rating in Forensic Science and Criminalistics

Ratings in Forensic Science and Criminalistics	%
61 - 65	1.45%
66 – 70	4.35%
71 – 75	13.04%
76 – 80	56.52%
81 – 85	21.74%
86 – 90	2.9%
91 – 95	0%

Criminology

The performance distribution in the Criminology subject reveals a mixed set of results, with a concentration of examinees scoring in the 76-80 range (39.13%), indicating that a large portion of students have a moderate to solid understanding of the subject matter, performing just above the minimum passing threshold. This suggests that while most students grasp the essential criminological concepts, there may be room for improvement in mastering more advanced topics or applying critical thinking skills. Additionally, 21.74% of examinees scored in the 71-75 range, reflecting basic competency, while 18.84% scored in the 66-70 range, indicating that a notable portion of students were on the lower end of the passing spectrum. This group may require further academic support to strengthen their understanding of criminology principles. On the higher end, 20.29% of students scored in the 81-85 range, suggesting that a fair number of examinees demonstrated a stronger grasp of criminological theories and principles,

although there was a notable absence of students scoring in the 86-90 range or above, which reflects a lack of exceptional performance. The complete absence of scores in the 91-100 range highlights a potential gap in developing advanced analytical skills, comprehensive knowledge of criminology, and the ability to apply these concepts in practical scenarios. Overall, while a majority of students are adequately proficient, there is a clear need for improvements in advanced criminology education, focusing on critical thinking, application of criminological theories, and possibly research skills to push students toward higher performance levels. Additionally, targeted interventions for those on the lower end of the scale could help them reach a more competitive level of competency.

Table 6: Frequency and Percentage Distribution of Respondents' Rating in Criminology

Ratings in Criminology	%
66 – 70	18.84%
71 – 75	21.74%
76 – 80	39.13%
81 – 85	20.29%
86 – 90	0%
91 – 95	0%
96 – 100	0%

Correctional Administration

The performance distribution in Correctional Administration shows that a majority of examinees (43.48%) scored in the 81-85 range, indicating that a significant portion of students have a strong grasp of the subject matter and demonstrate above-average proficiency. This suggests that most candidates have a solid understanding of key concepts in correctional administration, such as prison management, rehabilitation, and legal frameworks related to corrections. A large number of students (34.78%) also scored in the 76-80 range, indicating that many students performed adequately and have a moderate understanding of the subject. While this group is competent, there is an opportunity to push these students toward more advanced levels of understanding and application. On the lower end, 7.25% of examinees scored in the 71-75 range, suggesting that a small portion of students displayed just enough proficiency to pass, though they may require additional support to solidify their foundational knowledge. The presence of 11.59% of students in the 86-90 range demonstrates that a subset of candidates displayed strong competency, though the lack of students in the 91-100 range indicates that exceptional performance in this area is rare. Only 2.9% scored in the 91-95 range, and no students scored above 96, highlighting a gap in advanced mastery of correctional administration. This suggests that while most students possess adequate knowledge, there is a need to develop higher-order analytical and problem-solving skills, especially in areas like policy formulation, advanced corrections management, and rehabilitation strategies. In conclusion, the data suggests that while a large portion of students perform competently in correctional administration, there is significant room for improvement in pushing students towards exceptional performance and developing more advanced skills necessary for complex correctional challenges.

Table 7: Frequency and Percentage Distribution of Respondents' Rating in Correctional Administration

Ratings in Correctional Administration	%
71 – 75	7.25%
76 – 80	34.78%
81 – 85	43.48%
86 – 90	11.59%
91 – 95	2.9%
96 – 100	0%
Total	**100%**

Board Performance Rating per Major Subject Areas in the Criminologist Licensure Examination

Major Subject Areas	Total Mean	Rank
a) Correctional Administration	82.22%	1
b) Criminal Detection and Investigation	79.62%	2

c) Law Enforcement Administration	79.43%	3
d) Criminal Law Jurisprudence	78.32%	4
e) Forensic Science and Criminalistics	77.54%	5
f) Criminology	75.88%	6

IV. CONCLUSION

The analysis of the six criminology subjects in the Criminologist Licensure Examination (CLE) reveals several key findings.

1. The institutional performance in the Criminologist Licensure Examination (CLE) over the past twelve board examinations shows a consistent struggle to meet or exceed the national passing percentage, with only three out of twelve (25%) examination periods surpassing the national benchmark, while the majority (nine out of twelve, or 75%) fell below. The total mean passing rate of 35.66% indicates a moderate but insufficient overall performance, with fluctuations across different examination periods. The highest recorded performance was in June 2019 (50%), whereas the lowest occurred in April 2016 (11.11%), highlighting significant variability in examinee outcomes. Despite occasional improvements, the institution has generally failed to maintain a consistent upward trend, as seen in the declining results in recent years, particularly in June and December 2022, where performance remained below expectations. This pattern underscores the need for comprehensive institutional reforms, including enhanced curriculum development, intensive review programs, faculty training, and student support systems to improve board examination outcomes and ensure better preparedness for future criminologists.
2. The majority of examinees scored within the 76-80 range across all subjects, indicating a moderate level of competency but a lack of outstanding performance.
3. Among the six subjects, Correctional Administration emerged as the strongest, with the highest proportion of students scoring in the 81-85 range (43.48%), suggesting better comprehension in this area.
4. Criminology proved to be the most challenging, as it had the highest percentage of students scoring 66-70 (18.84%), indicating that a larger portion of examinees struggled to pass.
5. A critical concern across all subjects is the lack of top performers, as no students scored in the 96-100 range, and only a small fraction reached 91-95, specifically in Correctional Administration (2.9%). This highlights a gap in advanced application, critical thinking, and analytical skills in criminology education.
6. Subjects like Criminal Detection and Investigation, Forensic Science and Criminalistics, and Law Enforcement Administration showed a concentration of scores in the 76-80 and 81-85 ranges, reflecting general competency but limited mastery.
7. Given these findings, institutions must implement targeted interventions such as enhanced curriculum delivery, case-based learning, practical applications, and intensive review programs to help students achieve higher proficiency levels. Strengthening higher-order thinking, problem-solving, and specialized training will be essential in bridging the gap between average and outstanding performance, ensuring that criminology graduates are better equipped for professional practice.

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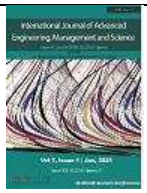

Density Based Traffic Control System and Emergency Vehicle Detection Using Arduino

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Abstract *— Urban traffic congestions cause delays and ineffi- cient fuel expenditure in cities. Regular fixed-time-based traffic systems are not able to respond quickly to real-time conditions and thus cannot manage traffic efficiently. This paper proposes an adaptive traffic control system using an Arduino microcontroller to automatically adjust signal timings based on vehicle density detected by IR sensors. Moving traffic is monitored by the system in real-time to optimize signal changes for better flow and reduce congestions. The other technology associated is RFID, which creates a foolproof emergency vehicle pass using minimal time delay at intersections. The system provides priority to emergency vehicles while optimizing other traffic. This system improves the efficiency of traffic and decreases the waiting time, which enables better road clearance for emergency service vehicles. The model is cost-effective, very adaptable, and promises a great step forward in urban traffic management.*

Keywords *— Adaptive Traffic Control, Arduino, IR Sensors, RFID, Emergency Vehicle Priority, Urban Traffic Management.*

I. INTRODUCTION

Traffic congestion has been and is one of the significant challenges facing urban planners in every corner of the world. As cities expand and the number of vehicles increases, tra- ditional traffic controlling systems either remain unable to manage the increased traffic flow or do so ineffectively. Con-ventional traffic signals are based on a fixed time interval-and hence do not change, to best suit real-time traffic conditions

[1]–[3]. This leads to prolonged delays, increased consumption of fuel, and created air pollution due to long idling vehicles at traffic lights. Instead, the density-based adaptive traffic control system seems a more efficient solution that changes signal timing according to the real-time density of vehicles. Such a system enables smooth traffic flow with less problem caused by traffic congestion. Besides general congestion, emergency vehicles, such as ambulances, fire trucks, and police cars, often get stuck at intersections behind traffic lights, causing further delays in life-saving operations. In critical cases, a matter of a second could spell the difference between life and death; every second counts, and one can just imagine the lifeline lost just by one second of intersection delay [4]–[7]. At present, traffic management authorities are depending upon manual systems or dedicated lanes for emergency vehicles, which does not guarantee efficacy, especially during peak hours. It is imperative that, in order to cut down emergency response times considerably, an automated smart system is called for, whereby an emergency vehicle being able to automatically detect and grant itself priority clearance [8]–[10]. To mitigate this problem, an adaptive traffic light controlling system based on traffic density on the road, using IR sensor to detect number of vehicles at an intersection, is proposed where the proposed system also detects the emergency vehicle separately to give priority to emergency vehicles [11]–[13].

II. METHODOLOGY

The entire design approach entails the design and the implementation of the input subsystem, control unit (control program), and output subsystem. The input subsystem is composed of sensors programmed and implemented according to some already existing principles to guarantee the maximum operational performance. The control unit is brought into operation through a microcontroller-based control program that interprets the input and interprets it to generate a desired output.

A. Block Diagram

Fig.1 shows the block diagram of the entire system that gives an idea of the basic elements of the system- Mains Supply, DC Power Supply, IR Sensors, Controller, Traffic Lights, and RFID module. The block diagram was drawn in such a way as to give an exact idea of the overall working of the system in a single glance; so the main supply supplies 230VAC power, which gets converted into 5VDC [VDD] through the DC power supply to run the IR sensor, the controller, the RFID module, and the traffic lights. The sensors provide information to the controller, and based on that, logical operations are executed to set the traffic lights' state to control traffic at the road intersection.

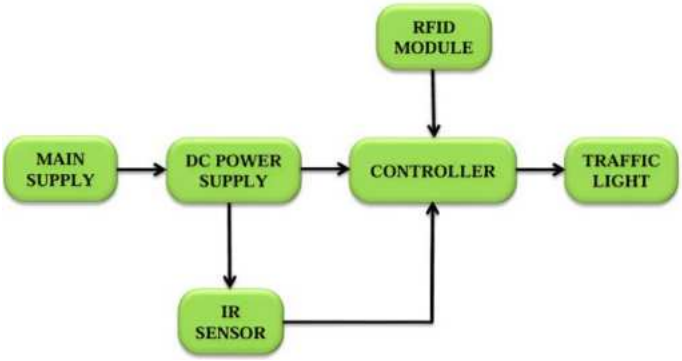

Fig. 1: Block diagram of density based traffic light control system

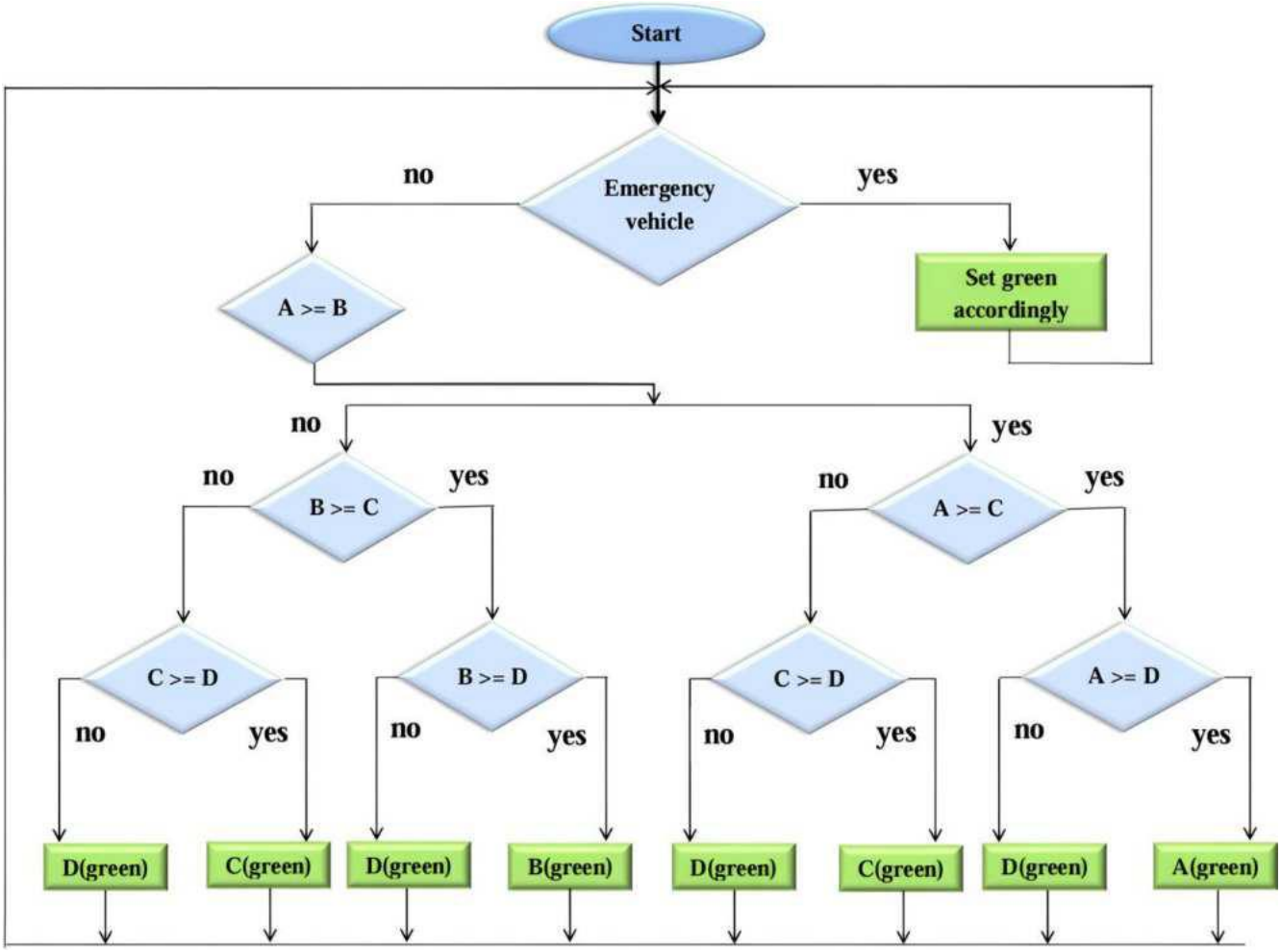

Fig. 2: Flow chart of the system

The main power supply builds a battery which increases the voltage steady thereon the safety controller, sensors, and many other components. The IR sensors fixed near the road check the density of the vehicles flowing at an intersection. This data is sent to the controller to dynamically vary the duration of the traffic signals on the basis of the actual vehicle counts: a longer green light for higher traffic density and a shorter green light under low traffic density.

In addition to handling normal traffic, this system is in- tended to facilitate the clearing of emergency vehicles when they approach illuminated Traffic Signal Junctions. Each such vehicle (in emergencies, typically ambulances, fire engines, and police cars) normally has an RFID tag attached to it. Upon approaching the traffic junction, the RFID reader reads the tag from the vehicle and sends a signal to the controller,

which shifts the green traffic light to the emergency vehicle immediately. There will not be any manual interference; response times in critical conditions will be minimized. The microcontroller acts as the brain of the system, takes inputs from both the IR sensors as well as the RFID module, efficiently provides intelligent control, and manages the flow of traffic lights accordingly.

The system design relied on Arduino because of its simplic- ity, cost-effectiveness, and flexibility. It can be easily paired with several other sensors such as infrared or ultrasonic to analyze traffic flow as well as detect emergency vehicles; quick responses made possible with real-time processing techniques adjust the signal based on traffic variations to contribute to the overall efficiency of the flow and the priority to emergency vehicles upon their detection; low power consumption keeps the overall operating cost low, allowing continuous activity without heavy energy expenses; in addition, because of Ar- duino's modular nature, it allows scalable aspects whereby new sensors or components can be easily introduced whenever

necessary; being an open-source platform, Arduino boasts extensive community support whereby many resources and libraries lengthen and quicken the development phase. Some connection options such as Wi-Fi or GSM appear to pro- vide convenience and efficiency for the remote monitoring and management of the system. All these features together contribute to making Arduino an ideal option for the construc- tion of an efficient and value-for-money smart traffic control system.

B. Flow chart

Fig.2 shows the flowchart of the entire system. The flowchart represents the systematic lanes priority based on traffic volume. First, it calls attention toward special cases for example, emergency vehicles like ambulance, fire brigade, etc. Then he follows simple hierarchy comparisons to decide which lane should get the green light, leading to restrictions based on traffic volume. This particular decision process is aimed at traffic management for streamlining vehicular movement in a safe and efficient manner.

This flowchart is the decision-making process for determin- ing which lane Broads A, B, C, or D gets the green signal at intersections. Following is a stepwise description:

1) **Start**
   - The process begins with the "Start" symbol.
2) **Checking for Emergency Vehicles**
   - The system first checks if an emergency vehicle is present in any lane.
   - **If Yes:** The signal is adjusted to allow the emer- gency vehicle to pass.
   - **If No:** The system proceeds to analyze traffic con- ditions.
3) **Comparing Lanes to Determine Priority**
   - The system prioritizes lanes based on traffic volume using a series of comparisons.

Case 1: $A \geq B$

- If lane A has traffic volume greater than or equal to

B, further checks are performed:

– **If** $A \geq C$, then check if $C \geq D$:

∗ **If Yes:** C gets the green signal.

∗ **If No:** Since $C < D$, lane D gets the green

signal.

– **If** $A < C$, then check if $A \geq D$:

∗ **If Yes:** A gets the green signal.

∗ **If No:** Since $A < D$, lane D gets the green signal.

Case 2: $A < B$

- If lane A has less traffic than B, the comparison continues with D:

– **If** $B \geq C$, a simpler comparison is made with

D:

∗ **If Yes:** C gets the green signal.

∗ **If No:** Since $C < D$, lane D gets the green signal.

– **If** $B < C$, then check if $B \geq D$:

∗ **If Yes:** B gets the green signal.

∗ **If No:** Lane D gets the green signal.

4) **Final Decision**

- Based on direct comparisons, the lane with the highest traffic volume is granted the green signal.

III. EXPERIMENTAL SETUP

In order to demonstrate the function of the traffic man- agement system that has been developed, a prototype was designed for testing in an environment of real-world demon- stration. The testing scenario for the system was created to allow for traffic flows to be monitored for the management of emergency vehicles, and in regard to this page, there are no processes for emergency vehicles. Fig.6 represents the exper- imental setup of the density-based traffic light control system in operation, which was used for our research project, while Fig.7 shows the connections of the Arduino with IR sensors and the RFID module. The experimental setup includes:

Arduino Uno Microcontroller: It is the core of the system; will act as the central control unit for the whole system and is quite simple with regard to implementation, as an open-source microcontroller is used often as a more concerned notion of other types, such as minimal price, multi-usage, and simplicity. This would be the main processing unit for the system. The Arduino Uno [14]–[16] will receive signals from the sensors, processes the input, and produce outputs, such as a traffic light change, or an emergency vehicle detection. Fig.3 shows arduino uno board.

Fig. 3: Arduino uno

Infrared Sensors on the separate lanes: This consists of four Infrared (IR) sensors [17] placed in appropriate locations to observe traffic density from the different lanes of the intersection; and each sensor can figure out if a vehicle either passed over or interrupted the infrared beam. The number of vehicles detected by the IR sensors is fed to the Arduino Uno for evaluating the situation of traffic in each lane, as the sensors are placed in such a way that they can identify or monitor the flow of traffic of each lane independently, which would contribute in a comparative way as occur in monitoring a specific lane signal more adequately. By means of these sensors, the system determines an accumulation of traffic on some specific lane and thus will adjust the signal timings to eliminate the bottlenecks. Fig.4 shows infrared sensor used in experimental setup.

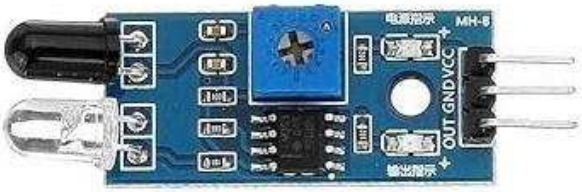

Fig. 4: Infrared Sensor

RFID Module for Emergency Vehicle Detection: This system has an RFID module [18] for the very important task of emergency vehicle detection, for which all emergency vehicles are fitted with electronically labeled or tagged from the entire

length of the RFID module. When an emergency vehicle comes to the intersection, the RFID module sends a signal to Arduino Uno in order to get a real-time response and prioritizes the emergency vehicle's passage. The system then adjusts the traffic signals by turning red for all other lanes, allowing the emergency vehicle to pass through the intersection without any obstruction or delay. Fig.5 shows RFID module.

LED Based Traffic Signals: This project incorporates LED-based traffic signals, simulating real-life traffic signals which offer advantages over the classical forms of traffic sig- nals. The LEDs allow better visibility while providing massive power savings in the traffic signals simulation. Arduino Uno will control the traffic signals working with inputs coming from the IR sensors and the RFID module. The LED signals based upon the detected emergency vehicle will, as such, turn the non-emergency vehicle lanes to red enabling the emergency vehicle lane dynamic enumerate processes. All this general traffic logic is controlled by the Arduino Uno, which actuates command upon input from the IR sensors and RFID module.

Fig. 5: RFID module

Power Supply Unit: To power all the system components, there must be a stable and resilient supply. Such a supply will enable proper feeding of the voltage and current to the system including the Arduino Uno, IR sensors, RFID module, and LED traffic signals to keep it functional. This is of utmost importance in order to provide the necessary integrity to the system and ensure that constant testing should be operational throughout the total procedure experiment. A stable power supply unit ensures that the system remains operational and responsive in real-time.

A system inclusive of different traffic management scenarios was effectively tested to examine the performance. The types of tests simulated various real-life situations with varied traffic density along the lines of emergency vehicles involved:

Traffic Density Variations: The experiment evaluates the appropriateness of the system adjusting for different traffic density conditions at an intersection. The low-density traffic condition indicates a situation with minimal vehicles, and the system minimizes the green lights duration, which ulti- mately permits very rapid passage of vehicles with limited waiting times for the initial vehicle. The infrared sensors sense very few vehicles and the Arduino Uno decreases the amount of green light duration to eliminate non-existent traffic queue and allow traffic passage to resume without delay. The moderate-density traffic condition allows the Arduino Uno to dynamically extend the green light duration for traffic lanes with moderate densities of heavy traffic or multiple vehicles present. The traffic lights changes thus will be displayed in real time allowing the system to optimally relieve traffic lane congestion and still promote efficient passage with moderate- density traffic conditions. The high-density traffic condition allows queues of vehicles to form, and the system allows the traffic lights to maximize the green light for the lane with the highest congestion while adjusting for all other lanes to not remain at red lights for extended periods. Each of the above conditions results in the adaptive signal timing to allow for the ultimate finite limits of passage of existing intersection. During the continuation of traffic density conditions the signal timing are dynamically adjusted based on the data of the infrared sensors which limits wait time, enhance throughput. This direct signal timing adjustment largely aids in congestion relief, minutes and seconds will ensure the decisiveness of the delay, promotes traffic flow, and can optimize signal performance for intersections with high volume or minutes, so an overall goal of intersection optimization is achieved.

Emergency Vehicle Scenarios: The second series of pro- cedures introduced an emergency vehicle into the system at intervals of time. When emergency vehicles that have RFID tags get close

to the intersection, the RFID module

Fig. 6: Density based traffic light control system in operation

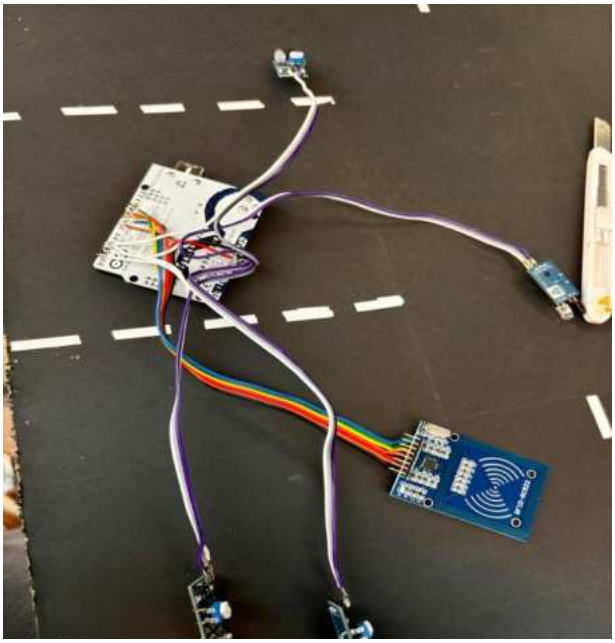

Fig. 7: Connections of arduino with IR sensors and RFID module

will detect the emergency vehicle. When the RFID module detects the emergency vehicle, it will send a signal to the Arduino Uno, which will receive the detection data and change the traffic light state to facilitate the emergency vehicle's movement through the intersection. When the system detects an emergency vehicle, it will change the traffic light to green for that lane of traffic and change other traffic lights to red. The objective is to provide the emergency vehicle as unobstructed

of a pathway through the intersection as possible. The system is designed to display traffic light patterns that respond to the arrival of emergency vehicles, and will do its best to provide priority to the emergency vehicle and allow the emergency vehicle to travel through the intersection without delay. Other vehicles will be stopped at the red traffic light to ensure the intersection is clear as soon as possible, while still minimizing the risk of delaying other traffic and enhancing emergent service response time.

Combination of Traffic and Emergency Vehicles: The last evaluation emulated a scenario of a heavily congested junction where traffic density converged with the presence of an emer- gency vehicle at the intersection. This evaluation was meant to ascertain how well the system was capable of handling not only an emergency vehicle's request for prioritization, as needed, while allowing normal traffic flow to maintain normal operations. Upon observing the emergency vehicle traveling through the intersection using the RFID module, the Arduino Uno modified or transitioned the traffic signal to prioritize the emergency vehicle's lane

through a green signal. The system maintained the emergency vehicle's lane in a green signal while all other lanes were held in a red signal until the emergency vehicle exited the intersection. One major difference, however, in comparison to normal traffic signal systems that could delay vehicles "non-emergency" vehicles traveling through the intersection excessively, was the systems capacity to balance both requests for vehicles traveling through the intersection. It was designed to give a sufficient amount of green time, while at the same time, adjusting the other vehicles in the lanes cycles or signal timing, by putting them back into a green once the emergency vehicle was cleared. The system would minimize the delay for vehicles proceeding with the green signal while still allowing for normal optimal traffic flow. In other words, the emergency vehicle just simply moves through the intersection unimpeded while still allowing the remaining vehicles to continue progressing through the intersection (reducing congestion on the roads overall) as marked by their signals.

IV. CONCLUSION AND FUTURE SCOPE

The proposed density-based traffic control system using Arduino successfully adapts signal timings for real-time traffic conditions. The RFID-based emergency vehicle detection al- lows for a quick clearance for emergency services. This system is cost-effective, scalable, and efficient for urban traffic control, greatly enhancing congestion control and emergency response. Other Future Improvements:

- Machine Learning Algorithms - to predict the traffic and optimize the signal timings.
- Vehicle-to-Infrastructure (V2I) Communication - allow- ing real-time updates between vehicles and traffic signals.
- Solar-Powered Traffic Lights - increasing sustainability and lowering operational costs.
- Integration with Smart City Infrastructure-centralized traffic management through IoT networks. This research thus sets the foundation for intelligent traffic management systems that constitute contributions to smarter and effi- cient urban transportation networks.

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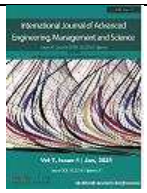

The Impact of Enforcement on Pedestrians: A Difference-in-Difference Model for Transportation Safety Policy in Taiwan

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Abstract *— The research examines the impact of Taiwan's 2024 pedestrian safety policy amendment, which increased penalties for failing to yield to pedestrians. Analysis of 528 data points from 2023-2024 using a Difference-in-Difference (DID) methodology revealed significant temporal and spatial variations in effectiveness. Early 2024 showed increased accident rates, particularly in January, but demonstrated improvement by mid-year, with notable reductions in July – August compared to 2023. Infrastructure analysis indicated varying risk levels across intersection types, with unsigned intersections showing the highest risk coefficient and signalized intersections and flashing-signal intersections having the lowest risk. Metropolitan areas exhibited more significant fluctuations than rural regions. Based on these findings, the study recommends implementing differentiated time management mechanisms, prioritizing infrastructure improvements at high-risk intersections, and establishing region-specific enforcement strategies. Additionally, the research emphasizes the importance of enhancing pedestrian safety education and driver awareness to address Taiwan's longstanding "car-superior" traffic culture and improve overall road safety outcomes.*

Keywords *— **Promote traffic safety policy, Yield to pedestrians, Difference-in-Difference analysis (DID)***

I. INTRODUCTION

Vehicle driving courtesy to pedestrians is crucial to preventing traffic accidents and ensuring the safety of pedestrians, which is not only related to the maintenance of traffic order but also a key factor in safeguarding the lives of pedestrians. As one of the most vulnerable groups of road users, pedestrians need the understanding and protection of other road users. In the modern urban transportation system, balancing the convenience of motorized vehicles and

the safety needs of pedestrians has become an essential issue in urban governance.

This low yielding rate directly impacts pedestrian safety, and the consequences are often very serious. Studies have shown that the yielding rate varies considerably from place to place: in Canada, the yielding rate for unprotected crosswalks is only about 10% (Fu et al., 2018); in Minnesota, it is about 30% (Craig et al., 2019); in Wisconsin, 28% of pedestrian-related crashes are due to failure to yield (Schneider and Sanders, 2015); and in 11 different locations in the United States, it is not surprising to find out that the yielding rate of pedestrians in the U.S. has increased by more than 20%.); Surveys in 11 different locations in the United States have found rates ranging from 8% to 100%, with an average of 66% (Anciaes et al., 2020). In China, discourtesy accounts for 13.88% of all traffic accidents, emphasizing the severity of the problem (Wang et al., 2021). These accidents not only cause injuries and deaths but also have huge social costs and family burdens. Even within the same country, there are significant differences in yielding behavior, and enforcement is one of the factors influencing the differences in driver yielding behavior and is a top priority for many law enforcement agencies (Wu et al., 2021; Liu et al., 2022; Xin et al., 2023; Xin et al., 2025).

In Taiwan, according to the Ministry of Transportation and Communications (MOTC), 394 pedestrians will be killed. More than 16,000 will be injured in traffic accidents in 2022. An average of about 47 pedestrians will be involved in roadway accidents daily, underscoring the seriousness of the pedestrian safety problem. The main reasons for the traffic safety problems of pedestrians in Taiwan are not only insufficient infrastructure and urban planning. In terms of traffic culture, Taiwan has long developed the concept of "cars are superior to pedestrians", which, coupled with weak law enforcement, has led to frequent illegal parking and sidewalk occupancy, as well as widespread driving disrespectful to pedestrians.

Therefore, Taiwan will amend the relevant laws and regulations in 2024 to increase the penalties for not yielding to pedestrians. To improve pedestrian safety in Taiwan, this study aims to analyze the implementation of this policy. The purpose of this study is to explore the changes in the policy of giving way to pedestrians after the implementation of the policy and to observe whether there are differences in the local patterns and the presence or absence of signs in the promotion of the policy. The results of this study will help pedestrian safety programmers better understand pedestrian-vehicle interactions and develop effective policy enforcement measures to reduce pedestrian-vehicle crashes and improve pedestrian safety. Following the chapters of this study, Chapter 2 explains why the DID methodology is used in this study by focusing on the impact of policy drivers on pedestrian safety and the application of the DID methodology in various domains. Chapter 3 describes how the data for this study was obtained and converted into the input data. Chapter 4 analyzes the situation of giving courtesy to pedestrians after the government promotes the policy. Finally, Chapter 5 explains the study's results and offers relevant recommendations.

II. LITERATURE REVIEW

2.1 The Impact of Policy Enforcement on Pedestrian

The impact of policy enforcement on pedestrian and driver behavior at street crossings remains understudied. While some research shows promising results—such as Sandt et al.'s (2016) findings that combining enhanced enforcement with minor

engineering improvements increases driver compliance at marked crosswalks—the evidence base is limited. After intensified enforcement efforts, Van Houten and Malenfant's (2004) observational study demonstrated improved yielding rates. Similarly, Nee and Hallenbeck (2003) observed that strengthened enforcement could enhance yielding rates and pedestrians' perceived safety. Retting and Scwartz (2017) support this view, arguing for enforcement's role in improving pedestrian safety outcomes and driver compliance. Teye-Kwadjo (2011) highlighted how insufficient enforcement can increase risk-taking behavior among road users. This aligns with Huang et al.'s (2006) observation that areas with weak traffic enforcement tend to see persistent unsafe driving attitudes and behaviors. Kim et al.'s (2008) research into violation patterns following enhanced enforcement revealed that drivers were more prone to infractions than pedestrians.

2.2 The Application of DID Analysis in Promotional Strategies

The DID methodology represents a sophisticated empirical strategy for evaluating causal effects of policy interventions and exogenous stimuli (Callaway and Sant'Anna, 2021). This econometric approach, which has gained substantial prominence in contemporary research frameworks (Krueger et al., 2020), is characterized by three fundamental components: the utilization of multiple temporal periods, variations in treatment timing, and the critical parallel trend assumption, which typically maintains validity only subsequent to controlling for observable covariates.

In the transportation domain, the DID methodology has demonstrated significant analytical utility across diverse empirical investigations. Empirical analyses have elucidated intergenerational variations in transport mode utilization between Generation X and Y cohorts, establishing the differential impacts of sociocultural, socioeconomic, and sociotechnical determinants across various transportation modalities. Kuo et al. (2021) validated the efficacy of DID in numerous traffic-related studies, providing robust evidence for causal relationships. Notably, comprehensive analysis of London's Night Tube operations by Zhang et al. (2022) has provided quantitative insights regarding its implications for nocturnal economic activity, real estate valuations, traffic incident frequencies, and criminal behavior patterns, thereby informing evidence-based urban planning and policy formulation. Furthermore, econometric evaluation by Biondi et al. (2022) of Poland's cycling initiative demonstrated a statistically significant 18% increment in bicycle traffic volume, substantiating the efficacy of targeted transportation policy interventions.

The methodological robustness of DID has been particularly evident in analyzing intermodal transportation dynamics. Empirical investigation by Zhang et al. (2018) of the relationship between high-speed rail (HSR) implementation and aviation demand patterns revealed significant competitive effects within the 500-kilometer market segment while simultaneously identifying complementary effects in long-haul markets exceeding 1500 kilometers, suggesting potential stimulation of extended-distance air travel demand. In the context of ride-sharing services, econometric analyses by Hall et al. (2018) have established that Uber's market entry generated positive externalities for public transit utilization, manifesting in a 5% increase in ridership over a 24-month period, with heterogeneous effects across urban scales and transit agency dimensions. These empirical findings

demonstrate the DID methodology's capacity to not only establish policy impact causality but also to quantify substitution and complementarity effects across transportation modalities, thereby contributing substantively to evidence-based transportation policy development and implementation strategies.

III. RESEARCH METHOD

3.1The Background

Pedestrian safety is an important issue in modern urban traffic management, and the courteous behavior of drivers towards pedestrians is not only the cornerstone of traffic order but also the key to safeguarding the lives of pedestrians. In a complex urban traffic environment, pedestrians are often the most vulnerable road users and require special attention and protection. However, Taiwan's current pedestrian safety problems stem from a combination of factors. Firstly, there is a lack of infrastructure and urban planning; secondly, the deeper problem lies in the deep-rooted culture of "cars over people". This culture, coupled with insufficient law enforcement, has led to frequent illegal parking, sidewalk encroachment, and driving disrespectfully to pedestrians.

This study examines the changes in driver behavior after implementing the policy of giving way to pedestrians. The study pays particular attention to the impact of different local morphologies and signalization on policy implementation. It aims to provide policymakers with concrete policy recommendations by analyzing the interaction patterns between pedestrians and vehicles. These findings will help formulate more effective enforcement measures, ultimately achieving the goals of reducing traffic accidents and enhancing pedestrian safety.

3.2 Data Preparation

The data for this study was obtained from the public information available on the website of the Taiwan Ministry of Transportation and Communications (MOTC) Road Traffic Safety Guidance Committee to get detailed information on the number of pedestrians killed in traffic accidents, the number of pedestrians injured in traffic accidents, whether they belonged to a large city, and whether there were traffic signals at the place where the accidents occurred for each county and city in Taiwan from 2023 to 2024. Five hundred twenty-eight data (as shown in Table 1) were collated to serve as inputs for the research model.

Table1 Structure of the data on the study

Country	Month	Car_dead	Policy promotion	Big city	Policy x big city	Car_cause	Car_sign_Yes	Car_sign_flashing_beacon	Car_sign_No
Keelung	January	16	0	0	0	16	6	1	4
Keelung	February	5	0	0	0	5	0	3	1
Keelung	March	14	0	0	0	14	3	3	3
…									
Keelung	November	14	0	0	0	14	1	4	5
Keelung	December	8	0	0	0	8	2	1	2
Taipei	January	78	0	1	0	78	23	4	20

Country	Month	Car_ dead	Policy promotio n	Big city	Policy x big city	Car_c ause	Car_sign _Yes	Car_sign _flashing _beacon	Car_sign_ No
Taipei	February	66	0	1	0	66	21	5	17
…									
Taipei	Novembe r	51	0	1	0	51	9	1	21
Taipei	December	63	0	1	0	63	15	5	19
…									
Keelung	Novembe r	16	1	0	0	16	5	1	6
Keelung	December	12	1	0	0	12	1	1	0
Taipei	January	67	1	1	1	67	17	5	22
Taipei	February	40	1	1	1	40	8	4	12
…									

3.3 DID Approach Measure Bus-to-Campus Policy

The DID method is usually used to analyze the effects of policies or other exogenous factors. First, the subject is divided into an experimental group that is affected by the policy and a control group that is not affected by the policy, and the difference between the experimental group and the control group before and after the policy is calculated separately. Since there are many factors that affect the explained variables, the differences in the differences can be eliminated by contrasting the control group with the experimental group to present the policy effects that the researcher wants to understand. In general, the DID measurement model is as follows.

$$y_{gt} = \beta_0 + \beta_1 g + \beta_2 t + \beta_3 g \times t + \varepsilon_{gt} \quad (1)$$

y_{gt} is the explained variable; g represents whether it is a dummy variable for the experimental group, 1 for the experimental group, 0 otherwise; t represents whether the time is a dummy variable after the policy is implemented, 1 if the sample is at the time after the policy is implemented, 0 otherwise; and g × t is the cross product of the two dummy variables. In the difference-in-difference model, the coefficient β_3 of g × t is the policy effect that we want to observe, i.e., the DID.

IV. THE RESULTS

4.1 Descriptive Statistics

An analysis of the 2023 and 2024 pedestrian fatality and injury statistics in Taiwan shows that the difference between the two years shows a significant phase change. The early part of the 2024 pedestrian fatality and injury data shows a considerable increase compared to the same period in 2023, especially in January, which may be closely related to the sudden increase in traffic during the Chinese New Year holiday. Looking at the mid-range, the trend gradually changes between April and August, with the gap between the 2024 fatality and injury figures and the 2023 figures narrowing. However, they remain relatively high between April and June. In particular, there was a significant turnaround in July and August, when the 2024 figure fell below the 2023 level for the first time, a change that may reflect the

beginning of the effectiveness of traffic safety management measures at this time. However, in the latter part of the year, the data show a different pattern, with the number of fatalities and injuries being significantly higher in 2023 than in 2024, with the difference being most significant in November and December, when the number of deaths and injuries climbed to a high of nearly 170, compared to a lower level in the same period in 2024. Such a difference in data demonstrates the positive impact of the enhanced enforcement efforts by the law enforcement agencies, which not only effectively raised drivers' awareness of traffic safety but also substantially improved road safety, showing that the relevant management measures have achieved the desired effect.

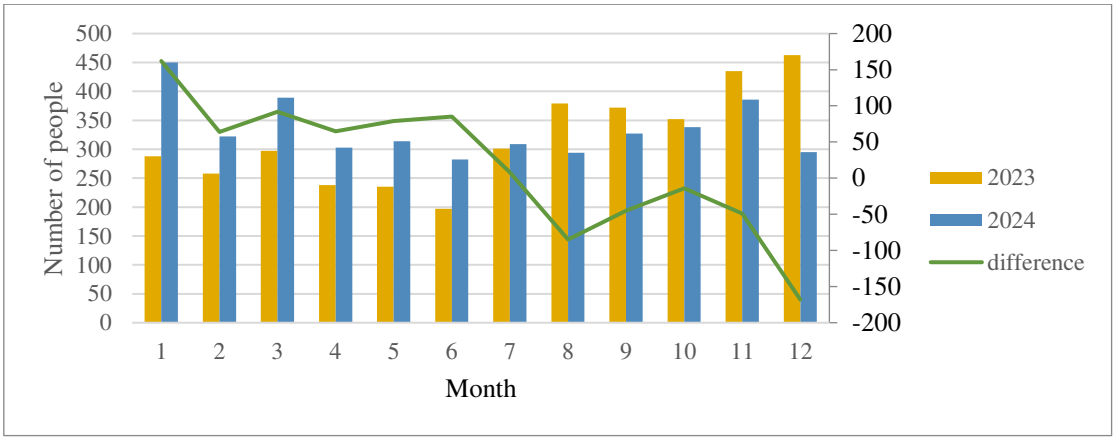


Fig. 1 The difference of promote safety policy between 2023 and 2024

According to the analysis of the trend chart, pedestrian fatalities and injuries at different types of signalized intersections showed significant seasonal variations, with higher fatalities and injuries at unsignalized intersections from January to March, especially in March when the difference reached nearly 200 cases, and then declining gradually thereafter. The performance of intersections with traffic control signs and pedestrian signals was relatively stable, indicating that traffic signals effectively ensure pedestrian safety. The overall casualty situation at flashing signalized junctions was better than that at unsigned junctions despite a few fluctuations in the middle of the year. Notably, all types of junctions showed significant decreases in fatalities and injuries in December. This consistent downward trend may reflect the increased awareness of pedestrian safety during the promotion of the policy or the effectiveness of the police in enhancing road safety management.

Overall, the data highlights the importance of traffic signaling facilities to pedestrian safety. It is recommended that the relevant authorities prioritize adding appropriate signaling facilities in road planning and continue to promote traffic safety education to reduce the incidence of pedestrian fatalities and injuries.

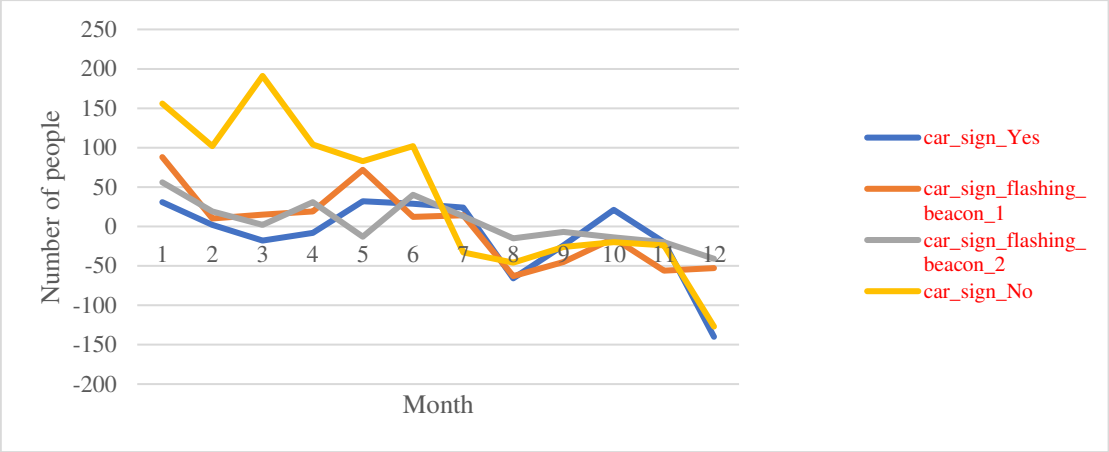
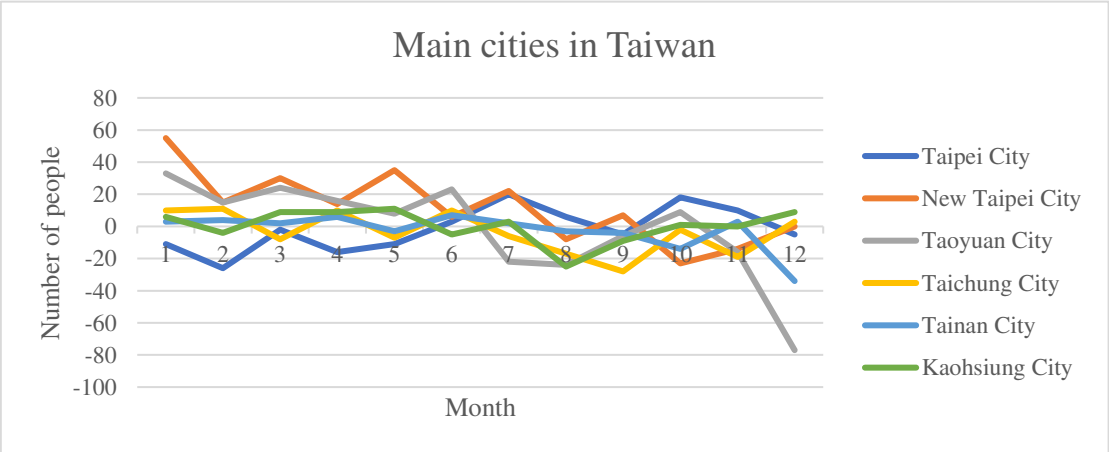
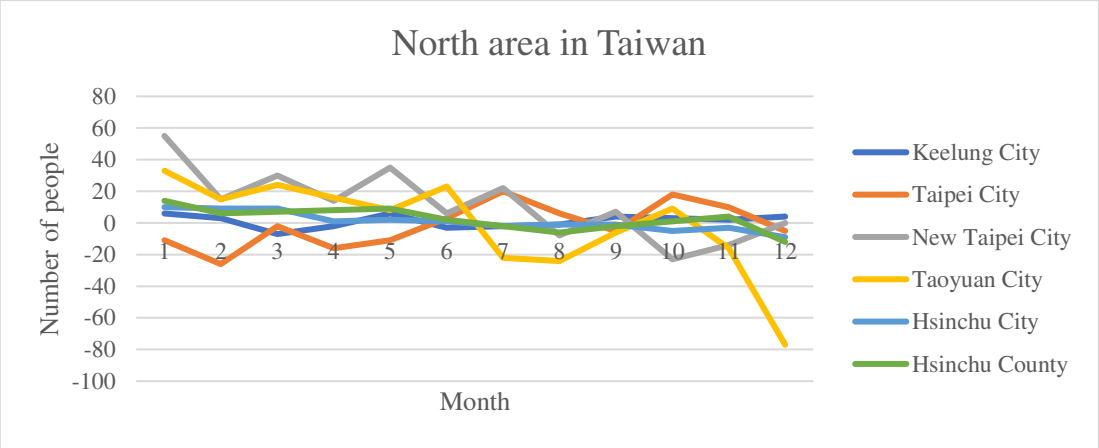


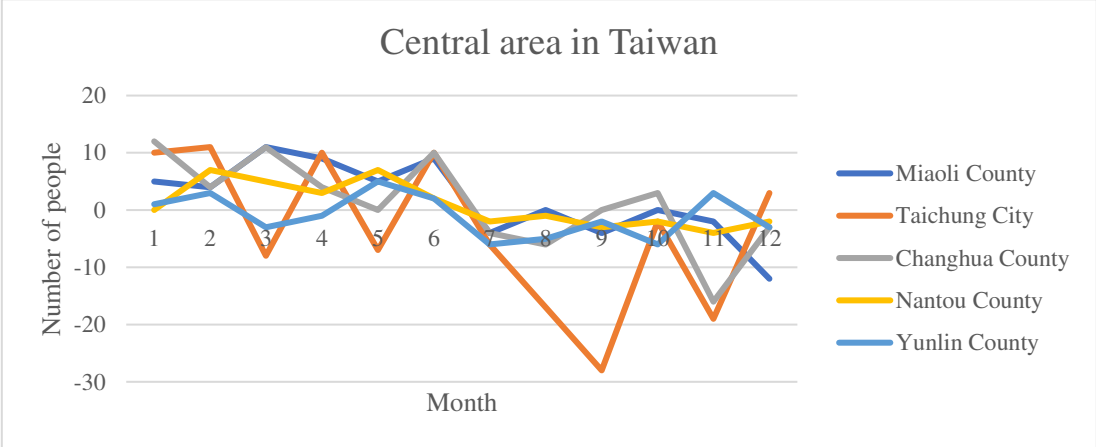
Fig. 2 The difference of signalized intersections between 2023 and 2024

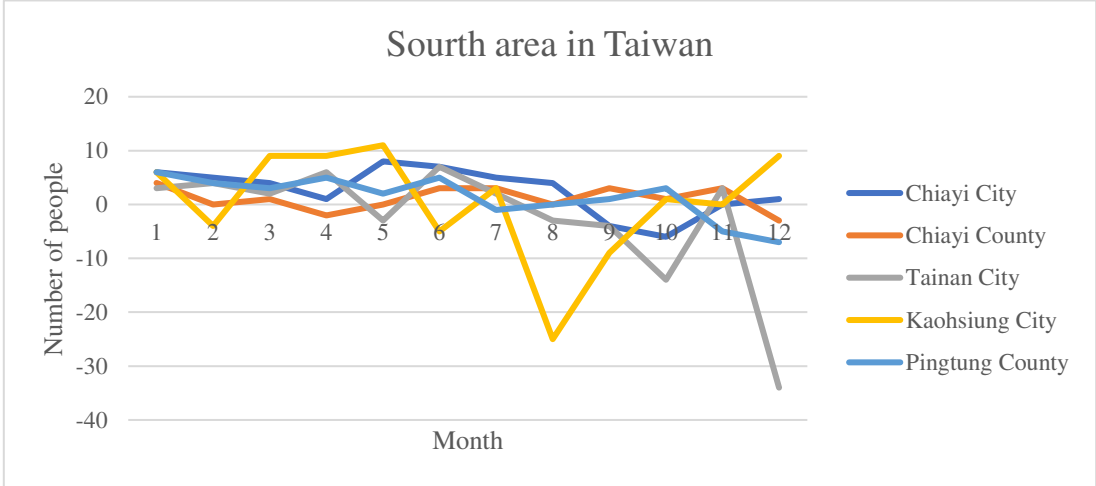
According to the analysis of pedestrian fatality and injury trends across Taiwan, the data from 2023 to 2024 show significant geographic differences. Among large cities, New Taipei City reached a peak of about 55 cases early in the year and then gradually declined, while Taipei City began to decline after reaching a peak in July. Most striking is the trend in December at the end of the year, with several regions showing significant declines, with Taoyuan City showing the most pronounced drop, with 80 fewer cases in 2024 compared to 2023. Changes in the central area are relatively mild, with most counties and cities remaining within a range of plus or minus 15 cases in 2024 compared to 2023, except for Taichung City, which shows a difference of 30 fewer cases in September. Conversely, the southern region shows more significant fluctuations in the second half of the year, with Kaohsiung City experiencing a decrease of 25 cases in August and Tainan City seeing a decrease of 35 cases by the end of the year. The eastern part of the country and the outer islands were relatively stable, with more minor fluctuations, except for Yilan County, which saw a significant drop at the end of the year.

Overall, the fluctuations in metropolitan areas were significantly more important than those in rural areas, especially during the end of the year, which may be related to the increase in festivals, climate change, or the implementation of specific policies, and are worthy of further attention and response by the relevant units.









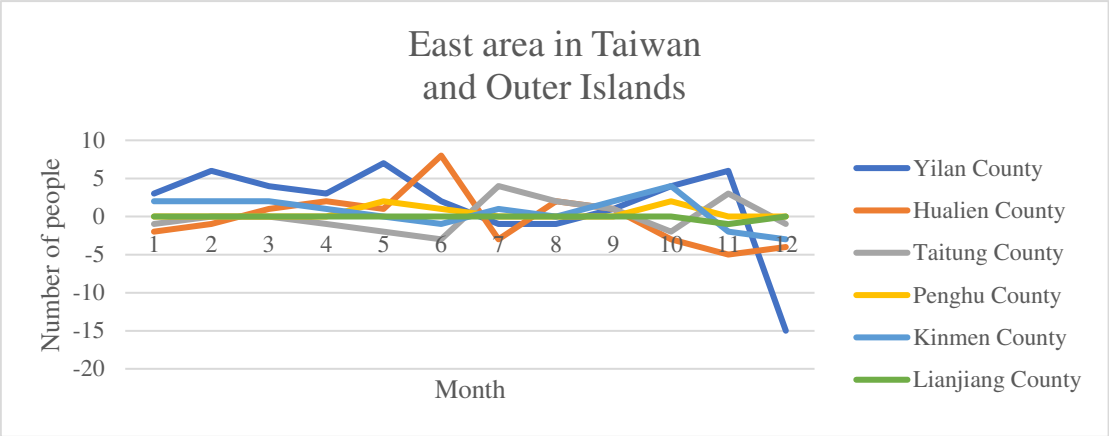


Fig. 3 The difference of promote safety policy between cities

4.2 Results of DID Analysis

1. Change in Fatalities before and After Courtesy Pedestrian Policies Promote

Based on the regression analysis results in Table 2, this study investigated the relationship between the impacts of pedestrian courtesy policy on pedestrian fatalities. The analysis showed that the constant term of the regression model was 10.774 (SD=0.815, t=13.227, p<0.001), which meant that when the city did not promote the policy, the base value of pedestrian deaths was 10.774. Its regression coefficient was 32.087 (SD=2.206, t=14.546, p<0.001), which meant that when the city did not promote the policy, the average increase of pedestrian deaths was 32.087 units per unit increase. This relationship is statistically significant. This relationship is statistically significant because the p-value is less than 0.001, indicating that we can be highly confident that this relationship is not randomly generated. In addition, the standardized coefficient (Beta) of 0.536 indicates that policy promotion has a moderate positive effect on pedestrian fatalities. This standardized coefficient allows us to compare the relative impacts of different scale variables. The regression equation can be expressed as car accident = 10.774 + 32.087 × did. All coefficients in the model are statistically significant (p<0.001), and the t-values are much larger than the threshold value of 2.

Table 2 the DID analysis result for pedestrian killed in car accident

	Unstandardized coefficient		Beta	t	Sing.
	Estimated value	Standard error			
Constant	10.774	.815		13.227	.000
DID	32.087	2.206	.536	14.546	.000
Dependent variable: Pedestrian killed in car accident					

Regarding traffic fatalities, the analysis shows in Table 3. There was extremely significant between-group differences (F = 1066.833, p < .001). The between-group variation (sum of squares = 149469.495) is substantially more important than the within-group variation (sum of squares = 73695.685), with a total variation of 223165.180, indicating apparent differences between groups in traffic fatality data.

Table 3 the ANOVA result in difference cities

		SS	df	Mean square	F	Sig.
Pedestrian killed in car accident	Between-groups	149469.495	1	149469.495	1066.833	.000
	Within-groups	73695.685	526	140.106		
	Sum	223165.180	527			

2. Pedestrian Yielding Policy Promotes Changes in stopping Behaviors of before and after Drivers

Based on the analysis results in Table 4, this study investigated the effect of drivers' stopping behavior changes before and after promoting the courtesy pedestrian policy. The analysis showed that the constant term of the regression model was 10.908 (standard error = 0.810, t = 13.467, p < 0.001), which indicated that when the policy was not promoted, the baseline value of pedestrian deaths due to driver failure to yield was 10.908. Its regression coefficient was 33.550 (standard error = 2.193, t = 15.296, p < 0.001), representing that for every unit increase in driver failure to yield, there is an average increase of 33.550 units in pedestrian deaths. This relationship is statistically significant because the p-value is less than 0.001, indicating that we can be highly confident that this relationship is not randomly generated. In addition, the standardized coefficient (Beta) of 0.555 indicates that driver failure to yield has a moderate positive effect on pedestrian fatalities. This standardized coefficient allows us to compare the relative influence of different scale variables. The regression equation can be expressed as driver failed to yield = 10.908 + 33.550 × did. All coefficients in the model are statistically significant (p < 0.001), and the t-values are much larger than the threshold value of 2.

Table 4 the DID analysis result for pedestrian died because driver failed to yield

	Unstandardized coefficient		Beta	t	Sing.
	Estimated value	Standard error			
Constant	10.908	.810		13.467	.000
DID	33.550	2.193	.555	15.296	.000
Dependent variable: Pedestrian died because driver failed to yield					

Regarding failure to yield to pedestrians, the data presents the highest F-value (F = 1117.103, p < .001), with the between-group variation (sum of squares = 154574.697) showing a significant difference from the within-group variation (sum of squares = 72783.149), totaling 227357.847. This result strongly suggests significant differences in pedestrian yielding behavior between groups (as shown in Table 5).

Table 5 the ANOVA result of driver failed to yield in difference cities

		SS	df	Mean square	F	Sig.
Pedestrian died because driver failed to yield	Between-groups	154574.697	1	154574.697	1117.103	.000
	Within-groups	72783.149	526	138.371		
	Sum	227357.847	527			

3. Driving Changes in Stopping Behavior of before and after Drivers at Signed Intersections

According to the results of regression analysis in Table 6, the promotion of pedestrian courtesy policy has a significant positive effect on crashes at all three different types of intersections ($p < .001$), with the most important effect on unsigned intersections (Beta = 0.559), followed by signed intersections (Beta = 0.502), and relatively small effect on flashing-signal intersections (Beta = 0.332 The effect on flashing signalized intersections was relatively small (Beta = 0.332).

Specifically, without the promotion of the pedestrian courtesy policy, accidents at unmarked intersections would increase by 9.983 units, at marked intersections by 10.992 units, and at flashing signal intersections by 1.610 units, which suggests that the pedestrian courtesy policy would have a similar and more significant impact on unmarked and marked intersections, and a relatively more minor impact on flashing signal intersections. This finding has important practical significance for traffic safety management. It suggests that there is a significant difference in the degree of influence of the pedestrian yielding policy factor in different types of intersections and that the impact of this factor needs to be considered more carefully, especially in unsignalized and signalized intersections. Meanwhile, the statistical validation results of all models showed good reliability (t-value greater than 2).

Table 6 The DID analysis result for pedestrian died at signed intersections

	Unstandardized coefficient		Beta	t	Sing.
	Estimated value	Standard error			
Constant	3.397 (1) .932 (2) 2.781 (3)	.305 (1) .074 (2) .238 (3)		12.778 (1) 12.637 (2) 11.671 (3)	.000
DID	10.992(1) 1.61 (2) 9.983	.825 (1) .200 (2) .645 (3)	.502 (1) .332 (2) .559 (3)	13.320 (1) 8.059 (2) 15.453 (3)	.000
Dependent variable: 1. Pedestrian dies that have signalized intersections 2. Pedestrian dies that have flash signalized intersections 3. Pedestrian dies that have not signalized intersections					

Although the result of the signalized intersections is smaller than the previous two items, it still shows a considerably high F-value ($F = 924.171$, $p < .001$). The between-group variation is 18983.594, with within-group variation at 10804.677 and total variation reaching 29788.271, similarly reflecting significant between-group differences. The result of the flash signalized intersections, while relatively more minor, remains statistically significant ($F = 173.611$, $p < .001$). The difference between its between-group variation (363.763) and within-group variation (1102.115) is comparatively more minor, with a total variation of 1465.879, indicating that while group differences exist, they are relatively mild. The result of un-signalized intersections shows significant results ($F = 590.468$, $p < .001$). The

between-group variation is 10478.183, with within-group variation at 9334.164, and total variation reaching 19812.347. This result demonstrates apparent between-group differences in this category as well (Table 7).

Table 7 the ANOVA result which signed intersections in difference cities

		SS	df	Mean square	F	Sig.
Pedestrian dies that have signalized intersections	Between-groups	18983.594	1	18983.594	924.171	.000
	Within-groups	10804.677	526	20.541		
	Sum	29788.271	527			
Pedestrian dies that have flash signalized intersections	Between-groups	363.763	1	363.763	173.611	.000
	Within-groups	1102.115	526	2.095		
	Sum	1465.879	527			
Pedestrian dies that have not signalized intersections	Between-groups	10478.183	1	10478.183	590.468	.000
	Within-groups	9334.164	526	17.746		
	Sum	19812.347	527			

V. SUMMARY OF DATA ANALYSIS

Before and after the promotion of the safety policy, the difference in the monthly pedestrian traffic accident fatality rate peaked in January-March, then stabilized in April-June, improved in July-September, and increased in December. The DID results further confirmed that the regression coefficients for the change in fatality rate were 32.087 (Beta = 0.536, $p < 0.001$) and the coefficient for the change in driving behavior was 33.550 (Beta = 0.555, $p < 0.001$), both of which were statistically significant. Regarding the presence or absence of signals, the analysis of intersection type effects showed that the highest risk coefficient was found for unsigned intersections (Beta = 0.559), followed by signaled intersections (Beta = 0.502), and the relatively low coefficient was found for flashing-signal intersections (Beta = 0.332). Finally, the regional variation analysis shows that the volatility of metropolitan areas is significantly higher than that of non-metropolitan areas, with the risk coefficient of New Taipei City reaching 0.55 at the beginning of the year and Taipei City peaking in July. Taoyuan City showed a significant downward trend (-0.80) at the end of the year. In contrast, the fluctuations in non-metropolitan areas were more minor, with the central region maintaining a range of ±0.15 and the southern region showing more significant variability in the year's second half but still more stable than the metropolitan areas.

A significant correlation exists between the configuration of the signaling system and the risk of accidents. The multivariate regression analysis indicates regression coefficients of 9.983 for unsigned intersections, 10.992 for signed intersections, and 1.610 for flashing signal intersections, highlighting the substantial impact of infrastructure configurations on pedestrian safety. Additionally, seasonal variation analysis demonstrates a notable cyclical pattern in accident frequency, with the highest risk coefficients occurring in the first quarter of the year, particularly in metropolitan areas.

VI. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From a practical application point of view, the findings of this study highlight the need to adopt differentiated strategies for traffic safety management at different types of junctions. In particular, for unmarked junctions most affected by the pedestrian yielding policy, priority should be given to enhancing the relevant safety measures. Signalized junctions, although the impact coefficient is slightly lower than that of unsignalized junctions, still need to be given high priority and may require optimization of signal timing or provision of additional ancillary facilities to reduce the risk of accidents. For flashing signal intersections, although the impact of the pedestrian yielding policy is relatively smaller than that of no-signal intersections, it should not be ignored, and consideration can be given to adjusting the operation mode of flashing signals or adding other safety measures according to the actual situation.

The findings of this study not only help to understand the relationship between the promotion of pedestrian yielding policy and traffic accidents at different cities and types of intersections in Taiwan but also provide an important reference for future traffic safety improvement measures. Through the results of these data analyses, traffic management departments can formulate more targeted safety strategies and optimize the allocation of resources to more effectively prevent and reduce traffic accidents at various types of intersections and enhance the overall level of road safety. In addition, this study also provides a reasonable research basis for further investigation of other factors affecting traffic accidents in the future, which will help to establish a better traffic safety assessment system.

5.2 Recommendations

According to the study, the government has established safety policies that necessitate a differentiated time management mechanism. Specifically, the high-risk periods of January to March and October to December require special management measures, whereas the safety performance during the summer months can serve as a reference for policy formulation. Additionally, the significant disparity between metropolitan and non-metropolitan areas underscores the necessity of implementing regionally tailored management strategies. Furthermore, the study highlights the crucial role of infrastructure provision and the importance of intersection signalization for enhancing pedestrian safety. However, considering the limited resources, it is recommended to prioritize the improvement of high-risk intersections.

Furthermore, the study highlighted that the allocation of enforcement priorities should account for spatial and temporal variability, particularly during high-risk periods and in high-risk areas. Additionally, pedestrian safety education and driver awareness are crucial. Nonetheless, this study has certain limitations, and it is recommended that future studies explore other influencing factors and develop more precise prediction models to enhance the evaluation system.

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Optimization of Growth Process and Structural Characterization of Nanoscale Compound Semiconductor Heterostructures

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Abstract *— This study focuses on optimizing the process sequence for fabricating a double quantum well structure composed of the compound materials AlAsSb/InGaAs/GaAsSb. The selection of optimized sequence parameters is guided by an extensive literature review on material properties, nanoscale engineering considerations, and molecular beam epitaxy (MBE) growth conditions. A key advantage of using heterostructures is the precise control over the thickness of individual material layers, which is crucial for device fabrication. To ensure uniform epitaxial growth of the ternary compounds AlAsSb, InGaAs, and GaAsSb, a slow deposition rate of 0.5 micrometers per hour is maintained during the MBE process.*

Keywords *— **MBE, Quantum well, Heterostructure, Compound Semiconductor.***

INTRODUCTION

Optoelectronic devices like light-emitting diodes (LEDs), laser diodes (LDs), Photodetectors (PDs) and optical waveguides are widely utilized in the field of optical fiber communication, medical science, automobile industries and spectroscopy for pollution monitoring and food control. This growth of the semiconductor optoelectronic components industry is mainly expected by the increased use of visible range and infrared components due to the long life, cheap and low power consumption demand. Nanoscale heterostructures, new materials and improved fabrication techniques have led to improvement in the performance of optoelectronic devices [1-4]. The heterostructure is the interface of two dissimilar materials with different bandgap energy. Nanoscale heterostructures involve quantum confinement so that it gives diverse electronic and optical properties which are useful for device development. The simulation work of the structure $AlAsSb/In_{0.59}Ga_{0.41}As/GaAs_{0.53}Sb_{0.47}$ is already simulated and discussed by the authors of this paper [5]. Heterostructure manufacturing generally requires the use of molecular beam epitaxy (MBE) and chemical vapor deposition (CVD) technology for the deposition of compound material layers. But at the nanoscale and for mass production, MBE provides more precise control over the thickness during the deposition process and creates a cleanly lattice match abrupt interface [6-9]. MBE is the process in which thin crystal layers are deposited on a substrate using an atomic or molecular beam in a high vacuum chamber. The major benefit of quantum well structure from the perspective of device fabrication is that we can regulate the thickness of the material layer during the film deposition. In this process optimization, the MBE process is proposed for the thin film deposition of nanoscale thickness because it precisely controls the thickness due to low deposition rate.

Structural Information and Process Sequence Optimization:

A schematic cross-section of the structure is shown in fig 1, where an AlAsSb (10 nm thick) confinement layer is proposed to grow on the GaAs substrate. Then P-doped InGaAs (mole fraction x=0.59) of 2 nm thick followed by the 4 nm GaAsSb (mole fraction x =0.53) material layer. After it again InGaAs and AsAsSb (10 nm) is proposed for deposition.

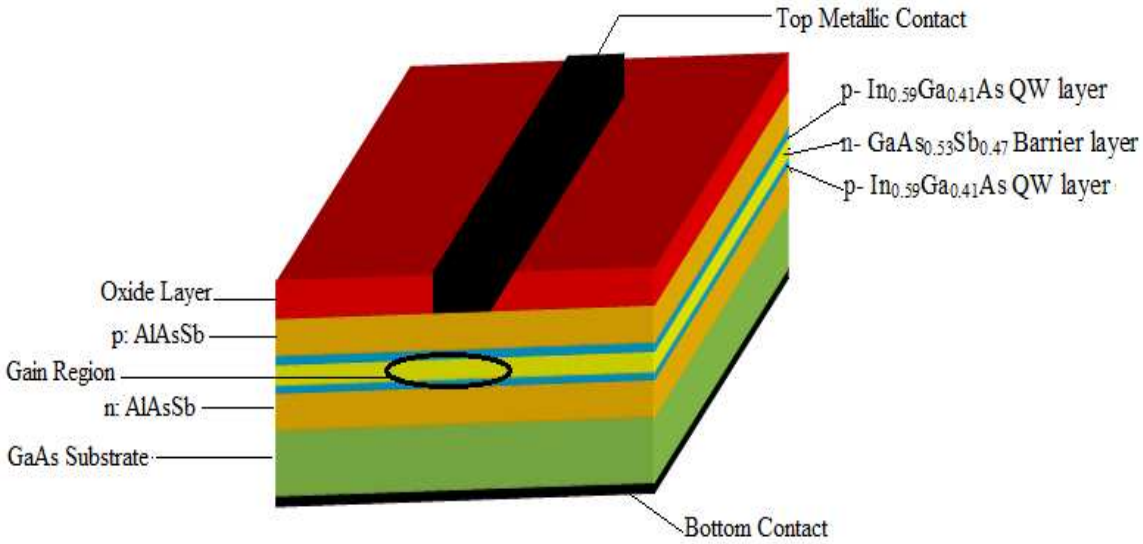

Fig.1. A schematic cross-section of the proposed structure for process sequence optimization

For epitaxial growth of these III-V compound semiconductor layers, GaAs substrate is usually utilized. So first we will take the standard p-type GaAs substrate and cleaned it with the standard process before going to molecular beam epitaxy. Pre-cleaning of the substrate is important because it removes the hydrocarbons, water molecules and other particles from a substrate. For effective results, the GaAs wafer cleaning includes the acid cleaning step in acetone solution for approximately 45 seconds, deionized water cleaning to remove the deposited cleaning solutions and a rotary drying process to dry the GaAs wafer. Rotary dryers work by tumbling material in a rotating drum in the presence of drying air. The substrate cleaning using these three steps provides the cleaned GaAs wafer without precipitate particles. After the substrate cleaning, the GaAs wafer is fixed on the MBE substrate heating holder for the epitaxial growth of the material layers. The optimized parameters of the sequences are selected based on the literature study of the materials properties, nanoscale engineering and MBE growth parameters [10-18].

Table 1: Quantum well structure with fabrication techniques

QW structure (Substrate- GaAs) with parameters	Design/ Fabrication technique	Emission wavelength (μm)
GaSb/AlGaSb	Molecular beam epitaxy (MBE)	1.65
GaInAs/GaAsSb	Metalorganic vapour-phase epitaxy (MOVPE)	1.2 - 1.47
GaInAs/GaAsSb	Metalorganic vapour-phase epitaxy (MOVPE)	1.2
GaAsSb/lnGaAs	Molecular beam epitaxy (MBE)	1.38, 1.43
GaAsSb/lnGaAs	Metalorganic chemical vapor deposition (MOCVD)	1.022, 1.075

For the deposition process, the materials (Al, Ga As, In, Sb and dopants) put in the MBE effusion cell. These cells provide highly efficient and controllable vapor deposition. The close-coupled thermocouple in the radiatively heated crucible ensures stability and reproducibility, not found in conventional evaporation sources. All the cells are heated using the heating coil and maintained temperature for vaporization. All the effusion cells have the shutter, so once the deposition is done for the required time, we close the shutter and no excess amount of material will be deposited that is why it is a very precise kind of method. For the designed heterostructure, Boron can be utilized for the p-type dopant and phosphor for the n-type dopant. The doping concentrations and the mole fractions are selected based on the atomic weight percentage and atomic mass of the materials. To find the mass percent of any element in the compound semiconductor, we divide the mass of the element in 1 mole of the compound by the compound's molar mass and multiply the result by 100. In general, the mole fraction and chemical composition can be determined using Augur spectroscopy. The substrate GaAs is fixed on the heating substrate holder and it is rotated, so that uniformity can be obtained in the deposition. The substrate temperature can be chosen at 200 °C. This high temperature of the substrate facilitates mobility and lesser defects. During the deposition process, we should be assured that atoms will not collide with any ambient atmosphere that is left in the chamber. For this purpose, the MBE base chamber pressure can be taken of the order of 10^{-9} Torr. The deposition pressure is of the order of 10^{-5} torr. This low pressure of the chamber is required so that the atoms can travel to the substrate without colliding with each other and a mean free path of around 10 meters with the ambient atmosphere. To attain this low pressure for the MBE chamber, we can use a rotary pump (up to 10^{-3} torr), diffusion pump (up to 10^{-6} torr) and turbomolecular pump (up to 10^{-9} torr). After making the high vacuum or low pressure inside the chamber the deposition process takes place. In order for uniform epitaxial growth of ternary material AlAsSb, InGaAs and GaAsSb, the deposition time is chosen very slow i.e. 0.5 micrometers per hour during the process in the MBE and layers are deposited as per the required thickness of the layer i.e. for the thickness of layer 10 nm the deposition time is taken 72 seconds for optimum growth. The deposition thickness can be determined by the use of a reflection high-energy electron diffraction (RHEED) gun, where the electrons are incident on the film, so we can control the thickness of the film more precisely. The top and bottom contacts for the characterization can be formed with the use of the thermal evaporation method.

CONCLUSION

In this research work, the process sequence optimization for the nanoscale heterostructures based on the ternary compounds is investigated for the NIR and visible range applications. The applications of the heterostructure depend on the emission wavelength. The choice of the materials and thickness of the material's layers are the critical parameters for the design of the heterostructures for an application. In the heterostructure, the thickness of the well layer or active layer is in our control. This is an important advantage of the heterostructures for device fabrication. So this research gives the choice of alternate materials for the development of optical sources for the NIR and visible range applications. The heterostructure designed in this work is of nanoscale and can be fabricated for device development. After the device fabrication, we can apply pn junction engineering to study the electro-photoluminescence (PL) spectra under the forward voltage, reverse voltage conditions and in open circuit conditions in order to know the internal quantum efficiency or emission property. It is expected that the heterostructures will give emission as proposed in the simulation work and these can be utilized for optoelectronic devices development.

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Mitigation of Rayleigh Backscattering in WDM Passive Optical Access Networks

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Abstract*— *Achievement of transmission (full duplex) over single fiber is a challenge for researchers for Wavelength Division Multiplexed Passive Optical Networks. There are many schemes available but they suffer from transmission issues because of using transmissions on the same wavelength with bidirectional transmissions. This results in the reduction of transmission distances between optical fiber terminal equipment and the optical network units. This happens because Rayleigh' backscattering noise and there is a need to reduce that noise substantially. In this research work channels capacity Dense Wavelength Division Multiplexing (DWDM), Passive Optical Networks (PON) are simulated after extensive testing. The main aim is enhancing the capacity over a distance with less bit error rates. This was achieved through the design optimization using Rayleigh' Backscattering elimination technique thus enhancing the performance.

Keywords*— *Rayleigh backscattering, DWDM, PON.

I. BACKGROUND

To begin with, one must comprehend the fundamental ideas of optical fiber networks. Optical fibers offer a great deal of benefits, including lengthy repeater spacing, minimal crosstalk or signal leakage, compact size and light weight, and service security. A glass or plastic fiber that is intended to direct light along its length is called an optical fiber (or fiber). Two methods for light to pass via an optical fiber are by reflection and refraction.

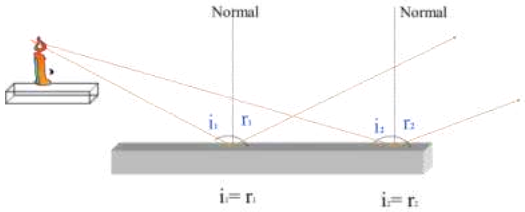

*Fig. **Error! No text of specified style in document.**: Total Internal Reflection of Light*

The other law is called the Total Internal refraction of Light.

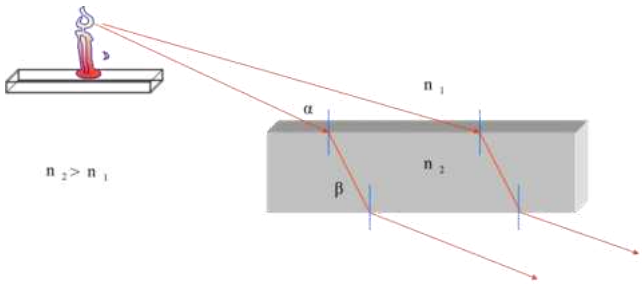

Fig.1: Total Internal Refraction of Light

Optical fiber is basically a glass waveguide. Now we will look at the architectures of optical fiber communications. FITL-Fiber in the loop can have many architectures such as.

- FTB - Fiber to the Building
- FTC - Fiber to the Curb

- FTH - Fiber to Home

Same is shown in the Fig below:

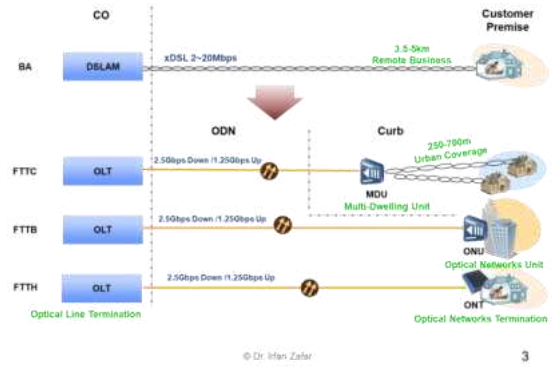

Fig.2: Optical Access Network (OAN) Architectures

OAN consists of the following scenarios:

- FTTB
- FTTC
- FTTH

Once we have studied various scenarios about the network architectures used for optical communications, it is also important to know what we mean by the PON (Passive Optical Networks).

PON features;

- OLT - Optical Line Terminal
- ONU - Optical Network Unit
- ODN - Optical Distribution Network

Typical PON architecture is shown in below Fig:

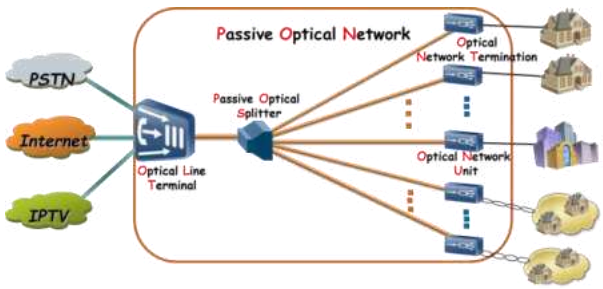

Fig.3: PON Architecture

Shown below are various protocols used for PON.

Table 1: PON Protocols

	BPON	EPON	GPON
Standard	ITU-T G.983	IEEE803.2ah	ITU-T G.984
Bandwidth	Downstream up to 622Mbps Upstream 155Mbps	Up to symmetric 1.25Gbps	Downstream up to 2.5Gbps Upstream up to 2.5 Gbps
Downstream λ (nm)	1490 and 1550	1550	1490 and 1550
Upstream λ (nm)	1310	1310	1310
Transmission	ATM	Ethernet	ATM, Ethernet, TDM

It's also important here to look at the Time Division Multiplexing concept. The below Fig explains the time division multiplexing.

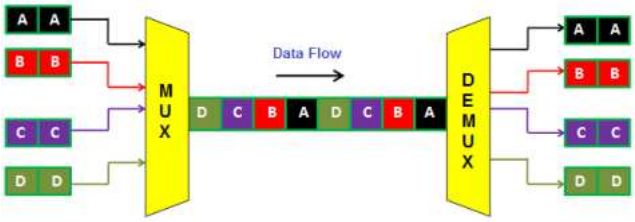

Fig.4: Time Division Multiplexing

The communication is divided into time slots and packets are sent in the allocated time frames. Nowadays TDM-PON standard is generally being used. It divides the users based on the fixed time slots where users share available bandwidth. Because of growing need of multimedia applications, TDM-PON is not effectively achieving high data rate which are necessary for communications [1]. A typical architecture is shown below.

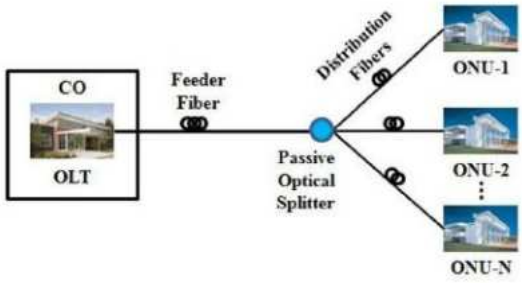

Fig.5: Time Division Multiplexed Passive Optical Network (TDM-PON)

The answer is the deployment of WDM-PON networks, which are the networks of the future that provide each user with a high-bandwidth link between the central office or exchange and the end user in order to achieve full bandwidth utilization [2]. Future high bandwidth networks are expected to use this kind of network. Moreover, DWDM-PON makes advantage of the less expensive ONU [3]. Lastly, efficient use of wavelengths is a crucial prerequisite [4].

A select number of tactics, tools, and attributes are examined and evaluated in order to satisfy the requirements of low-cost ONUs. Injectable Fabry-Perot lasers [5,6,] Reflective semiconductor optical

amplifiers [7], and semiconductor optical amplifier with reflective electro-absorption modulators [8] are used to implement the usage of light transmission in order to do this. Temperature management is necessary for transmissions utilizing Fabry-Perot lasers, but [5]. The approach of Reflective Semiconductor Optical Amplifiers is seldom used by researchers [9]. Due to their large bandwidth, semiconductor optical amplifiers used by ONUs result in significant levels of signal interference [10]. Consequently, there is a large degree of Rayleigh Backscattering throughout the transmission process [11].

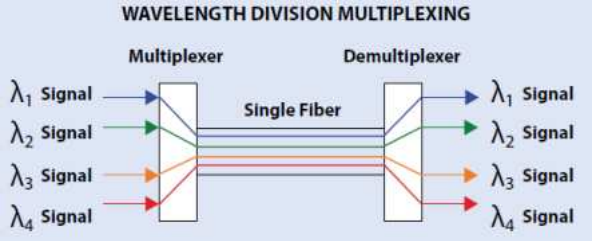

Fig.6: Basic Wavelength Division Multiplexing Technology Diagram

Before reviewing basic requirements of DWDM-PON system, it is helpful to have a look at its origin.

- CWDM is an abbreviation for Coarse Wavelength Division Multiplexing
- DWDM is an abbreviation for Dense Wavelength Division Multiplexing

Essential Components of DWDM are;

- Optical Source
- Optical Multiplexer & DE multiplexer
- Optical Amplifiers
- Supervision of DWDM System

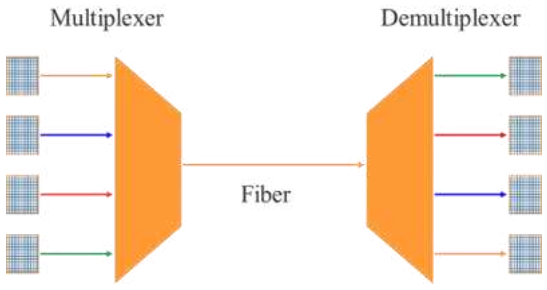

Fig.7: DWDM Multiplexer and DE Multiplexer

Typical Network Element types of DWDM are;

- OADM - Optical Add Drop Multiplexer
- OTM - Optical Terminal Multiplexer
- Regenerator
- OLA - Optical Line Amplifier

A typical DWDM network architecture is shown in the below network drawing.

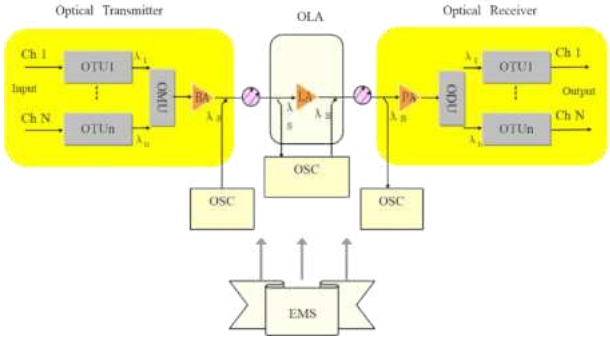

Fig.8: DWDM System Architecture

Common network elements in the DWDM networks are shown below;

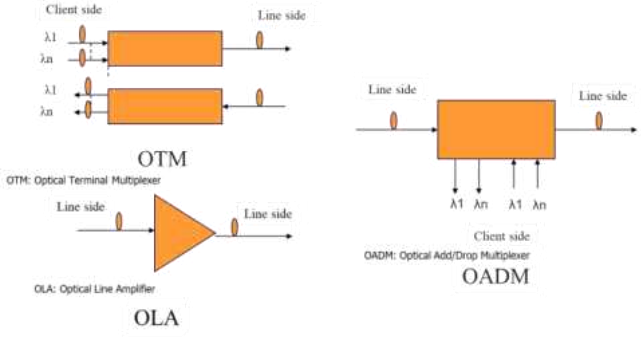

Fig.9: Common Network Elements in DWDM System

Rayleigh Distribution has significant internal loss at low absorption window [12,13, 14, 17].

For taking care needs of DWDM-PON systems (e.g. inexpensive ONU with RB termination produced by reflective transmitters) there is a need to meet the other two requirements of DWDM-PON which includes reducing channel spaces and effective wavelengths usage. Wavelength Shift/Optical Carrier-Suppressed Subcarrier-Modulation avoid RB and obtain the appropriate level of long-distance use [18,19]. However, these methods are extremely complex requiring different modelling techniques [18-20]. Adding Continuous Wave to a remote location is another way [21]. It avoids RB effect and

achieves low cost requirement of ONU [4]. Cross-seeding RB uses the elimination process, as introduced recently [22,23] provides a significant reduction in RB, which achieves high wavelength, as well as ONU with low cost. One might conclude that the seed method achieves a complete RB reduction and better performance of Bit Error Rate (BER) in comparison to other ways to reduce RB. It is however achieved by going for high cost of the system [18-23].

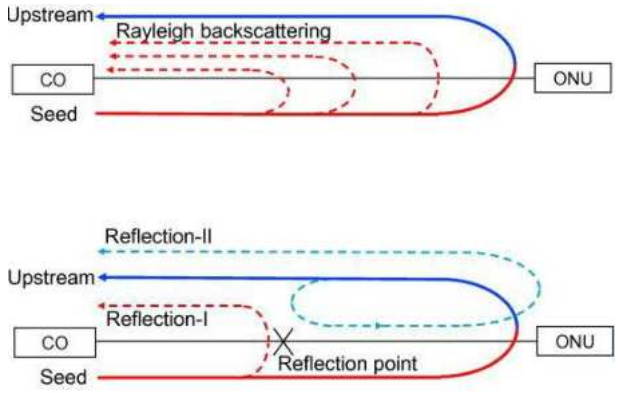

Fig.10: Rayleigh Scattering

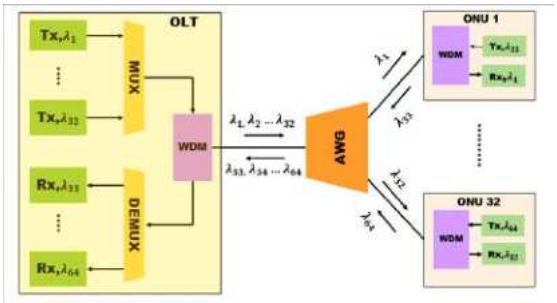

Fig.11: Typical DWDM-PON Architecture

RB reduction by DWDM-PON construction is tested and evaluated in this research. It can be successfully achieved with reasonable channel interruptions. Lower channel upgrade, bit rate improvement, reduction of active components, and storage is the main objective of this function.

Numerous methods for suppressing RB noise and transmitting downstream and upstream on a single cable have been developed by researchers. Using a multi-wavelength source at the service node (ONU), Differential Quadrature Phase Shift Keying for downstream transmission, and Re-modulated On-Off Keying for upstream transmission, RSOA-based WDM-PON techniques reduce RB noise by applying chirping and clipping effects.

Additional methods rely on carrier distributed WDM-PONs, which employ line coding in PON networks together with electrical and in-band optical filtering. Even though various techniques have shown enhanced resilience against RB-induced noise, their effectiveness is diminished due to their extremely complex designs, the need for additional components that come with high deployment costs, and their low receiver sensitivity and data rate limitations for both upstream and downstream transmissions. Therefore, if we want to achieve a cost-effective design, we shouldn't employ Erbium Doped Fiber Amplifier and Dispersion Compensated Fiber. Below is a picture of the architecture.

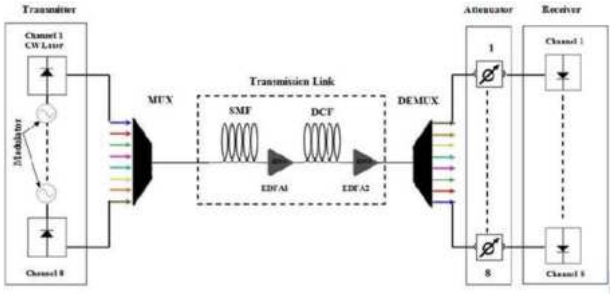

Fig.12: Optical Communication System Block Diagram

II. PROBLEM STATEMENT

In optical Fiber communications, there are issue related to transmission because of the use of same wavelength with bidirectional transmissions resulting in reduction of transmission distances between OF (Optical Fiber) terminal equipment and optical network units as a result of the Rayleigh backscattering noise.

Objectives

The main aim is to enhancing the capacity over a distance with less bit error rates. This was achieved through the design optimization using Rayleigh Backscattering elimination technique thus enhancing the performance. These can be summarized as;

- Performance enhancement/ Capacity enhancement.
  - ✓ Dispersion
  - ✓ Slope

- ✓ Attenuation Coefficient
- ✓ Effective core area
- ✓ Non-Linear index-coefficient (mitigation of RB noise in WDM-PONs).

- Realizing very high capacity DWDM-PON system.
- Enhancing the upstream capacity to 26 km using Single-Mode Fiber.
- Error Rate Reduction.
- Design optimization (effective Rayleigh Backscattering elimination).

Research Questions

- Is it possible to effectively realize high capacity DWDM-PON system?
- How to enhance the upstream capacity to 26 km using SMF - Single-Mode Fiber?
- How to achieve Error Rate Reduction?
- How to come up with a design optimization technique for Rayleigh Backscattering elimination.
- How to achieve system's performance (enhancement/capacity enlargement)?

III. LITERATURE REVIEW

High-definition films and live streaming are among the bandwidth-hungry services that are taking over our lives due to the internet's continued growth and usage. Fiber-to-the-home broadband access networks have been introduced in response to the rapidly increasing demand for high capacity. Passive optical networks appear to be an appealing option for providing high bandwidths to users in between different fiber to the house applications. Because it is constructed point-to-multipoint, the PON system not only delivers high bandwidth but also abundant coverage, decreased fiber transmission, and lower maintenance costs because intelligent network equipment is used.

Higher bandwidth may be supported when wavelength division multiplexing division is combined with PON as opposed to normal PON, as each length of route is allotted to a single subscriber. Other benefits of WDM-PON include its robust network security, high data flexibility, simplicity of management and optimization, and protocol openness. It is widely regarded as the next generation of FTTH and access technology [24–29]. Nevertheless, because point-to-point connections are built, the WDM-PON system must consider certain wavelength transmission to the subscriber area's optical line terminal, central telecom office, and optical network units.

The majority of WDM-PON research is concerned with cost-effectiveness, particularly from the user's perspective where expenses are crucial. Colourless ONUs and numerous WDM-PON loopback access networks have recently been suggested [30–41]. Fabry Pérot laser diodes and semiconductor optical amplifiers are examples of low-level lasers or modulators that are used in many of these systems. Continuous seed light is delivered from the OLT to the ONU and back to the OLT receiver. You can use one fiber [14–41] or two strands [30–33] to receive this round-trip transmission.

Because it may minimize the number of visible fibers used, which lowers system costs, single-fiber loopback transmission is more appealing than two-string systems. Reusing the visible signal is also something that many people are very interested in [32], [42-46]. It costs more since these arrangements do not require extra seed light. On the other hand, signal-to-noise distortion results from single-fiber bidirectional loopback transmission. Because of the internal structure of the fiber and its fluctuating refractive index, Rayleigh backscattering in fiber cannot be avoided [47]. Therefore, it is crucial to look at the influence of the opposite direction on single-fiber bidirectional WDM-PON network access, as this will aid in system performance monitoring and network configuration optimization.

The adoption of different fixed or mobile-wide services will lead to a large increase in access network users. [49–49]. This is a result of the need for networks to integrate with one another and the elimination of active sites, which will eliminate traffic aggregators and switching areas from service provider access-to-point sites [50]. Because wavelength-division-multiplexing (WDM) passive optical networks can satisfy all of the aforementioned characteristics, they form the foundation of optical access networks [51–52].

Utilizing colourless transmitters at the optical networking units is a major factor in the development of WDM-PON access networks as it lowers expenses and prevents inventory problems. The best methods are to use loop-back techniques to generate colourless ONU transmitters [53], [54]. Nonetheless, using two fibers—one for upstream and one for downstream transmission—is the way to get around these issues.

Likewise, cross-modulation strategies were put forth to boost fiber use efficiency and lessen performance deterioration brought on by Fresnel reflections and Rayleigh backscattering [55–61].

IV. RESEARCH DESIGN

The idea behind the suggested Rayleigh Backscattering noise-resilient design mitigation is that upstream and reflected downstream signals tend to conflict in the frequency range when continuous wave seeding light is employed for downstream communication. In order to create a multi-subcarrier downstream signal and reduce this low frequency interference, the frequency must be modulated onto the downstream wavelength. In this way, the upstream signal carrier is muted, preventing interference with the downstream wavelength reflection.

- Comprehensive simulation analysis of schemes by using latest version of Optisystem will be done by changing various design parameters and studying the related effects.
- Graphical representation of the simulation results will be done while presenting an optimal solution by comparing their parameters including, Dispersion, Slope, Attenuation Coefficient, Effective core area and Non-Linear index-coefficient (mitigation of RB noise in WDM-PONs).

The researcher has come up with a DWDM-PON design as shown in the Fig below:

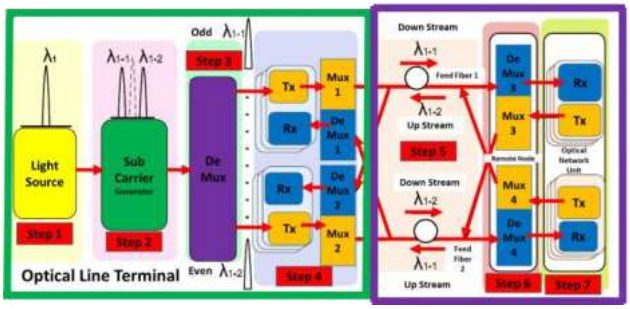

Fig.13: Dense Wavelength Division Multiplexing PON Architecture

The optical Line Terminal is divided into the following stages or steps;

Step 1 = Input Light Source (8 continuous wave light sources with wavelength spacing of 25GHz)

Step 2 = Sub Carriers Generator (16 continuous wave light sources with wavelength spacing of 12GHz)

Step 3 = Subcarriers DE multiplexed (Odd and Even Subcarriers for transmission on bidirectional Fiber Feed 1 and Fiber Feed 2 respectively)

Step 4 = The Even and Odd subcarriers are modulated using On Off Keying Technique (Transmitter Tx and Receiver Rx)

Step 5 = Downstream (from OLT to ONU) and Upstream Transmission (from ONU to OLT). Rayleigh Backscattering elimination.

Step 6 = Remote node consisting of two multiplexers and two DE multiplexers. The Even and Odd subcarriers are modulated using On Off Keying Technique (Transmitter Tx and Receiver Rx)

Step 7 = Tx and Rx are used for the demodulation/re-modulation. The Even and Odd subcarriers are modulated/demodulated using On Off Keying Technique (Transmitter Tx and Receiver Rx)

Also, the odd and even Downstream signals are multiplexed to be transmitted through Feed Fiber 1 and Feed Fiber 2 respectively. Rayleigh Backscattering is eliminated at step 5 through the use of cross-seeding technique.

V. PARAMETERS

The following parameters have been set for the analysis of the designed architecture.

Table 2: Set Parameters

S/No	Equipment	Set Parameters	Value
1	Continuous Wave Laser	- Wavelength - Spacing - Launching Power	- 193.025 THz - 25.00 GHz - 0 Db
2	Sine Wave Generator	- "f" (Frequency)	- 6.250 GHz
3	Optical Line Terminal (Transmitter)	- Down Stream (BR)	- 10.0 Gb/s
4	Optical Fiber (Bidirectional)	- L - Length - A - Attenuation	- 25 Km - 0.2 Db/Km
5	Optical Network Unit (Transmitter)	- Up Stream Bit Rate (BR)	- 2.5 Gb/s
6	No of Channels	- Channels	- 8 + 8 = 16
7	Extinction Ratio	- Ratio	- 30 dB

Now we will break down the conceived network architecture into further segmentations. Steps 1-4 relate to Optical Line Terminal and step 7 relates to Optical Network Unit. Steps 5-6 relate to bidirectional fiber transmission through the use of multiplexers and DE multiplexers.

Step 1

In step 1, the first λ is launched at 193.025 THz (0 dB) power from the continuous wave light source. Same goes for the remaining six wavelengths. Furthermore, the system capacity is increased by introducing sixteen subcarriers by reducing the channel spacing from 25 GHz to 12.5 GHz.

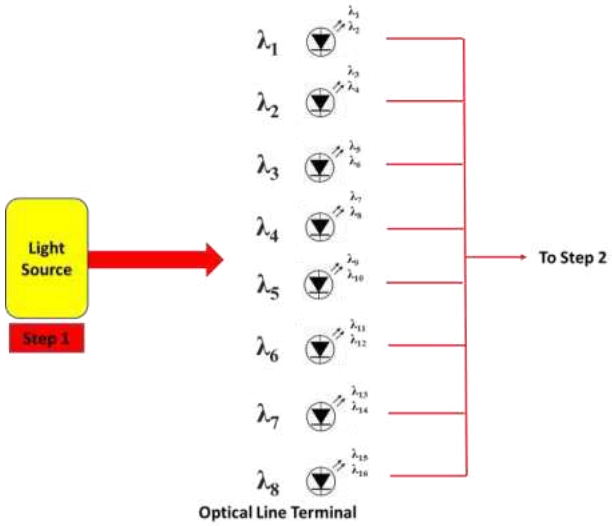

Fig.15: Step 1 – Continuous Wave Light Source (λ1 to λ8)

Step 2

In step 2, the Modulator is fed with 6.25 GHz through sine wave generator and fed into Erbium-Doped Fiber Amplifier.

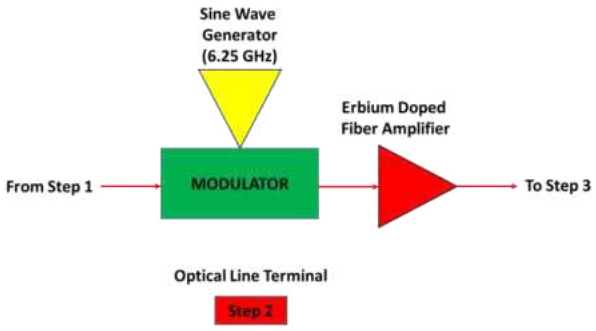

Fig.16: Step 2 – Sine Wave Generator Feeding, Modulator & Amplifier

Step 3

In step 3, a DE multiplexer is used having 0 dB insertion loss. Odd and Even Sub-Carriers are segregated.

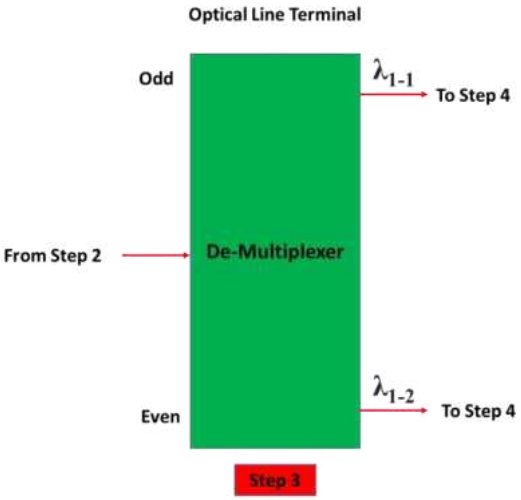

Fig.17: Step 3 – Sine Wave Generator Feeding, Modulator & Amplifier

Step 4

Step 4 has a receiver for the upstream signal. Photodetector with LPF (Low Pass Filter) to demodulate upstream signal is used.

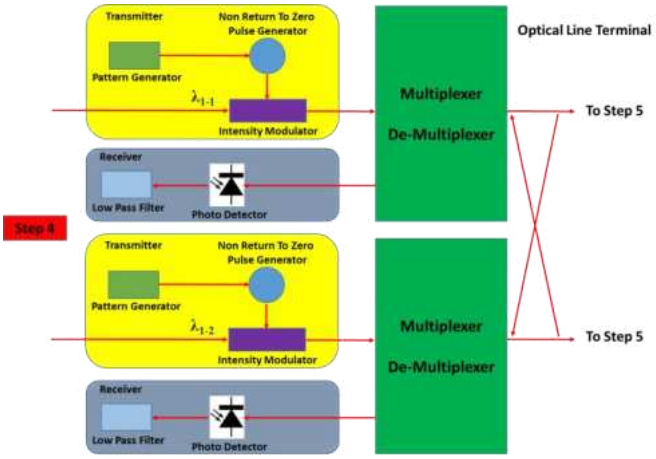

Fig.18: Step 4 – Transmitter, Receiver, Low Pass Filter

Step 5

Bidirectional Fiber Transmission of distance 26 Km is shown below at this step.

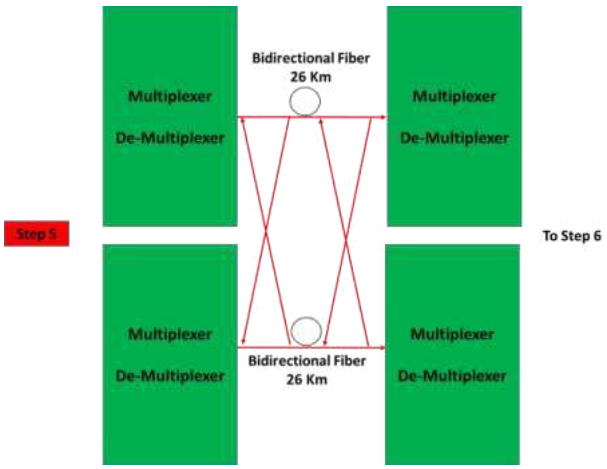

Fig.19: Step 5 – Bidirectional Fiber Transmission (26 Km)

Step 6

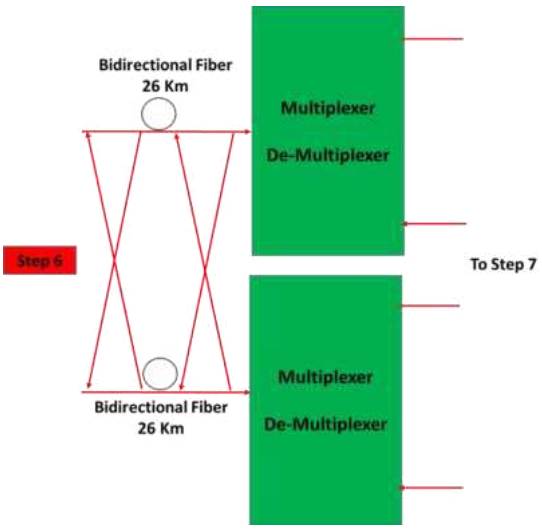

Fig.20: Step 6 – Multiplexing / DE Multiplexing

Step 7

Now we come to the last step of our network architecture design. Transmitters and Receivers are used for demodulation/re-modulation at this step after the received signal.

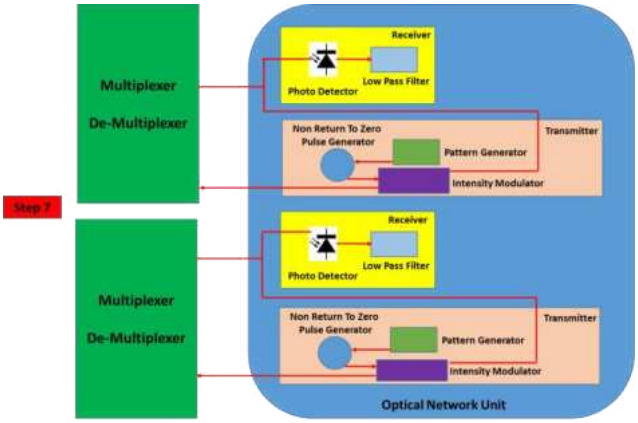

Fig.21: Step 7 – Optical Network Unit Section

Combining the above 7 steps, we get the complete conceived network architecture.

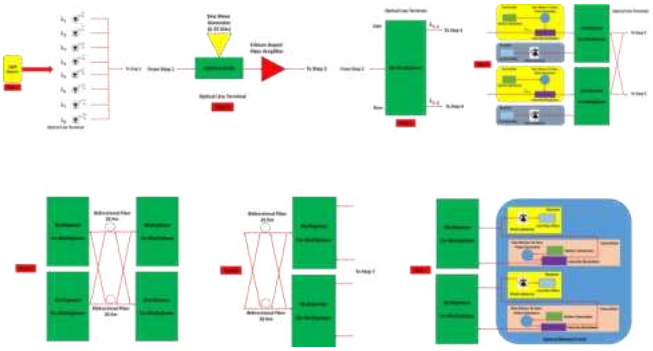

Figure 22: Proposed DWDM-PON System

VI. RESULTS AND DISCUSSION

Results of the simulation will be analysed and discussed. To do the verification of the research goals, evaluations and system tracing will be performed.

- System Trace and Evaluation

Sixteen down-stream channels with a spacing of 12.50 GHz are included in the NS2 simulations. Additionally, eight down-stream "odd" channels and eight "even" channels are included before they are transmitted through fiber feed 1, down-stream odd channel λ1-1 is placed before the optical network unit, down-stream even channel λ1-2 is placed before the optical network unit, up-stream odd channel λ1-1 is placed after the up-stream path, and up-stream even channel λ1-2 is placed after the up-stream path. The simulation details are shown in the Figs below.

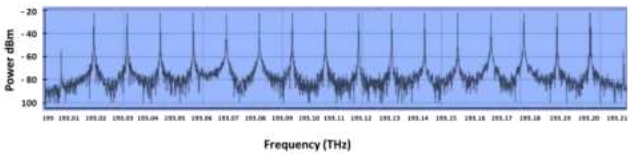

Fig.23: Sixteen (16) Down Stream channels with spacing of 12.5 GHz

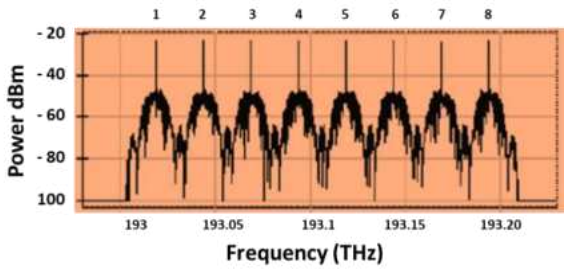

Fig.24: 8 Down Stream odd channels before their transmission through the Fiber Feed 1

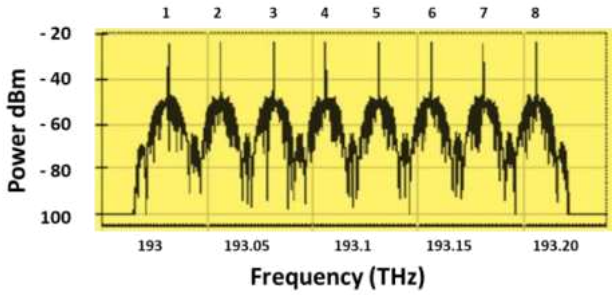

Fig.25: 8 even channels before their transmission through Fiber Feed 2

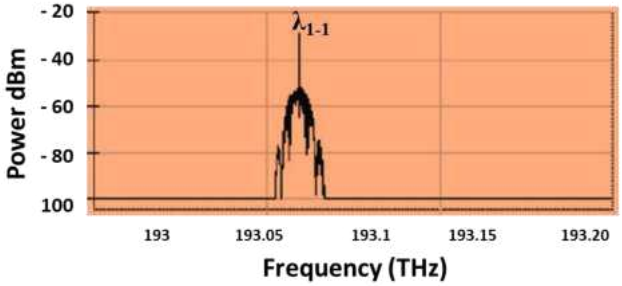

Fig.26: Down Stream odd channel λ1-1 before the Optical Network Unit

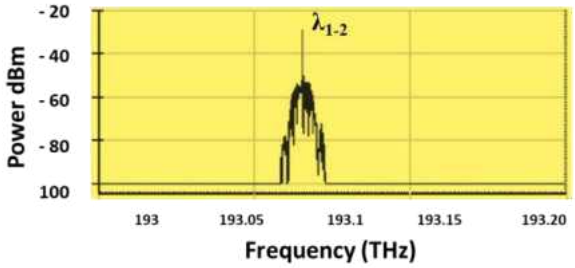

Fig.27: Down Stream even λ1-2 channel before the Optical Network Unit

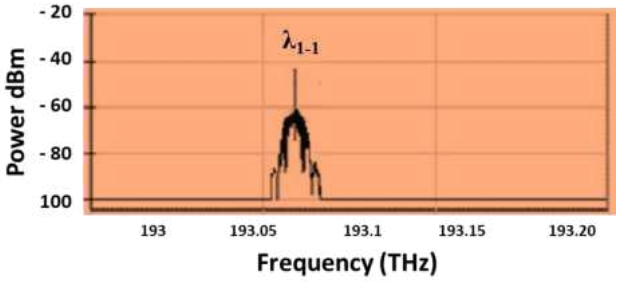

Fig.28: Up Stream odd channel λ1-1 after the Up Stream Path

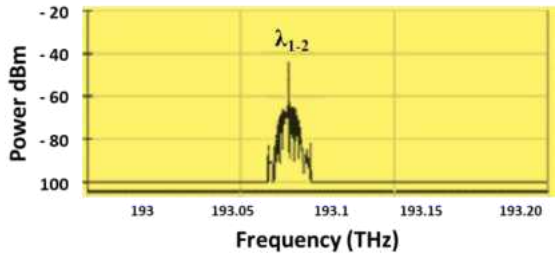

Fig.29: Up Stream even channel λ1-2 after the Up Stream Path

Sixteen Downstream channels have a channel spacing of 12.5 GHz starting from λ_{1-1} at 193.019 THz to λ_{8-2} at 193.06 THz. These sixteen channels were Generated from eight continuous wave light sources having 0 db power using the sine wave generator and the modulator. After the DE multiplexing, even/odd downstream channels are modulated using intensity modulator. These channels are then fed to the downstream modulator in order to come up with cross-seeding (odd/even spectrum) which is then transmitted through feed fibers 1 and 2 respectively. The above simulations depict these scenarios. Transmission takes place over 26 Km through feed fiber 1 after being DE multiplexed before an Optical Network Unit receiver. Signals are then retransmitted back through the upstream path through feed fiber 2. Similar signal analysis is done for the upstream path at the chosen frequencies.

- **Eye Diagrams**

Eye diagrams (for odd/even channels) after retransmitting path λ_{1-1}, λ_{1-2}, λ_{8-1} and λ_{8-1} is shown below;

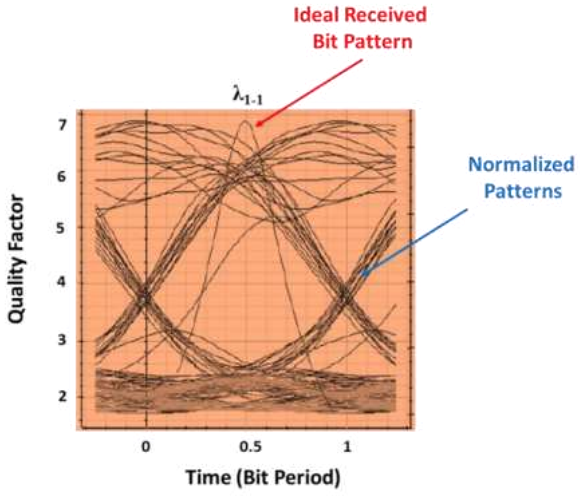

Fig.30: Eye Diagram λ1-1

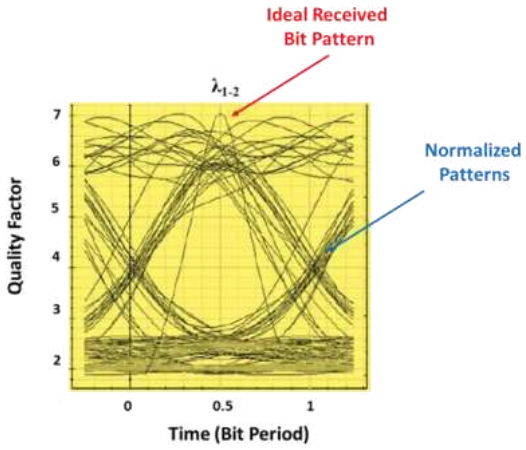

Fig.31: Eye Diagram λ1-2

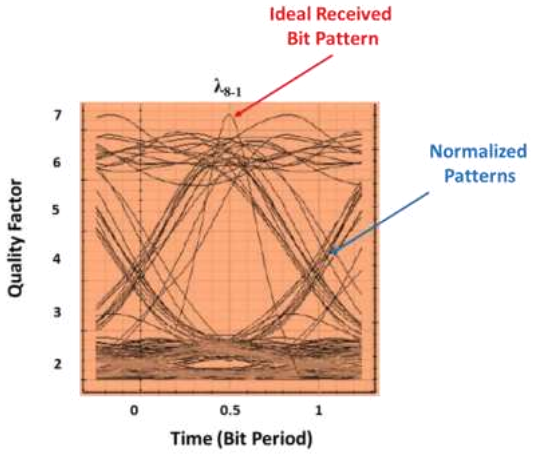

Fig.32: Eye Diagram λ8-1

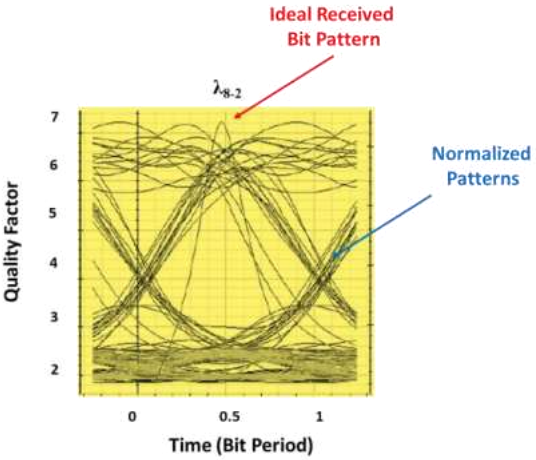

Fig.33: Eye Diagram λ8-2

The channel with the lowest simulated bit error rate, λ1-1 of 10-13, has a quality factor of 6.79, whereas channel λ1-2 of 10-14 has the highest simulated bit error rate, with a quality factor of 7.01. For the

remaining channels, an average bit error rate of better than 10-13 can be seen. In Fig., the blue line denotes normalized patterns while the red line represents the ideal received bit pattern.

Eye Diagram gives a qualitative analysis of the signals. It gives an understanding of system performance by depicting the channels imperfections. Signal-to-Noise Ratio can also be ascertained through visual approximations in addition to the jitter, skew, rise time, fall time, bit error rate and quality factor etc.

- Results Comparison

The below table shows the previous studies in comparison to the latest research done by this researcher to come up with a better model.

Table 3: Comparison Between Related Studies

Research	System	Channels	Length (Km)	Channel Spacing (GHz)	Maximum Up Stream Bit Rate (Gb/s)	Maximum Down Stream Bit Rate (Gb/s)	Bit Error Rate
Xu, Z.;Wen, Y.J.; Zhong,W.D.; Chae, C.J.; Cheng, X.F.; Wang, Y.; Lu, C.; Shankar, J. High-speed WDM-PON using CW injection-locked Fabry-Perot laser diodes. Opt. Express 2007, 15, 2953–2962.	WDM-PON	16	15	140	10	10	10^{-9}
De Valicourt, G.; Make, D.; Landreau, J.; Lamponi, M.; Duan, G.; Chanclou, P.; Brenot, R. High Gain (30 dB) and High Saturation Power (11 dBm) RSOA Devices as Colorless ONU Sources in Long-Reach Hybrid WDM/TDM-PON Architecture. IEEE Photonics Technol. Lett. 2010, 22, 191–193.	WDM/TDM PON	8	45	100	2.5	2.5	10^{-7}
Lin, S.Y.; Chi, Y.C.; Su, Y.C.; Liao, J.W.; Wang, H.L.; Lin, G.C.; Lin, G.R. Coherent Injection-Locking of Long-Cavity Colorless Laser Diodes with Low Front-Facet Reflectance for DWDM-PON Transmission. IEEE J. Sel. Top. Quantum Electron. 2013, 19, 1501011.	WDM-PON	2	25	100	1.25	10	10^{-11}
Zhou, Z.; Xiao, S.; Qi, T.; Li, P.; Bi, M.; Hu, W. 25-GHz-Spaced DWDM-PON with Mitigated Rayleigh Backscattering and Back-Reflection Effects. IEEE Photonics J. 2013, 5, 7901407.	DWDM-PON	6	25	25	1.25	10	10^{-9}
Mohammed, Nazmi & Manzi, Ahmed Hamdi. (2019). Performance Enhancement and Capacity Enlargement for a DWDM-PON System Utilizing an Optimized Cross Seeding Rayleigh Backscattering Design. Applied Sciences. 9. 4520. 10.3390/app9214520.	DWDM-PON	16	25	12.5	2.5	10	10^{-11}
This Research	DWDM	16	26	12.5	2.5	12	10^{-13}

It is to be noted that the main difference between this researchers cross-seeding technique used and the other techniques relate to the DWDM-PON system requirements. Researchers achieved higher upstream and downstream rates but the transmission distances were limited and restricts the ability to use more channels. Every used technique as shown in the above table has its drawbacks hence there was a need to come up with an optimal design based on the architecture. Rayleigh backscattering leads to severe degradation in the performance.

To solve these issues and increase usage efficiency, the researcher developed the cross-seeding system. The network architecture has been created with this research effort to minimize Rayleigh backscattering.

VII. CONCLUSIONS

- Summary

- This research contribution simulated enhanced cross-seeding-based DWDM-PON system with channel as per ITU-T G.694.1 defined standard for Dense Wave Division Multiplexing for Passive Optical Networks.
- Channel spacing of 12.5 GHz is used.
- Enhanced performance characteristics/parameters were targeted for this research work.
- The performance characteristics included the following.
    - Enhancing downstream channel capacity
    - Enhancing Up-Stream bit rate.
    - Minimizing active components in network
    - Maintaining and improving BER Performance.
- Based on researcher's design enhancement, conceptualized DWDM-PON has achieved the following.
    - Record of 16 channels,
    - Upstream capacity 2.50 Gb/s over 26 km of transmission.
    - Average BER of 10^{-13}.
- Comparison among researcher's studies was done. This is for ensuring validity of proposed system.

- Contribution to Knowledge

The study contributed to increasing the number of channels to sixteen while enhancing the upstream capacity covering a larger distance which was 25 Km previously thus enhancing it by 1 Km more with improved bit error rate which was previously 10^{-12} and now it has come to 10^{-13}.

- Limitations of the Study

This scheme can be further improved if the amount of data which was analysed is enhanced to get better results.

Future Recommendations

The network architecture should be further improved in the future work by integrating different techniques on different segments of the optical fiber network by breaking it down thus reducing the Rayleigh backscattering further.

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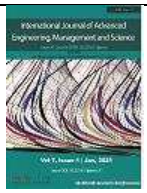

The Influence of HRM Practices, Workplace Culture, and Training on Employee Performance

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Abstract *– This study analyzed the influence of Human Resource Management (HRM) practices, workplace culture, and training and development on employee performance at National Irrigation Administration (NIA) – Upper Pampanga River Integrated Irrigation Systems (UPRIIS), Division II, in Talavera, Nueva Ecija. Using a quantitative research design, data were collected from 84 employees through a structured Likert-scale questionnaire. Descriptive statistics, particularly the mean, were used to summarize employee perceptions, while inferential tools such as ANOVA, Pearson r correlation, and multiple regression analysis were employed to test hypotheses and assess statistical significance. Results showed that perceptions of HRM practices, workplace culture, and training and development were consistently positive across gender, length of service, and employment status, with no significant group differences observed. Correlation analysis revealed strong positive relationships between each independent variable and employee performance, with training and development emerging as the most highly correlated factor ($r = 0.919$). Regression analysis further demonstrated that training and development was the only variable with a statistically significant influence on employee performance ($\beta = 0.444$, $p < 0.001$), while HRM practices had a marginal effect ($p = 0.052$) and workplace culture was not a significant predictor ($p = 0.151$). The regression model explained 86.9% of the variance in employee performance, highlighting the critical role of training initiatives. These findings underscore the need for NIA to prioritize investment in employee training and continuous development. Strategic improvements in HRM practices and workplace culture may further support performance outcomes and sustain organizational effectiveness.*

Keywords *— **Employee Performance, HRM Practices, Workplace Culture, Training and Development, Pearson r, ANOVA, Regression Analysis, Public Sector***

I. INTRODUCTION

Employee performance remains a pivotal concern for organizations striving for sustained success, thereby necessitating a comprehensive understanding of the factors that contribute to its enhancement (Ciobanu et al., 2019). It is a critical factor in ensuring the efficiency and effectiveness of any organization. Human Resource Management practices, workplace culture, and training initiatives have emerged as critical determinants in shaping

individual and collective performance within organizational settings (Altalhi, 2021; Haines & St-Onge, 2011). When employees hold favorable perceptions of implemented policies, it can substantially augment individual-level outcomes by cultivating heightened commitment, amplifying engagement, and fostering overall job satisfaction, thereby indirectly driving improvements in performance metrics . The National Irrigation Administration (NIA) – Upper Pampanga River Integrated Irrigation Systems (UPRIIS), Division II, in Talavera, Nueva Ecija, as a government institution responsible for irrigation management, relies on its workforce's efficiency to meet organizational goals. However, limited studies have examined the influence of HRM practices, workplace culture, and training & development on employee performance in this context. This study aims to bridge this gap by analyzing these key factors and their relationship.

Furthermore, this investigation seeks to provide actionable recommendations for NIA-UPRIIS Talavera to optimize its HRM strategies, cultivate a positive workplace culture, and implement effective training programs to maximize employee potential and achieve organizational objectives. The intention is to offer practical guidance to NIA-UPRIIS Talavera, enabling them to fine-tune their HRM strategies, promote a more vibrant and supportive workplace culture, and create impactful training programs. These improvements are aimed at unlocking the full potential of their workforce and driving the organization towards its strategic goals.

II. CONCEPTUAL FRAMEWORK

This study is grounded in the premise that Human Resource Management (HRM) practices, workplace culture, and training and development are key determinants of employee performance in public sector organizations such as the NIA-UPRIIS, Talavera, Nueva Ecija. The conceptual framework illustrates how these three independent variables influence the dependent variable (employee performance), while demographic and employment-related characteristics (gender, length of service, and employment status) serve as grouping variables to examine performance variations across different employee classifications.

The conceptual framework of this study is presented in Figure 1. The model is informed by several studies highlighting the impact of HRM on performance. It was constructed as a result of a careful review and synthesis of related literature, which consistently emphasized the role of HRM, workplace culture, and training in improving employee outcomes. Gutterman (2023) emphasizes that effective HR strategies aligned with organizational goals significantly enhance performance by attracting and retaining top talent, fostering development, and sustaining an empowering workplace culture. Similarly, Natsir et al. (2024) said that HRM practices such as recruitment, performance appraisal, and training play a critical role in increasing organizational efficiency and effectiveness. Moreover, Richman (2015) supports the view that HRM and HRD (Human Resource Development) are vital for high-performance organizations, underlining the importance of training and learning in driving employee adaptability and productivity.

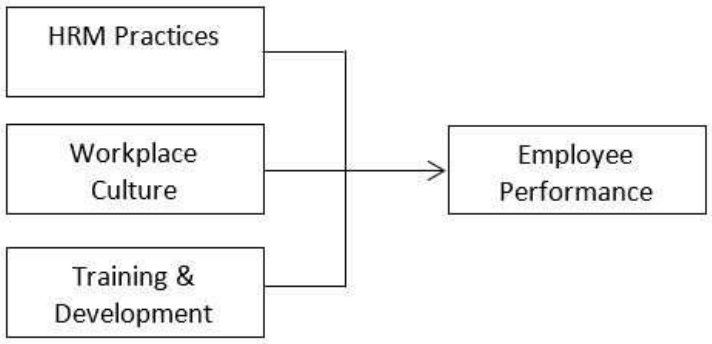

Fig.1. Research Framework

Research Objectives

This study aims to assess the factors that influence employee performance at the NIA-UPRIIS, Talavera by examining key organizational practices and employee characteristics. Specifically, it seeks:

1. To describe the factors that affect employee performance when grouped according to:
   1.1 Gender
   1.2 Length of Service
   1.3 Employment Status
2. To determine whether there are significant differences in HRM practices,

workplace culture, and training & development at the National Irrigation Administration, Talavera, when grouped according to:

2.1 Gender

2.2 Length of Service

2.3 Employment Status

3. To assess the relationship among factors that affect employee performance in terms of:

   3.1 HRM practices;

   3.2 Workplace culture; and

   3.3 Training and Development.

4. To analyse the influence of the factors that affect employee performance.

Hypotheses:

H1: There are significant differences in perceptions of HRM practices, workplace culture, and training & development based on gender.

H2: There are significant differences in perceptions of HRM practices, workplace culture, and training & development based on length of service.

H3: There are significant differences in perceptions of HRM practices, workplace culture, and training & development based on employment status.

H4: There is a significant relationship between HRM practices and employee performance.

H5: There is a significant relationship between workplace culture and employee performance.

H6: There is a significant relationship between training & development and employee performance.

H7: HRM practices significantly influence employee performance.

H8: Workplace culture significantly influences employee performance.

H9: Training & development significantly influences employee performance.

Research Design

This study employed a quantitative research design to analyze the effect of various organizational factors on employee performance. Quantitative data were collected using a structured questionnaire based on a Likert scale. To describe the general perceptions of respondents, descriptive statistics, particularly the mean, were used to summarize responses for HRM practices, workplace culture, training & development, and employee performance. Furthermore, ANOVA, Pearson r correlation, and regression analysis were utilized to test the hypotheses and examine the statistical significance of differences and relationships among variables.

Respondents/Participants

The respondents for this study were employees of the NIA-UPRIIS, Talavera, Nueva Ecija, with a total sample size of 84. They were categorized into three employment types: 39 permanent employees, 24 job order employees, and 21 casual employees. To ensure equal representation from each employment category, the study employed a stratified random sampling technique.

Data Gathering Tools and Techniques

Data was gathered using a self-administered structured questionnaire that includes Likert-scale questions covering HRM practices, workplace culture, training & development, and employee performance. The questionnaire was pre-tested for validity and reliability before full implementation. Surveys were distributed digitally, with necessary follow-ups to maximize response rates.

The validity and reliability testing of the instrument demonstrated strong results, ensuring its suitability for assessing HRM practices, workplace culture, training & development, and employee performance. Construct validity was confirmed through Confirmatory Factor Analysis (CFA), with high factor loadings for all constructs: HRP (0.748), WC (0.754), TD (0.790), and EP (0.754), all above the acceptable threshold of 0.70. Additionally, excellent model fit indices (CFI = 1.00, TLI = 1.00, RMSEA = 0.00) further validated the instrument. Reliability testing using Cronbach's Alpha showed high internal consistency across all variables: HRP (0.963), WC (0.944), TD (0.954), and EP (0.931), with an overall reliability score of 0.980, indicating excellent reliability. These findings confirm that the instrument used in this study is both valid and reliable for accurately measuring the intended constructs.

Statistical Tools or Method of Analysis

The study utilized various statistical tools to analyze the data. Descriptive statistics, specifically the mean, were used to summarize the responses and describe the general perceptions of employees regarding HRM practices, workplace culture, training & development, and employee performance across different groups. ANOVA (Analysis of Variance) was employed to compare employee performance and organizational factor ratings across gender, length of service, and employment status. Pearson r correlation analysis was conducted to examine the relationships between the independent variables—HRM practices, workplace culture, and training & development—and the dependent variable, which is employee performance. Lastly, regression analysis was used to determine the effect of these factors on employee performance.

Ethical Considerations

This study adhered to the following ethical principles:

1. Informed Consent: All participants were informed about the study's objectives, procedures, and their right to withdraw at any time.
2. Confidentiality: Respondents' identities remained anonymous, and data was used strictly for research purposes.
3. Voluntary Participation: Participation was entirely voluntary, with no coercion or pressure on employees.
4. Data Protection: All collected data were securely stored and accessible only to authorized researchers.
5. Approval: Ethical clearance was sought from relevant authorities before conducting the study.

III. RESULTS AND DISCUSSION

1. Factors that Affect Employee Performance when grouped according to gender, years of services, and employment status.

Table 1 Factors that Affect Employee Performance according to gender

Gender	HRP	VI	WC	VI	TD	VI
Female	3.27	Agree (A)	3.27	Agree (A)	3.39	Agree (A)
Male	3.34	Agree (A)	3.33	Agree (A)	3.34	Agree (A)

Both male and female employees agree that the organization implements sound HRM practices, fosters a supportive workplace culture, and provides sufficient training and development opportunities. The close range of scores between genders indicates a generally consistent perception of organizational practices. Although there are minor differences, with males slightly rating HRP and WC higher, and females slightly favoring TD, both groups express a positive experience overall.

Table 2 Factors that Affect Employee Performance according to Length of Service

Length of Service	HRP	VI	WC	VI	TD	VI
Less than 1 year	3.51	Strongly Agree (SA)	3.53	Strongly Agree (SA)	3.31	Agree (A)
1–5 years	3.17	Agree (A)	3.13	Agree (A)	3.24	Agree (A)
6–10 years	3.26	Agree (A)	3.32	Agree (A)	3.33	Agree (A)
More than 10 years	3.36	Agree (A)	3.34	Agree (A)	3.43	Agree (A)

Employees with less than one year of service have the most favorable perception of HRM practices and workplace culture, indicating a highly positive first impression of the organization. Meanwhile, employees with longer service continue to agree, though with slightly lower ratings, suggesting stable but slightly moderated perceptions over time. Training & development is consistently rated as agreeable across all tenure groups, with the most experienced employees (10+ years) showing the highest appreciation.

Table 3 Factors that Affect Employee Performance according to Employment Status

Employment Status	HRP	VI	WC	VI	TD	VI
Casual	3.41	Agree (A)	3.35	Agree (A)	3.4	Agree (A)
Job Order	3.17	Agree (A)	3.16	Agree (A)	3.13	Agree (A)
Permanent	3.35	Agree (A)	3.38	Agree (A)	3.48	Strongly Agree (SA)

Across employment types, all respondents agree that HRM practices, workplace culture, and training & development are present and valued. Permanent employees rated training & development the highest, falling into the "Strongly Agree" category, which may reflect greater access to development programs. Job order employees, while still in the "Agree" range, rated all areas slightly lower, suggesting room for improvement in support or resources provided to them.

2. Differences in Employee Perceptions of HRM Practices, Workplace Culture, and Training & Development Across Gender, Length of Service, and Employment Status

Table 4 ANOVA Results on Employee Perceptions of HRM Practices, Workplace Culture, and Training & Development Across Gender, Length of Service, and Employment Status

Profile Variable	Organizational Factor	F-value	df1	df2	p-value	Interpretation
Gender	HRM Practices (HRP)	.1911	1	67.8	.663	Not Significant
	Workplace Culture (WC)	.1172	1	68	.733	Not Significant
	Training & Development (TD)	.0755	1	68	.784	Not Significant
Length of Service	HRM Practices (HRP)	.51	3	24.3	.679	Not Significant
	Workplace Culture (WC)	.599	3	25.1	.622	Not Significant
	Training & Development (TD)	.19	3	22.1	.902	Not Significant
Employment Status	HRM Practices (HRP)	.511	2	38.7	.604	Not Significant
	Workplace Culture (WC)	.566	2	39.1	.573	Not Significant
	Training & Development (TD)	1.357	2	39.5	.269	Not Significant

The ANOVA results show that across all demographic categories—gender, length of service, and employment status—there are no statistically significant differences in the way employees perceive HRM practices, workplace culture, and training & development, as all p-values exceed the 0.05 level of significance. This suggests that the organizational practices at NIA-UPRIIS Talavera are implemented consistently across different employee groups, indicating an equitable and uniform application of policies and programs.

3. Relationship of HRM Practices, Workplace Culture, Training & Development, and Employee Performance

Table 5 Relationship of HRM Practices, Workplace Culture, Training & Development, and Employee Performance

Independent Variable	Correlation with EP	p-value	Interpretation
HRM Practices (HRP)	.915	< .001	Significant positive relationship.
Workplace Culture (WC)	.897	< .001	Significant positive relationship.
Training & Development (TD)	.919	< .001	Significant positive relationship.

Correlation analysis revealed strong positive relationships between employee performance and the three key organizational factors: HRM practices (r = 0.915), workplace culture (r = 0.897), and training & development (r = 0.919), all with p-values less than 0.001. These findings support the claim that effective HR strategies directly influence employee engagement and productivity (Gutterman, 2023). Furthermore, according to Natsir et al. (2024), strategic HRM practices—such as competency-based recruitment, performance evaluation, and continuous development—are essential to enhancing both individual and organizational efficiency. The particularly strong correlation between training & development and performance underscores the importance of employee learning and capability-building as a core driver of workforce productivity.

4. Analysis of Factors that Affect the Employee Performance

Table 6 Regression Analysis of Factors Influencing Employee Performance

Factor	Regression Coefficient	p-value	Interpretation
HRM Practices (HRP)	.303	.052	Marginally significant.
Workplace Culture (WC)	.186	.151	Not significant.
Training & Development (TD)	.444	< .001	Highly significant.
Model R^2	.869	-	86.9% of variance in employee performance explained.

Regression analysis revealed that the overall model explains 86.9% of the variance in employee performance, indicating a high predictive capability of the combined factors: HRM practices, workplace culture, and training & development. Training & development emerged as the most significant predictor of performance ($p < 0.001$, Estimate = 0.444), highlighting the need to prioritize continuous learning and capability enhancement, consistent with Richman's (2015) assertion that training is vital for equipping employees to meet changing organizational demands. HRM practices were marginally significant ($p = 0.052$, Estimate = 0.303), suggesting that while foundational, their effectiveness may depend on execution quality. Meanwhile, workplace culture showed a weaker influence ($p = 0.151$, Estimate = 0.186), which may indicate the need for a more strategically aligned cultural development process. This aligns with Sonar and Pandey (2023), who emphasized that while a positive culture contributes to organizational success, its impact is maximized only when embedded within broader strategic HR systems.

Table 7 Summary of Hypothesis

Hypothesis	Statement	Statistical Test	p-value	Decision	Interpretation
H1	There are significant differences in perceptions of HRM practices, workplace culture, and training & development based on gender.	ANOVA	HRP = .663 WC = .733 TD = .784	**Rejected**	No significant difference based on gender.
H2	There are significant differences in perceptions based on length of service.	ANOVA	HRP = .679 WC = .622 TD = .902	**Rejected**	No significant difference based on length of service.
H3	There are significant differences in perceptions based on employment status.	ANOVA	HRP = .604 WC = .573 TD = .269	**Rejected**	No significant difference based on employment status.
H4	There is a significant relationship between HRM practices and employee performance.	Pearson r	r = .915 p < .001	**Accepted**	Strong positive and significant relationship.
H5	There is a significant relationship between workplace culture and employee performance.	Pearson r	r = .897 p < .001	**Accepted**	Strong positive and significant relationship.
H6	There is a significant relationship between training & development and employee performance.	Pearson r	r = .919 p < .001	**Accepted**	Strongest positive and significant relationship.
H7	HRM practices significantly influence employee performance.	Regression	β = .303 p = .052	**Marginal**	Marginal influence, borderline significant.
H8	Workplace culture significantly influences employee performance.	Regression	β = .186 p = .151	**Rejected**	No significant influence found.
H9	Training & development significantly influences employee performance.	Regression	β = .444 p < .001	**Accepted**	Most significant predictor of performance.

The results of the hypothesis testing reveal that there are no significant differences in employee perceptions of HRM practices, workplace culture, and training and development when grouped according to gender, length of service, and employment status, leading to the rejection of H1 to H3. This suggests that organizational practices at NIA-UPRIIS Talavera are applied consistently and equitably across various demographic and employment groups. In contrast, hypotheses H4 to H6 were accepted, as Pearson r correlation analysis showed strong and statistically significant positive relationships between each of the three organizational factors and employee performance. Among the three, training and development exhibited the strongest correlation, emphasizing its critical role in enhancing workforce effectiveness. Regression analysis for H7 to H9 further established that training and development is the most significant predictor of employee performance, while HRM practices had a marginal effect and workplace culture showed no significant direct influence. These findings highlight the importance of investing in targeted training initiatives, while also revisiting and strengthening HRM strategies and cultural interventions to achieve more substantial performance outcomes.

IV. CONCLUSIONS

The analysis of mean scores across gender, length of service, and employment status reveals that employees generally agree that HRM practices, workplace culture, and training and development are evident within the organization. Both male and female respondents showed consistent agreement in their perceptions, indicating a shared positive experience regardless of gender. Employees with less than one year of service expressed the most favorable views, particularly in HRM practices and workplace culture, suggesting a strong initial impression of the organization. Meanwhile, those with more than ten years of service maintained high agreement levels, especially in training and development. Across employment status, permanent employees expressed the highest satisfaction in training and development, even reaching the level of strong agreement, reflecting their access to more formal development opportunities. While job order employees reported slightly lower scores, their responses still fell within the "agree" range, signifying a generally positive but moderately lower experience. Overall, the consistent ratings across all groups indicate that the organization maintains a relatively inclusive and favorable environment in terms of HRM practices, workplace culture, and training efforts.

The ANOVA results indicate that there are no significant differences in employee perceptions of HRM practices, workplace culture, and training and development when grouped according to gender, length of service, and employment status. This suggests that employees, regardless of their demographic or employment classifications, generally perceive these organizational factors in a similar way. The uniformity in perceptions implies that NIA-UPRIIS Talavera implements its human resource policies and development programs in a consistent and equitable manner across various employee groups, reflecting a fair and inclusive organizational environment.

The study found that HRM practices, workplace culture, and training and development are all significantly and positively related to employee performance. With correlation coefficients exceeding 0.89 and p-values less than 0.001, the relationships are both strong and statistically significant. Among the three, training and development demonstrated the highest correlation with employee performance ($r = 0.919$), indicating its prominent influence. These findings imply that enhancing HRM systems, promoting a supportive organizational culture, and strengthening training initiatives can lead to improved employee performance. Furthermore, the high inter-correlations among the independent variables suggest they are interconnected and likely contribute collectively to performance outcomes.

Regression analysis confirmed that training and development is the most significant predictor of employee performance, with a regression coefficient of 0.444 and a p-value below 0.001. This demonstrates that improving training programs and development opportunities can yield substantial gains in employee productivity. HRM practices, on the other hand, showed a marginal effect ($p = 0.052$), implying a possible but less robust impact. Meanwhile, workplace culture did not significantly influence employee performance ($p = 0.151$),

suggesting that although it may enhance the work environment, it does not directly drive performance outcomes. The overall model explains 86.9% of the variance in employee performance ($R^2 = 0.869$), highlighting the strong predictive power of the combined factors. Nevertheless, the results underscore the need to prioritize training and development as the primary driver of employee performance improvements.

V. RECOMMENDATIONS

Based on the findings of the study, it is recommended that the organization enhance training opportunities for job order employees, who reported lower ratings in training and development, by making learning programs more accessible, role-specific, and tailored to their job functions. To maintain the strong initial perceptions of new employees, particularly in terms of HRM practices and workplace culture, NIA-UPRIIS should strengthen its onboarding processes and early engagement initiatives. Mid-tenure employees, who exhibited slightly lower satisfaction levels, may benefit from targeted development strategies such as mentorship, coaching, or job enrichment programs to re-engage and motivate them. Meanwhile, permanent employees, who expressed the highest satisfaction in training, should continue to receive access to structured and advanced training programs that support their long-term career growth.

It is also recommended that NIA-UPRIIS Talavera continue to uphold and reinforce the equitable implementation of its organizational policies and programs. While the study found no significant differences in perceptions across demographic groups, the organization should remain proactive in addressing emerging needs by conducting regular feedback sessions and employee satisfaction surveys. These measures will help ensure that the voices of newly hired, job order, and long-serving employees are heard, contributing to the maintenance of a positive, responsive, and inclusive workplace culture.

Given the strong and statistically significant correlations between HRM practices, workplace culture, training and development, and employee performance, NIA-UPRIIS should consider investing further in these areas. For HRM practices, enhancements in recruitment, performance appraisal, and compensation systems should be made to ensure fairness, transparency, and alignment with organizational goals. To foster a more inclusive and motivating workplace culture, team-building activities, employee recognition programs, and open communication platforms should be encouraged. As for training and development, programs should be continuously improved, made relevant and practical, and aligned with both employee needs and organizational priorities. Conducting regular training needs assessments can help identify gaps and tailor interventions more effectively. Since training and development demonstrated the strongest correlation with employee performance, additional resources should be allocated to expand skill-building, continuous learning opportunities, and mentorship initiatives.

Lastly, the regression analysis highlighted that training and development is the most significant predictor of employee performance. Therefore, it is recommended that NIA-UPRIIS prioritize the design and delivery of comprehensive training programs that address both current and future competency needs. Providing continuous professional development opportunities—such as workshops, seminars, and structured mentoring—will likely result in significant performance improvements. While HRM practices had only a marginal influence, revising appraisal systems, offering competitive benefits, and establishing clear career advancement pathways may still yield positive outcomes. Although workplace culture was not found to be a significant predictor of performance in this study, it remains important for employee satisfaction and retention. As such, promoting values of inclusivity, collaboration, and employee recognition can contribute to a more positive work environment. Ultimately, by focusing on strengthening training and development while improving HRM systems and workplace culture, NIA-UPRIIS can maximize employee performance and organizational effectiveness.

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Impact of Artificial Intelligence in Space of Digital Marketing

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Abstract *— The journey of AI development has changed the face of technology and put humans into a new race. Along with excelling in technical fields, AI has proved its worth in finance and business. Initially, commercial roles, including marketing, were a very cornered topic when mixed with technology, but with the dynamic shift in technology-driven businesses, AI-business strategies are breaking limitations. This research paper explores the integration of AI in the world of digital marketing and its implementation for growth in digital marketing.*

Keywords *— AI, technology, integration, digital marketing.*

I. INTRODUCTION

Marketing refers to the activities a brand or a company does in order to promote their services or products. Marketing isn't just a fancy word but actually includes advertising and allows businesses to sell products and services to consumers, other businesses, and organizations.

According to the American Marketing Association, approved in 2017, "Marketing is the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large. "

Marketing consists of an incredibly broad and diverse set of strategies. The industry continues to evolve, and the strategies below may be better suited for some companies over others.

Traditional Marketing Strategies: Before technology and the Internet, traditional marketing was the primary way companies would market their goods to customers. The main types of traditional marketing strategies include: Outdoor Marketing: In this type of marketing, an open approach is used. People can view it outside in the open space. Billboards and posters

towering in the public are excellent examples of outdoor marketing.

Print Marketing: This entails small, easily printed content that is easy to replicate. Traditionally, companies often mass-produced printed materials, as the printed content was the same for all customers. Today, more flexibility in printing processes means that materials can be differentiated.

Direct Marketing: This kind of marketing involves all about reaching out directly to potential customers. Coupons, a special offer, or a free sample, businesses would use targeted print materials to personally connect with individuals.

Electronic Marketing: This entails the use of TV and radio for advertising. Through short bursts of digital content, a company can convey information to a customer through visual or auditory media that may grab a viewer's attention better than a printed form.

Event Marketing: This uses attempting to gather potential customers at a specific location for the opportunity to speak with them about products or demonstrate products. This includes conferences, trade shows, seminars, roadshows, or private events.

Digital Marketing: The marketing industry has been forever changed with the introduction of digital marketing. From the early days of pop-up ads to targeted placements based on viewing history, there are now innovative ways companies can reach customers through digital marketing.

Now, with the introduction of digital marketing, the current world is growing dramatically with the growth in technology. Artificial Intelligence has wiped out many spaces with complete rearrangement in plannings and strategies. Modern organizations gather massive amounts of data from various sources, including smart sensors, user-generated content, monitoring systems, and log files. Artificial intelligence (AI) is then used to analyze this data and support business functions in a more efficient way. For instance, AI can interact with customers in support chats, generate creative content like images and text for marketing, and provide insightful recommendations for analytics. But before understanding how and why AI affects the marketing field, let's look upon the definitions and understand the concept of AI. AI is a machine's ability to perform the cognitive functions we associate with human minds, such as perceiving, reasoning, learning, interacting with the environment, problem-solving, and even exercising creativity. You've probably interacted with AI even if you don't realize it—voice assistants like Siri and Alexa are founded on AI technology, as are some customer service chatbots that pop up to help you navigate websites. Artificial Intelligence (AI) is intelligence created artificially by humans using programming languages such as Python, R, Java, C++, and Julia. It is a computer system capable of performing complex tasks that traditionally required human intelligence, but at higher speed and great efficiency.

One of the greatest innovators in the field of machine learning John McCarthy, widely recognized as the "Father of Artificial Intelligence" He was the first who stated the term that "Artificial Intelligence" defined as "the science of making intelligent machines" (w3school.com). Since then, AI has made remarkable progress. Today AI is directly or indirectly integrated in every field. Many companies use AI to perform simple tasks such as customer service chatbots, AI-assisted call centers, and even low level software engineers are also being replaced. In spite of all these, AI is helping mankind in different ways, such as in medical fields, education, optimizing renewable energy generation, etc. In a short period, various AI tools such as ChatGPT, Claude ai, Microsoft Copilot, and the recently introduced DeepSeek gained immense popularity. These AI tools are used by students, professionals in various industry applications. However, AI should remain a tool that enhances human capabilities rather than becoming an absolute necessity. Artificial Intelligence (AI) is intelligence created artificially by humans using programming languages such as Python, R, Java, C++, and Julia. It is a computer system capable of performing complex tasks that traditionally required human intelligence, but at higher speed and great efficiency. One of the greatest innovators in the field of machine learning John McCarthy, widely recognized as the "Father of Artificial Intelligence" He was the first who stated the term that "Artificial Intelligence" defined as "the science of making intelligent machines" (w3school.com). Since then, AI has made remarkable progress. Today AI is directly or indirectly integrated in every field. Many companies use AI to perform simple tasks such as customer

service chatbots, AI-assisted call centers, and even low level software engineers are also being replaced. In spite of all these, AI is helping mankind in different ways, such as in medical fields, education, optimizing renewable energy generation, etc. In a short period, various AI tools such as ChatGPT, Claude AI, Microsoft Copilot, and the recently introduced DeepSeek gain immense popularity. These AI tools are used by students, professionals in various industry applications. However, AI should remain a tool that enhances human capabilities rather than becoming an absolute necessity.

Digital marketing is the art and science of promoting products, services, or brands using digital channels and technologies. Unlike traditional marketing, which relies on mediums such as print, radio, and television, digital marketing leverages the internet and electronic devices to reach and engage with audiences. It's a dynamic field that encompasses a wide range of strategies and tactics designed to attract, engage, and convert potential customers online.

It refers to the use of digital channels, technologies, and strategies to promote products, services, or brands to a targeted audience. It involves online platforms such as search engines, social media, email, websites, and mobile apps to engage potential customers and drive business growth. Key components include Search Engine Optimization (SEO), Social Media Marketing (SMM), Content Marketing, Email Marketing, and Affiliate Marketing. Digital marketing provides businesses with data-driven insights, cost-effectiveness, and a global reach, making it an essential strategy in today's digital world. `Digital marketing is continuously evolving, driven by advancements in technology and changes in consumer behavior. It requires a combination of creativity, technical skills, and strategic thinking to create impactful campaigns that resonate with audiences in the digital age.

In the era of digital transformation, AI has brought deep alterations to advertising, unlike health and financial services; ad tech has been the industry that has got widely disrupted. AI-driven advertisement unleashes the possibility of running much-more-effective, focused, and personalized campaigns maximising advertisement budget and improving consumer engagement.

Programmatic advertising offers an automated, computer-aided means to buying and selling advertising, thus providing the most revolutionary approach today. Right from automated ad buying, with an AI-controlled assortment of subjective advertising target objectives, to execution of advertisements, netting the highest personalization.

With AI-based performance analytics, advertisers may monitor and optimize the performance of their campaigns, thus ensuring that they are always improving.

2. Programmatic Advertising and AI-Powered Ad Targeting. AI-driven ad targeting offers a high level of customisation through algorithms and user data. In a self-learning environment, AI systems sift through vast data sets to segment audiences and, using machine learning models to predict, evaluate which users, if any, are most likely to respond to a particular advertisement. Programmatic advertising stands for real-time ad placement, optimization, and purchase of ad distribution space, powered through AI algorithms. In this sense, programmatic advertising allows advertisers to deliver dynamic content best suited to a defined audience segment, whereas traditional advertising was extremely costly to run and quite ineffective.

3. AI-Based Campaign Optimization and Performance Analytics. AI enhances performance analytics, creating insight into advertising performance that would have, otherwise, gone unnoticed. The mention of analyzing user behaviour, conversion rates, or any other metrics or key performance indicators (KPIs) will quickly point to artificial intelligence (AI) enabling integration and evaluation of data across various channels such as social media, search engines, and websites.

AI optimizes campaigns by continuously fine-tuning campaign strategies according to pre-agreed performance criteria to maximize engagement with ads. The analysis of the data through predictive modelling helps advertisers to assess their performance impact and take corrective measures in their campaigns.

4. *AI-Enhanced Advertising Case Studies-*

The following section covers real-life case studies in companies that employed AI-driven advertising strategies and their results. The findings from these

case studies further illustrate how AI technologies enabled businesses towards achieving better ROI, higher audience engagement, and advanced targeting skills.

II. LITERATURE SURVEY

2.1 Gartner defines customer analytics as "the use of data to understand the composition, needs, and satisfaction of the customer. Also, the enabling technology is used to segment buyers into groupings based on behavior, to determine general trends, or to develop targeted marketing and sales activities." To find, attract, and retain the most profitable clientele, businesses should learn and analyze as much as they can about their customers. A customer data-driven company can make more informed decisions faster and respond to new opportunities and challenges. Companies can use metrics like purchase histories and survey data to better understand customer habits and impressions. They can track customers across various touchpoints and produce meaningful insights. They can research consumer attitudes toward their goods, the sector, and the overall economy. Understanding the return on investment for marketing initiatives and product design choices is another benefit of using customer analytics. For example, studying customer information can unearth relevant demographic information, such as which segments of customers buy the most products. It can then do customer segmentation, where it can personalize messages and spend more ad budget to reach those high-value customers. Using analytics to improve client conversion and retention boosts profitability and may result in more sales through favorable word-of-mouth. [1].

Whether the buyer wants a certain product or not, marketers must find things like likes and dislikes while sifting through a lot of small details. The majority of companies employ AI technologies to lower expenses and boost output while lowering the possibility of mistakes. Businesses may build long-lasting relationships with their clients with the aid of AI. AI processes vast volumes of data from several sources, finds trends, and makes predictions to assess customer behavior and preferences. The foundation for an analysis is established by connecting these three key points.AI can assist in keeping up with the latest developments and trends in the industry.

According to studies, 49% of consumers would return to an online location if AI was present. To enhance their stay, the customer is paired with suitable hosts and postings, as well as experiences and surroundings. When the customer receives help like this, they are less inclined to shop elsewhere the next time they need a break. The ease of use for customers Artificial Intelligence is creating a vast array of possibilities that will greatly improve the buying experience for the buyer. It follows that organizations must continue to recognize trends. The usage of speech recognition technology by consumers: Most voice search users are currently restricted to using gadgets like the Amazon Echo, which they use for a number of reasons. Discourse acknowledgment search is being used by more and more consumers to obtain information more quickly and accurately. Customer Trust in Brands: The easiest way for brands to build consumer trust is by providing a noteworthy amount of substantial value as a result of their customers' subtleties. AI can help in this situation. As demonstrated by Google Now, buyers have faith in AI-powered products that personalize the user experience while providing a huge amount of value. [2]

Corporate executives believe AI will become a crucial tool in the future, according to a report called "A Revolutionary Partnership: How AI is Pushing Man and Machine Closer," which polled 2,500 American customers and company decision marketers. When taken as a whole, 72% said it helped businesses. Using AI in the creative realm of business, such as writing content (68%) or creating images (22%), the majority of the organizations that participated in Talent Alpha's survey employed AI to support marketing (54%) and sales (47%) aspects of their businesses.

Banking: The banking sector uses artificial intelligence (AI) in a number of ways. There are several situations in which artificial intelligence is being used. One significant application of AI is in customer service. The leading private sector bank in India, HDFC Bank, introduced On Chat, an AI-powered Chabot, on Facebook Messenger in 2016. During its first year of use, the Chabot—which was created in partnership with Niki.AI—saw a 160% increase in transactions month over month. With more than 300,000 users connected, HDFC Bank On Chat completed transactions totaling about Rs 2.5 crore as

of April 2018. Eva, the HDFC Bank virtual chatbot accessible via Google Assistant and Amazon Alexa, is another example of AI in conversational banking. Options for loans and credit: Banks have started incorporating AI-based technologies to help them make safer and more profitable lending and credit decisions. Unquestionably, all of these credit monitoring services commonly make errors, exclude real transaction information, and identify creditors wrongly. An AI-based lending system may use behavioral patterns to determine a consumer's creditworthiness even if they have a spotless credit history. The system also alerts banks to certain actions that could increase the likelihood of default. In summary, these technological advancements are radically altering the way that consumer loans are processed going forward.

Online Retail Industry:

Loan and credit decisions: Banks have started incorporating AI-based technologies to help them make safer and more lucrative lending and credit decisions. These days, many banks still make their decisions solely on a person's or business's creditworthiness, taking into account their credit scores and customer references. All of these credit monitoring services undoubtedly include errors, exclude detailed information about transactions, and identify creditors wrongly. An AI-based lending system may evaluate a consumer's creditworthiness based on their behavior patterns even if they have a clean credit history. The technology also alerts banks to specific actions that could accelerate the default risk. All things considered, these technology developments are fundamentally changing how consumer loans are handled moving ahead.

Amazon case study The best example of how AI may be successfully incorporated into online retail is provided by Amazon, the biggest online retailer in the US. It is possible to create a more specialized shopping experience in addition to the wide selection, fast delivery, and affordable costs. As a result, Amazon customers can benefit from location-specific pricing, pay in their local currencies, and receive location-relevant communications. More individualized and customer-focused search experiences are made possible by artificial intelligence (AI) in online retail, which boosts sales. New technology, including artificial intelligence (AI) systems, encourages the creation of innovative marketing techniques to improve consumer experiences and connect with target groups. [3] Let's take a simpler yet popular example of Nike. Only a few brands are as iconic as Nike. When Nike asked a trio of Parisian artists who make AI- inspired designs, to develop new iterations of the Air Max sneaker in 2020, it had a consideration about the design that it should not deviate too much from the Nike's signature style. The artists fed the generative AI model the pictures of Air Max 1, the Air Max 90 and the Air Max 97 and used the model to create a vast array of design ideas. Just to be sure that in 2020, the combined revenue from the resale of Nike and Air Jordan was valued at $7.1 billion. This is how AI in the correct hands, with market interest, can do for the company. [4]

2.2 The discipline of digital marketing has been significantly impacted by recent advancements in AI and predictive analytics. In predictive analytics, a large dataset is analysed to produce predictions about upcoming events or behaviours using statistical algorithms and machine learning [1]. On the other hand, AI refers to the ability of machines to carry out activities that require human intelligence, such as speech recognition or natural language understanding. Depending on the precise objectives of the marketing campaign, a variety of AI and predictive analytics models can be used in digital marketing.

Here are a few illustrations: A common recommendation engine technique in the media and e-commerce industries is collaborative filtering. In order to recommend products or information that users are likely to find interesting, it looks at consumer behavior and preferences.

b. Neural Networks: These models use layers of data analysis to identify trends and estimate future behavior. They can be used to find high-value prospects and predict client turnover, among other things.

c. Decision Trees: This model uses a structure like a tree to base choices on the properties of the data. It can be used to predict customer behavior, categorize customers, and decide which marketing strategies to apply.

d. Bayesian Networks: These models use causal relationships and probability to predict future

behavior. Among their many applications are sales forecasting, social media trend identification, and customer behavior prediction.

e. Regression Analysis: Regression analysis is a statistical model that may be used to analyze the relationships between different variables, such as the amount of money spent on sales and advertising. It can be used to identify the channels that produce conversions the best and to enhance marketing strategy.

f. Clustering: This methodology separates the data into clusters based on the commonalities among the data points. It can be used to identify client segments and customize marketing tactics for each. [5]

Challenges and Ethical Considerations:

Predictive analytics powered by AI has many advantages, but there are still a number of obstacles to overcome. The quality of the data is one important concern. The availability of high-quality data is crucial for AI models, because missing or subpar data can result in predictions that are not correct. Furthermore, it can be difficult and expensive to integrate AI systems with current corporate infrastructure, especially for small and medium-sized businesses. Predictive analytics powered by AI also brings up ethical issues, particularly with regard to algorithmic bias and data privacy. Biased training data can provide biased predictions, according to studies, which could have discriminatory effects on recruiting, financing, and law enforcement, among other areas. Furthermore, companies must make sure they abide by data privacy laws like the CCPA and GDPR as AI models depend on enormous volumes of personal data.It is anticipated that AI's contribution to predictive analytics will grow in the future. The use of AI technologies in commercial decision-making will increase as they develop further, including natural language processing (NLP) and reinforcement learning. Additionally, analytics powered by AI will likely become more accessible to a wider range of businesses as cloud-based AI services and platforms become more prevalent There is also growing interest in explainable AI, which seeks to make AI predictions more transparent and understandable to human users. This is critical for building trust in AI systems, especially in industries such as healthcare and finance, where Understanding the reasoning behind predictions is essential. [6]

2.3 The simplest definition of a chatbot is a computer software that mimics and interprets spoken or written human communication, enabling people to engage with digital gadgets just like they would with a real person. Chatbots can be as basic as simple programs that respond to a single question with a single line, or they can be as complex as digital assistants that learn and develop to provide ever-higher levels of customization as they collect and analyze data. For instance, a message inquiring if you need assistance appears on your screen while you are using your computer to investigate a product. Or maybe you're using your smartphone to chat for a ride while you're heading to a concert. Or you might have used voice commands to order a coffee from your neighborhood café and received a response telling you when your order will be ready and what it will cost. These are all examples of scenarios in which you could be encountering a chatbot.[7]

The concept of chatbots traces back to Alan Turing's question in 1950 about whether a machine could engage in human-like conversations, leading to the Turing Test. The first chatbot, ELIZA, developed in 1966, simulated a psychotherapist by using pattern matching and response templates. However, its capabilities were limited to specific domains and short conversations. In 1972, PARRY was developed to mimic a patient with schizophrenia. Unlike ELIZA, it introduced a personality and an assumption-based response system. However, it still struggled with language comprehension, response speed, and learning capabilities. The 1988 chatbot, Jabberwacky, attempted to improve contextual pattern matching but was constrained by limited speed and scalability.[8] Conversational depth, emotional intelligence, and contextual awareness have all improved in modern chatbots. Maintaining relevance, comprehending intricate requests, and guaranteeing security in chatbot exchanges are still difficult tasks, nevertheless. Global chatbot research is led by the USA, followed by the UK and Japan, underscoring the expanding importance of chatbot technology across a range of industries.

Driven by AI, automated rules, natural-language processing (NLP), and machine learning (ML), chatbots process data to deliver responses to requests

of all kinds.

There are two main types of chatbots.

- Task-oriented (also known as declarative) chatbots are programs designed to do a specific task. Rules, natural language processing, and minimal machine learning are used to produce conversational, automated answers to user questions. These chatbots are best suited for support and service roles; think of them as interactive, comprehensive FAQs. Interactions with them are very specialized and structured. Task-oriented chatbots are capable of answering routine inquiries, including those concerning business hours or straightforward transactions that don't require a lot of variables. They use natural language processing (NLP) to allow end users to interact with them in a conversational manner, although their capabilities are somewhat limited. At the moment, these chatbots are the most widely utilized.
- Predictive (conversational) and data-driven: Often called virtual assistants or digital assistants, chatbots are far more advanced, interactive, and customized than task-oriented chatbots. These contextually aware chatbots use machine learning (ML), natural language understanding (NLU), and natural language processing (NLP) to learn as they go. Based on user profiles and historical behavior, they leverage analytics and predictive intelligence to enable personalization. Digital assistants are able to anticipate needs, provide recommendations, and gradually understand a user's preferences. They have the ability to start discussions in addition to tracking data and intent. Alexa from Amazon and Siri from Apple are two instances of consumer-focused, data-driven, predictive chatbots.[7]

Role of Chatbots in Digital Marketing

Enhancing Customer Engagement

Chatbots provide real-time interaction, allowing businesses to engage with customers instantly. By addressing inquiries, guiding users through websites, and recommending products, chatbots help businesses maintain continuous customer engagement. This improves user experience and increases conversion rates.

Personalization in Marketing:

Modern chatbots analyze customer preferences and past behaviors to deliver personalized content and recommendations. This personalization enhances customer satisfaction and strengthens brand loyalty. AI-driven chatbots can send notifications for products a customer is looking for, promotional offers, and reminders, ensuring a more effective experience between the brand and the customer.

Cost-Effectiveness and Efficiency:

Businesses can cut operating expenses by automating client interactions, which eliminates the need for human intervention. Chatbots can't handle more complicated tasks, so humans can concentrate on them. Chatbots handle multiple customer queries simultaneously, improving efficiency and response times. This enables businesses to allocate human resources to more strategic activities.

24/7 Availability:

Unlike human agents, chatbots operate 24/7, providing customer support at any time. They assist customers whenever needed, ensuring continuous engagement and catering to global audiences across different time zones. [9]

Challenges of Implementing Chatbots in Digital Marketing

Although chatbots have revolutionized digital marketing by streamlining customer interactions and automating engagement, they come with several challenges that businesses need to address for optimal performance.

- Difficulty in Handling Complex Queries
- Chatbots may struggle to understand intricate, multi-layered customer inquiries. Since they primarily rely on predefined algorithms and training data, they might provide inaccurate or repetitive responses when faced with unexpected questions.
- Lack of Human-Like Emotional Understanding
- Unlike human customer support agents, chatbots lack emotional intelligence, making it difficult to interpret user sentiment. This limitation can result in robotic and impersonal conversations, leading to dissatisfaction in situations that require empathy.
- High Development and Maintenance Costs

- Implementing an advanced chatbot requires significant investment in AI training, natural language processing (NLP), and integration with existing business systems. Regular updates are necessary to enhance its functionality and maintain relevance, increasing operational costs.

Privacy and Security Concerns :

Since chatbots collect and store user data to personalize responses, they pose potential security risks. Organizations must comply with regulations like the General Data Protection Regulation (GDPR) and ensure data encryption to prevent unauthorized access.

- *Strict Rule-Based Reactions*

Certain chatbots follow preset scripts, which restricts their ability to adapt to specific client issues. If the chatbot cannot go beyond its programmed knowledge, it may frustrate users and negatively impact customer experience.

- *Complicated Integration with Current Systems*

Businesses often face challenges integrating chatbots with customer relationship management (CRM) software, e-commerce platforms, and other digital tools. A poorly integrated chatbot may disrupt workflow efficiency instead of improving it.

- *Risk of Over-Automation*

While automation enhances efficiency, excessive reliance on chatbots can make customer interactions feel overly mechanical. Businesses must strike a balance between automation and human involvement to maintain a personalized touch.

- *Language and Cultural Limitations*

Despite advancements in NLP, chatbots may still struggle to interpret regional dialects, slang, and cultural nuances. This can lead to misunderstandings and miscommunication, especially in global markets.

- *Customer Resistance to AI Interactions*

Some users prefer direct human interaction and may feel frustrated when forced to engage with a chatbot. If the chatbot fails to provide accurate responses or does not escalate issues to a human representative when needed, it can result in a poor user experience.

- *Continuous Training and Optimization Required*

To remain effective, chatbots need ongoing learning and updates to improve their response accuracy. This requires businesses to analyze chatbot interactions, refine AI models, and ensure that responses align with evolving customer needs. [9]

2.4 An essential component of the digital marketing landscape, search engine optimization (SEO) plays a crucial role in improving a company's online visibility, which in turn affects how easily it can reach its target audience.Deeper understanding of search engine user behavior is possible with a strategic SEO approach, which guarantees wiser business choices and a strong online presence. As digital environments change, so do the tools and approaches that underpin SEO. This change in perspective signifies a departure from an SEO strategy that emphasises keywords to one that emphasises comprehending the full context of a user's search. In the vanguard of this evolution is AI. AI has changed both the user's search experience and the strate-gies implemented by companies to optimize their content. With AI, search engines become more adaptive, focusing on user needs and delivering more personalized results.

AI and Local SEO : With the growth of mobile search and the growing significance of location-based inquiries, local SEO has gained traction. Visibility in Google's local pack, Maps, and Bing Places is the main goal of local SEO. Essential steps include optimizing a Google My Business listing, gathering positive reviews, creating localIntelligence's Revolutionary Role in Search Engine Optimization.

AI and Off-Page SEO : Off-page search engine optimization, or "link building," is centered on the activities of third-party websites. It emphasizes the quantity and quality of backlinks . In addition to link building, it seeks to increase brand visibility and online reputation using strategies including influencer outreach, content marketing, social media, and guest blogging. The objective is to gain authority and credibility through external endorsements from trusted sources on various platforms. AI is enhancing off-page SEO by optimizing external online presence strategies. It can monitor and manage the online reputation of a website and its competitors. Using sentiment analysis, AI algorithms can track brand mentions across the internet, distinguishing positive comments from negative ones.

AI and On-Page SEO: By optimizing elements within a website's pages, on-page SEO increases its visibility.

At first, search engines depended on keyword density, meta tags, and content, which caused websites to overuse keywords. Modern on-page SEO addresses both content and technical aspects, emphasizing the right balance of keyword relevance with user value. Elements like title tags, meta descriptions, URLs, and image optimization play vital roles. Image strategies focus on user experience and efficient loading, such as compressing images and using descriptive filenames. Mobile SEO, a subset, ensures websites are user-friendly on mobiles, highlighting responsive design and easy navigation.

AI and Voice Search: The emergence of smartphones marked the beginning of the mobile SEO era, as mobile searches surpassed desktop searches. Voice search moved away from keyword-based searches and toward context-driven, natural language questions, thanks to the popularity of assistants like Alexa and Siri. By comprehending and effectively answering conversational inquiries and capturing subtleties and intents as consumers organically engage with voice-activated devices, artificial intelligence (AI), including algorithms like BERT, is essential to improving Voice Search SEO. Algorithms pick up on subtleties in language, accurately aligning material with user intent. AI-driven analytics optimize real-time results by predicting user queries based on past data and patterns. AI improves voice search by guaranteeing contextual relevancy and a more user-friendly interface.Although it has presented difficulties, AI has revolutionized SEO. Businesses must constantly adjust to the constantly evolving AI algorithms. Many AI models are "black-box" in nature, which adds unpredictability and makes it difficult for experts to get consistent results. Ethical questions around digital equity, power, and possible manipulation surface as AI affects online visibility. It emphasizes how crucial it is to combine openness, moral behavior, and inclusivity with AI in SEO.

2.5 Ethical Concerns and Limitations of AI-Generated Content: As AI becomes more prominent in content creation, various ethical concerns and limitations must be addressed. AI can be a powerful tool, but it also poses risks related to originality, misinformation, bias, and quality. Below is a detailed breakdown of these concerns and limitations: *Ethical Concerns:* Since AI-generated material sometimes draws on pre-existing data, questions concerning originality are raised. Certain AI models might unintentionally replicate words, concepts, or even whole passages from previously published works, which could be against copyright regulations. **Possible hazards include duplicate search engine content penalties. legal repercussions for unauthorized use of protected content. Reduced credibility for businesses and content creators.** AI models can't fact-check in real time, but they can create content based on patterns in existing data. Disseminating inaccurate or misleading information is one outcome of this. Generating inaccurate claims or out-of-date statistics, misrepresenting difficult subjects because one does not comprehend the context.

AI models learn from vast datasets, which may contain biases reflecting societal prejudices. This can lead to:

- Content that favors certain demographics over others.
- Stereotyping and discriminatory language.
- Underrepresentation of minority groups in AI-generated text.

AI cannot replicate human emotions, cultural sensitivity, or deep creative thought. This results in:

- Generic, formulaic writing that lacks depth.
- A robotic tone that may not engage readers.
- Difficulty in capturing humor, satire, or poetic expression.

As AI-generated content becomes more common, concerns about job losses in the creative industries rise. While AI can enhance productivity, it may reduce demand for:

- Copywriters and content marketers.
- Journalists and news reporters.
- Creative writers and editors.

AI-generated content can be misused for deceptive practices such as:

Clickbait headlines that mislead users.

Fake reviews to boost product ratings.

Deepfake content used to spread false narratives.

Limitations of AI-Generated Content

1. Lack of Context & Nuance.AI models struggle with understanding:Industry-specific terminology and technical subjects.

Cultural and regional nuances in language.

Sarcasm, humor, and tone variations in writing.

2. SEO vs. Quality Balance

AI can generate keyword-heavy content, but over-optimization may harm readability. This can lead to:

- Keyword stuffing, making content unnatural.
- Repetitive phrases reducing engagement.
- Lower dwell time due to poor readability.

2.6. Dependence on Prompts

AI-generated content quality heavily depends on input prompts. Poorly crafted prompts can lead to:

- **Irrelevant or generic responses**.
- **Misaligned content** that doesn't fit brand tone.
- **Inconsistent quality** across different articles.
- **4. Limited Real-Time Awareness-**AI models do not have real-time updates unless explicitly connected to live data sources. This means:
- **News-based content** may lack accuracy.
- **Trending topics** may not be fully captured.
- **Data-driven reports** may not include the latest statistics.
- **5. Ethical & Legal Compliance-**AI cannot always ensure content complies with:
- **Data privacy laws** (GDPR, CCPA).
- **Advertising guidelines** (FTC disclosures).[10]

2.7 Case Study 1: E-commerce Targeted Advertising:

By refining ad targeting and personalization, the e-commerce platform enhanced sales via programmatic advertising and an AI recommendation engine. Machine learning was used to refine ad targeting based on predicted consumer preferences, thereby making ads more relevant and increasing conversion rates.

2.8 Case Study 2: Optimizing Social Media Campaigns:

A social media platform monitored user engagement and made real-time adjustments to ad strategies using artificial intelligence-based campaign optimization techniques. This allowed for much more correlation between ad spending and user engagement while also resulting in a stark decrease in customer acquisition.)

5. Challenges for AI Advertising's Further Development:

These numerous challenges include algorithmic biases, privacy of data, and the challenge of integrating AI with existing advertising technology. Advertisers who are about to use these AI tools should blend ethical responsibility with the AI management of sensitive user data.

III. RESULT AND DISCUSSION

In recent years, the integration of **Digital Marketing** and **Consumer Analytics** has become critical for businesses seeking to optimize their marketing strategies, enhance customer engagement, and drive sustainable growth. By leveraging advanced tools and methodologies in both fields, companies can achieve a deeper understanding of their customers' behaviors, preferences, and purchasing patterns.

Key Insights and Trends:

Consumer Behavior Understanding: Digital marketing platforms, paired with consumer analytics, provide valuable insights into how customers interact with various digital touchpoints. By analyzing data from websites, social media, mobile apps, and email campaigns, businesses can identify trends such as:

- Which channels drive the most traffic or conversions
- Time spent on particular content or products
- Customer demographics and psychographics

This granular understanding allows marketers to tailor messages and offers to specific audience segments, resulting in more effective campaigns.

Personalized Marketing: Consumer analytics enables the creation of highly personalized experiences. By utilizing data from previous interactions, companies can deliver targeted content, product recommendations, and advertisements that resonate

with individual consumers. Personalized marketing strategies have been proven to increase engagement, improve customer satisfaction, and drive higher conversion rates.

Predictive Analytics and Future Trends: One of the most powerful aspects of consumer analytics is predictive analytics. By analyzing historical consumer data and leveraging machine learning algorithms, businesses can predict future behavior and trends. For example:

- Forecasting which products are likely to be popular in the coming months
- Predicting customer churn and developing retention strategies
- Identifying high-value customers for loyalty programs

Predictive models help companies allocate marketing resources more effectively and reduce wasted spend.

Multi-Channel Marketing Effectiveness: Digital marketing analytics also helps businesses evaluate the performance of multi-channel campaigns. Insights into customer journeys across various channels (e.g., social media, email, search engines) provide a clear picture of the most effective touchpoints. Businesses can then optimize their approach to focus on the channels that yield the highest ROI.

Real-Time Data and Agile Marketing: One of the greatest advantages of digital marketing is the ability to track and analyze real-time data. This real-time feedback allows businesses to adjust their strategies quickly in response to changing consumer behavior or market conditions. Agile marketing practices, powered by instant analytics, help brands stay ahead of trends and remain competitive.

Data-Driven Decision Making: With accurate consumer data at hand, marketers can move away from gut-feeling decisions to **data-driven strategies**. This eliminates guesswork and aligns marketing efforts with actual consumer interests, improving campaign efficiency and impact.

IV. RESULT AND DISCUSSION

According to the survey, chatbots have transformed digital marketing by enhancing client engagement, allowing for greater customization, and lowering operating expenses. AI-powered chatbots are being used by an increasing number of companies to provide real-time responses, guide users through websites, and make tailored suggestions based on past exchanges. These chatbots are available around-the-clock, guaranteeing seamless customer service and increased conversion rates. Compared to rule-based, task-oriented chatbots, predictive, data-driven chatbots with natural language processing (NLP) and machine learning are more adept at having more engaged, conscious discussions.

Despite their advantages, the use of chatbots for digital marketing is plagued by a number of issues. Among the issues noted are the inability to handle complex queries, a lack of emotional intelligence comparable to that of humans, and implementation expenses. Because chatbots gather user data for customization, privacy and security issues are still very important and must be strictly adhered to by data protection laws. Additionally, strict, rule-based responses and linguistic barriers could make customers unhappy. For businesses to continue providing a productive and customer-friendly experience, automation and human engagement must be carefully balanced. Continuous advancements in AI, NLP, and emotional intelligence are required to maximize chatbot integration in digital marketing. Chatbots with improved algorithms can have more in-depth conversations and be less erroneous. Flow efficiency can be further improved by integration with e-commerce platforms and CRM systems. Personalization, security measures, and multilingual implementation to expand the possibilities in international markets are some prospective areas of advancement. Chatbots have a bright future in digital marketing, but this promise will only materialize if obstacles are effectively overcome.

Search Engine Optimization (SEO) has become a fundamental pillar of digital marketing, significantly enhancing a business's online presence. By optimizing websites for search engines, businesses can improve their visibility and reach their target audience more effectively. A well-planned SEO strategy not only helps attract potential customers but also provides valuable insights into user behavior, enabling informed decision-making and a stronger digital footprint. As the digital world evolves, so do SEO techniques and technologies. Traditionally, SEO relied

heavily on keywords and backlinks. However, search engines have now shifted towards understanding the intent and context behind user searches. This transition marks a move from keyword-focused optimization to a more holistic approach that prioritizes content relevance and user experience. Artificial Intelligence (AI) is at the forefront of this transformation. AI has revolutionized how search engines interpret queries and deliver results, making them more adaptive and user-centric. By leveraging AI, search engines can analyze vast amounts of data, predict user intent, and offer personalized search results. Businesses, in turn, are using AI-driven tools to optimize content in a way that aligns with these evolving search algorithms, ensuring they remain competitive in the digital landscape.

V. CONCLUSION

Without a doubt, the advertising industry has undergone transformation due to AI, which is a vehicle for the effective generation of focused campaigns. Brands can now engage their audiences in ways thought impossible before the combination of machine learning, predictive analytics, and programmatic advertising. However, the full potential of AI in advertising can be tapped only if algorithmic bias and data privacy issues are adequately resolved.

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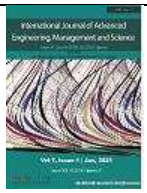

Factors Influencing Career Choices Among First-Year Students: Focus on Hospitality and Tourism Management

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Abstract**—** *The study aims to investigate how first-year students select a career in the hospitality and tourism industry. As the industry is growing globally, it is important to know students' motivation, perception, and career expectations to create development plans in alignment with their goals. It is surveyed using the Likert scale, which investigates the factors that have significant influence, such as personal interest, family, industry growth, and education. The result shed the foundation for designing an individualized career development plan to encourage students' academic progress while contributing towards their prepared future in hospitality and tourism management.*

Keywords**—** ***Academic progress, Career choices, First-year students, Hospitality Management, Tourism Management***

I. INTRODUCTION

Hospitality and tourism are among the world's fastest-growing industries, with many career opportunities. However, as noted by Qiu, S., Dooley, L., & Palkar, T. (2019), advice from teachers and counselors strongly influences students' decisions about careers in hospitality. Finally, it highlights the role of students' motivations, making navigating the terrain between external and internal trends worthwhile. Korir, J., & Wafula, W. (2021) showed intrinsic factors like expectations for a career that are desirable and extrinsic factors like support from family, which influences Kenyan hospitality students. Its emphasis on considering social and economic contexts involves examining external influences (e.g., family, societal). This study investigates the factors that impact first-year students in Nueva Ecija to take up careers in this industry. Kahraman, O. C., & Alrawadieh, D. D. (2021) illustrate the influence of perceived education quality and self-efficacy on the career decisions of hospitality students. It is also quite illuminating to consider what role educational curriculum plays in determining students' career paths. The research study aims to build a relationship between personal interest, family support, industry growth, the curriculum's effect, and its influence on students when choosing their careers by focusing on motivational and external factors. Anthony, G. (2020) The Career Aspirations of Undergraduate Hospitality Students in Ghana. He notes that perceptions about the industry and an unclear picture of potential career pathways serve to deter students from pursuing careers in humble hospitality. This aligns with investigating the impact of personal enthusiasm and field expansion. These findings will inform the formulation of a customized career development program that will aid students' learning journeys with a pathway to success in the evolving hospitality and tourism management landscape.

Objectives

1. Demographics of First-Year Students as a Hospitality and Tourism Management Career.
2. What motivates first-year students to pursue a career in hospitality and tourism?
3. How do external conditions, like industry expansion and educational curriculum, make students choose hospitality and tourism as their career?
4. What challenges do first-year students have to reaffirm their decision to pursue the industry?
5. How can a career development plan be developed that meets the needs of students and aligns with career aspirations in hospitality and tourism based on the findings?

II. MATERIALS AND METHODS

This study aims to investigate the dimensions of motivation and external factors that influence first-year students in Nueva Ecija to pursue careers in the hospitality and tourism industry. Based on a descriptive research design and an IPO framework, the study explores students' demographic profiles, personal interests, family influences, social perceptions, and the effects of industry expansion and educational curricula. A structured Likert-scale survey was designed to collect data on the extent of agreement with statements relating to personal motivation, family and social influence, industry growth, educational factors, and career expectations. Statistical analyses were conducted on the collected data to identify trends, key factors, and challenges affecting students' career decision-making. The results underscore the importance of intrinsic interest, parental encouragement, industry demand, and hands-on learning opportunities in career decision-making. Other challenges included uncertainty about the long-term outlook and the need for career guidance. The results of this study try to guide the response to developing the career development plan between students to guarantee students' skills required in the hospitality and tourism industry and their expectations of the job market. The study becomes a valuable input in knowing how to support students following their career purposes and how to approach what the industry needs. Al-Jubari, I., & Mosbah, A. (2023) examine the motivational dimensions of students in the hospitality and tourism industry and how these are affected by external factors such as education, family influences, and industry trends, analyzing survey data and using statistical analysis of results.

Chalapati, S., & Leung, R. (2018) found factors that affect first-year students' experiences in education as motivation, curriculum design, and outside factors (such as industry trends), which relate to many concepts in the statement.

III. RESULT AND DISCUSSION

Table 1 Frequency and Percentage Distribution of Demographic Profile

Demographic Variable	Frequency (f)	Percentage (%)
Age		
18-20	45	60%
21-23	25	33.3%
24 and above	5	6.7%
Gender		
Male	40	53.3%
Female	35	46.7%
Family Income		
Below Php 20,000	30	40%
Php 20,001-40,000	25	33.3%
Above Php 40,000	20	26.7%
Previous Exposure to Industry		
Yes	50	66.7%
No	25	33.3%

The respondents' demographic information adds to the knowledge regarding the possible demographics they could have been the indicators of their choice of career in hospitality and tourism. 60% of the respondents were between 18 and 20 years old, while 33.3% were between 21 and 23, and only a small group (6.7%) was above 24. The split is almost even in gender, as only 53.3% of the respondents are male and 46.7% female. As for family income, most respondents (40%) have families earning below Php 20,000, which shows a moderate financial background. Remarkably, a high percentage of respondents (66.7%) were previously introduced to the hospitality and tourism industry by traveling, working part-time, or being influenced by other family members. This was a young and engaged demographic, with a more or less even gender split and a fair amount of prior exposure to the industry, all of which potentially shaped their motives and challenges to work in this space. Other researchers, Aziz, Y. A., Hussin, S. R., & Nezakati, H. (2018) also investigate demographic characteristics, including age, gender, and socioeconomic background, which relate to socioeconomic implications of the statement, particularly in addressing if gender is parity between genders based on interest or earlier occupational experience.

Table 2 Motivational Factors Influencing Career Choice

Statement	Mean (M)	Verbal Description
I have a strong personal interest in hospitality and tourism.	3.60	Strongly Agree
I believe the hospitality and tourism industry offers promising career opportunities.	3.45	Agree

My passion for travel and service motivated my career choice.	3.50	Agree
I see myself working in the industry for a long time.	3.40	Agree
Weighted Mean	**3.49**	**Agree**

Legend: **3.50 - 4.00**: Strongly Agree, **2.50 - 3.49**: Agree, **1.50 - 2.49**: Disagree, **1.00 - 1.49**: Strongly Disagree

The survey used to gather the data was beneficial to general research on student motivations and to help readers understand why students choose these careers in hospitality and tourism. With a mean of 3.60, the statement "I have a strong personal interest in hospitality and tourism" also indicates that most students strongly agree that they are personally passionate about the field, which suggests that intrinsic motivation is critical when making decisions. A mean determination of 3.45 was also noted for the statement, “I believe the hospitality and tourism industry offers promising career opportunities,” which signifies student agreement that the industry offers a good career prospect.

The response "My love for travel and service drove my career choice" had a mean score of 3.50, indicating that students are motivated by their passion for travel and providing excellent service; it is at the heart of the industry. Moreover, this also reflects the student's "I see myself working in the industry for a considerable time" score of a mean of 3.40, which implies the confidence of students that they will have a sustainable and long-lasting career in hospitality and tourism.

This indicates that when combining all responses, students agree that personal interest, career opportunities, and passion are the motivational factors that heavily impact their decision to choose a career in hospitality and tourism (weighted mean = 3.49).

Findings indicated that personal interest and career opportunities are the most important factors that push students to enter hospitality and tourism. Their excitement for travel and service is a natural fit for the field, and they show poise in making long-term career commitments.

These findings highlight the importance of institutions supporting students’ motivations by providing programming that extends to their interests and career aspirations. Farmaki, A. (2018); High-Impact Internship for Tourism and Hospitality Students Career Decision-Making: Impact of Internship Experiences; Motivational factors are found to drive decision-making processes among tourism and hospitality students when considering an internship experience, focusing on personal interests, career opportunities, and experiential learning.

Table 3 External Factors Influencing Career Choice

Statement	**Mean (M)**	**Verbal Description**
I chose hospitality and tourism because of the industry's growth.	3.55	Strongly Agree
The wide range of job opportunities influenced my decision.	3.50	Strongly Agree
I believe the hospitality and tourism industry is stable and has long-term prospects.	3.40	Agree
The curriculum offered in my chosen course helped me make my decision.	3.45	Agree
My professors' experiences and teachings motivated me to pursue this field.	3.50	Strongly Agree
Weighted Mean	**3.48**	**Agree**

Legend: **3.50 - 4.00**: Strongly Agree, **2.50 - 3.49**: Agree, **1.50 - 2.49**: Disagree, **1.00 - 1.49**: Strongly Disagree

The survey results reveal how outside variables shape students' career decisions in hospitality and tourism. With a mean of 3.55, "I decided on hospitality and tourism because of the growth of the industry" implies considerable agreement, highlighting the rapidly growing trend in the industry and its importance in securing a position and a career in the long run. Likewise, ”The wide range of job opportunities influenced my decision,” which means 3.50, meaning most students agree that the broad range of career options available within the industry heavily affected their decision.

The mean score of 3.40 for the statement "I believe that there are stability and long-term prospects in the hospitality and tourism industry" indicates that students agree that the industry provides stability even in a rapidly changing world. In addition, the statement "The curriculum offered in my chosen course helped me make my decision" had a mean of 3.45, emphasizing how course design and content assisted in the decision process of student career choice. Finally, the statement "My professors' experiences and teachings motivated me to pursue this field" provided a mean of 3.50, indicating that faculty members impact students in educating and encouraging students toward this career path.

The weighted mean of 3.48 thus indicates that students agree to a certain degree that external factors, namely industry growth, job opportunities, stability, educational curriculum, and faculty influence, are significant in their career decision-making process.

Perceived industry growth and opportunities within it as key external factors shaping career decisions. Students include the growth of the industry the job is within and the variety of jobs available as two of the key external factors that impact their career decisions. Also, educational curriculum and professors' experience contribute to their decisions.

It is also worthwhile for educators and industry leaders to reinforce students' aspirations to build careers in hospitality and tourism by highlighting the industry's stability and tailoring such a curriculum toward current workforce demands.

Future Directions for Research Chuang, N. K., Lee, P. C., & Kwok, L. (2020) provide a good understanding of the backing provided to students from industry growth, casual-level careers, and well-being in education as external influencing factors in hospitality and tourism career choices, further highlighting the influences of those in behind the scenes of choice selection.

The challenges of first-year students have to reaffirm their decision to pursue the industry:

Revisiting the decision to establish a career in hospitality and tourism as a first-year student is very common. The biggest concern is uncertainty about long-term job security — particularly in a rapidly changing economy and amid global emergencies like COVID-19. This frequently results in students straying away from the field they originally signed up to pursue. Students also complain about the lack of career guidance and mentorship throughout their studies, pointing to an absence of structure to assist them in relating their area of study with their post-university jobs.

Additionally, students from low-income households face increasing financial obstacles that could prevent them from pursuing specific work or placements. Those fears only grew during the pandemic, which prompted some students to reconsider their career aspirations in the industry.

More applicable/correlational education can also help students do well because they will be interested in their learning. It can pose universities to themselves by establishing a proper career guidance program, mentorship opportunities, skill development programs, workshops, and internships, catering to its challenges.

Sayitoğlu, F. (2019) explores the challenges for hospitality students, such as their experience and barriers to practical training, financial hardships, and career prospects. Interviews are excellent for showing how internships and exposure to real industry play a role in career decisions.

However, in your statement, you mentioned a set of themes that we /particular/all focused on and reacted to. The research explored challenges hospitality education students face, such as career development path certainties, tuition structures, and advocacy for structured mentorship and support (Mooney, S., & Jameson, S. 2018), which points to key student struggles.

A career development plan was developed that meets students' needs and aligns with their career aspirations in hospitality and tourism:

This development proposal addresses key elements to cultivate student growth and preparedness in the hospitality and tourism industry. On campus, students benefit from the dedicated career center, which offers workshops on career planning, resume building, and interview skills to strengthen career guidance, giving students clarity and confidence in their careers. This will be achieved by cooperating with local and overseas organizations for practical exposure where intern and student training opportunities exist. Mentorship programs where students will enter their university years can tap into alums and faculty mentors who could help provide personalized mentoring on academic and career development based on their lived experiences. In some organizations worldwide, we must adapt the curriculum according to industry directions and trends: sustainability, cultural compatibility, and technological evolution. Workshops will also be organized as part of the program to upskill the participants with soft skills like communication, teamwork, leadership, and adaptability. Supported by collaborative initiatives and finances from academia and industry members, these programs can prepare students for careers beyond hospitality audit and management.

Area for Development	Program/Activities	Objectives	Person Involved	Resources Needed	Source of Funds	Time Frame	Expected Results/Outcomes
Career Guidance and Counseling	Organize career planning workshops, resume building, and interview skills sessions.	To provide personalized career guidance and address students' concerns.	Career counselors, faculty, external speakers	Workshop materials, counseling space, audio-visual aids	University budget, external sponsors	Every semester	Students gain clarity in career paths and confidence in job readiness.
Industry Exposure and Internships	Develop partnerships with local and international hospitality organizations for internships.	To offer practical experience and prepare students for industry demands.	Faculty, industry professionals, internship coordinators	Partnership agreements, internship coordinators, training materials	Industry partnerships, university grants	Ongoing throughout the academic year	Students acquire hands-on experience and understand industry demands.
Mentorship Programs	Connect students with alumni and faculty mentors for guidance.	To guide students in academic and career planning through experienced mentors.	Alumni, faculty mentors, industry experts	Mentor database, communication tools	Alumni contributions, university funding	Initiate during the first semester and continue year-round	Students receive tailored guidance, boosting academic and career outcomes.
Curriculum Enhancement	Update the curriculum to include sustainability, cultural sensitivity, and technology advancements.	To ensure the curriculum aligns with current industry trends and demands.	Curriculum developers, faculty members, industry consultants	Updated teaching materials, industry reports, technology resources	University funds, government grants	Review annually, implement changes in the following academic year	Curriculum meets industry standards, enhancing student preparedness.
Skill Development Workshops	Conduct workshops on communication, teamwork, leadership, and adaptability.	To enhance students' soft skills critical for hospitality and tourism.	Workshop facilitators, industry professionals	Workshop materials, event space, training equipment	University budget, private sponsorships	Quarterly workshops	Students improve soft skills, fostering success in the industry.

IV. CONCLUSIONS AND RECOMMENDATIONS

Finally, this study determines what factors can be explored, considering the first-year student in Nueva Ecija's choice for a career in the Hospitality and Tourism Industry. The research is based on a combination of internal and external drivers that influence career decisions within the industry. The primary drivers are that the working student loves to travel and serve people and that they see a thriving industry with great opportunity.

The results suggest that students find the sector stable, with a long-term impact and guaranteed work opportunities, which aligns with their preference for a sustainable and rewarding career. This study also highlights the significant influences of family and school faculty. Upon being asked, the students thanked their training programs and the formal guidance they received from their teachers and programs, and they acknowledged that the industry was growing.

However, financial challenges, such as lack of exposure and inadequate guidance due to global impulses

like COVID-19, can destabilize their motivation. Therefore, the study recommends the importance of a mentorship and formal career development plan structured to meet the needs of both the students and the industry. It includes career guidance and counseling, experiential learning from internships, mentorship, and curriculum adjustment to reflect current talent needs.

Therefore, workshops to improve student communication, leadership, and teamwork skills are fundamental to preparing an adequate workforce.

In conclusion, while compelling career motivation is found in the first-year students in Nueva Ecija, these recurrent challenges necessitate stakeholders' cooperation in a well-structured industry talent training plan. Such a plan will ensure that the industry has the requisite talents and is well-motivated toward career achievement. This will happen when the learning institutions motivate their students to achieve the integral paths toward the industry they desire to develop.

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Using Tokenization and Random Forest Models to Predict Pandemic Trial Outcomes

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Abstract *– Since the onset of the COVID-19 pandemic, thousands of clinical trials have been launched to evaluate the effectiveness of interventions aimed at preventing or treating the virus. While many of these studies reached completion, a notable proportion were prematurely cessated. Using a comprehensive XML dataset of 5,783 COVID-19 trials registered on ClinicalTrials.gov, we developed a machine learning model to predict whether a trial was likely to be completed or cessated. Our findings, supported by token frequency analysis, highlighted those specific variables, namely the type of intervention and the trial location, played a significant role in distinguishing between outcomes. Trials that included 'hydroxychloroquine' or 'azithromycin' as interventions, and those conducted in locations such as 'France,' were more frequently associated with early cessation, reflecting shifting scientific consensus and regulatory changes over time.*

Keywords *– **COVID-19, clinical trials, cessation, interventions, machine learning.***

I. INTRODUCTION

SARS-CoV-2, first identified in Wuhan, China, is the causative agent of the COVID-19 pandemic, which has led to substantial global morbidity and mortality. In response to the emerging crisis, numerous international collaborations accelerated the development of pharmacological interventions to mitigate the health impacts of the pandemic. On January 6, 2020, Chinese authorities alerted the World Health Organization (WHO) about the novel coronavirus, prompting the U.S. Centers for Disease Control and Prevention (CDC) to activate a Level 2 emergency response shortly thereafter [1, 2]. By April 2020, the National Institutes of Health (NIH) launched the Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV) public-private partnership, designed to prioritize and expedite the evaluation of promising treatments and vaccines through coordinated clinical research [3]. This effort culminated in the release of a comprehensive NIH strategic plan in July 2020 to fast-track the development of effective therapeutics, vaccines, and diagnostic tools [4].

To secure regulatory approval by the U.S. Food and Drug Administration (FDA), these interventions required robust premarketing clinical trial data demonstrating safety and efficacy. As a result, thousands of trials were initiated globally to assess a wide range of COVID-19 prevention and treatment strategies. While many of these trials reached successful completion, others were suspended, terminated, or withdrawn due to evolving evidence, safety concerns, logistical barriers, or shifts in the pandemic landscape. Although several retrospective analyses have explored factors associated with trial completion or cessation, few studies have leveraged predictive modeling to identify trials at high risk of early discontinuation [5]. Given the ongoing need to optimize resource allocation and research planning in the face of future pandemics or emerging health threats, we aim to develop a model that can proactively predict which COVID-19 clinical trials are at greater risk for cessation.

II. MATERIALS AND METHODS

DATA SOURCE

The dataset utilized in this analysis comprises 5,783

COVID-19 clinical trials registered on ClinicalTrials.gov, the most comprehensive registry of private and publicly funded clinical studies conducted globally. Managed by the U.S. National Library of Medicine [6], ClinicalTrials.gov serves as a central resource for accessing detailed information on clinical research and is recognized as the gold standard for trial registries worldwide [7]. The dataset consists of XML-formatted files, with each file representing a single study and capturing extensive trial-specific information.

Key variables extracted from each trial entry include study conditions, sponsoring agency, agency classification, brief and detailed summaries, study status, start date, and participant eligibility criteria. Eligibility information is further delineated into inclusion and exclusion criteria to support refined cohort analysis. Additional metadata includes enrollment size, study phase, and type (e.g., interventional or observational), as well as intervention characteristics such as type and name. Critical elements of study design are also documented, including allocation methods, masking protocols, observation models, time perspectives, primary purposes, endpoint classifications, and geographic locations. This comprehensive structure allows for robust exploration of trial characteristics and enables predictive modeling to assess the factors associated with study cessation.

III. DATA PROCESSING

Data analysis for this project was conducted using Spyder for Python version 4.2.5. The process began with importing all necessary libraries, followed by loading the XML dataset into the working environment. Initial exploration was performed using the .info() command to manually assess the structure of the data. The original dataset contained 5,783 entries and 27 variables. To refine the analysis, we filtered the dataset to include only interventional studies, narrowing the sample to 3,322 trials.

Preprocessing steps included initializing empty lists to store reformatted variables and parameterizing key attributes such as participant age, study phase, trial start and end dates, sponsoring organization, funding source, and reported condition. Regular expressions (regex) were used to clean and standardize text inputs: columns with multiple entries were split using the pipe ("|") delimiter, special characters were removed, and textual numeric values were converted into integers where applicable.

Sponsorship data was recoded into three main categories; government, industry, and other to facilitate subgroup analysis. For age-related data, numerical values were extracted alongside keywords such as "months" and "years" and were classified into three distinct age brackets. The intervention and location fields, which consisted of unstructured free text, underwent additional cleaning procedures. These included removal of special characters, tokenization into individual words, conversion to lowercase, and elimination of stop words—terms that do not add substantive meaning (e.g., "the," "and," "of"). This preprocessing enabled more precise feature extraction for modeling and interpretation.

IV. DATA ANALYSIS

Our investigation was driven by two primary research questions. First, what are the underlying factors that differentiate COVID-19 trial cessation (defined as trials that were terminated, suspended, or withdrawn) from trial completion? Specifically, what contextual or design-related factors may influence whether a trial ceases or completes? Second, can we develop a predictive model to accurately classify COVID-19 trials as either completed or cessated based on available metadata?

To explore the first question, we began by computing descriptive statistics to compare characteristics between completed and cessated trials. We then directed our focus toward two unstructured text variables, location and intervention, which we hypothesized to be contextually significant in determining trial outcomes. We aimed to identify specific words or terms that appeared more frequently in completed trials versus those that were cessated. Using custom Python scripts, we calculated word frequencies and conditional probabilities for each variable and stratified the results by trial status. The distributions of term frequencies were then visualized using the matplotlib library to detect meaningful patterns.

To address our second research question, we constructed a predictive model using the same two variables (location and intervention) as input features. First, we vectorized the cleaned text strings using the Word2Vec algorithm from the gensim library to convert unstructured language into numerical representations. We then implemented a Random Forest classifier from the scikit-learn library. The model was trained on 80% of a balanced dataset, which consisted of 208 randomly selected completed trials and all 208 cessated trials. The remaining 20% of the dataset was used for testing to evaluate the model's performance in predicting whether a trial would complete or cease based on the intervention and location inputs.

V. RESULTS

Table 1: Characteristics of completed and cessated COVID-19 clinical trials.

	Completed	Cessated
Total number of trials included in dataset	460 (13.9%)	191 (5.75%)
Median number of participants	91	0*
Randomized	319 (69.3%)	153 (80.1%)
Non-Randomized	51 (11%)	7 (3.7%)
Open Label	255 (55.4%)	103 (53.9%)

*Most cessated trials were withdrawn, hence the large number of studies with 0 participants.

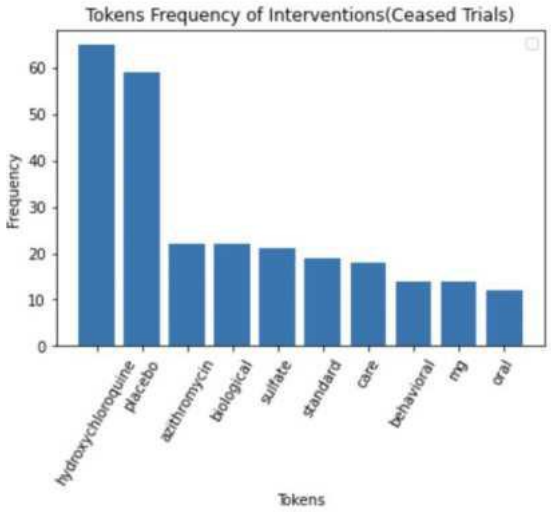
Out of the 5,783 clinical trials in our dataset, 3,322 were classified as interventional in design and were included in our final analysis. Among these, 191 trials (5.75%) were classified as *cessated*, encompassing studies that were withdrawn, terminated, or suspended prior to completion. Specifically, of the 191 cessated trials, 96 (50.3%) were withdrawn, 70 (36.6%) were terminated, and 25 (13.1%) were suspended. A full breakdown comparing completed and cessated trials is provided in Table 1.

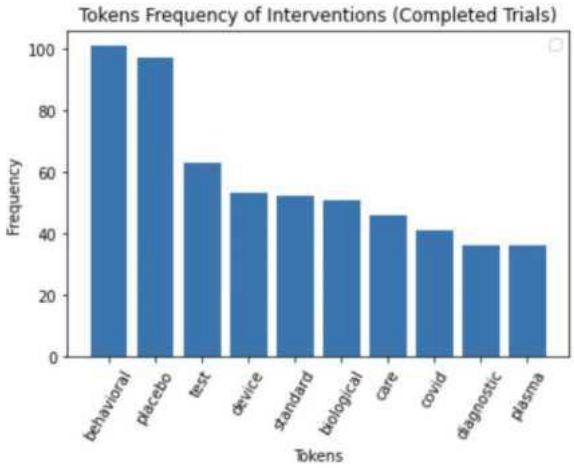
Regarding study design, the majority of cessated trials (144; 75.4%) utilized a parallel assignment model. Other study designs included single group assignment (34 trials; 17.8%), sequential assignment (9 trials; 4.7%), factorial assignment (3 trials; 1.6%), and crossover assignment (1 trial; 0.5%). Enrollment patterns varied significantly between completed and cessated trials. The median number of participants enrolled in cessated trials was 0, with an interquartile range of 0 to 47.5. Notably, 103 of the cessated studies (53.9%) had no participants enrolled at all. When excluding withdrawn studies and examining only suspended and terminated trials, the median enrollment increased to 50 participants, with a range of 17 to 133. In contrast, completed trials had a much higher median enrollment of 91 participants, ranging from 1 to 734,383 participants.

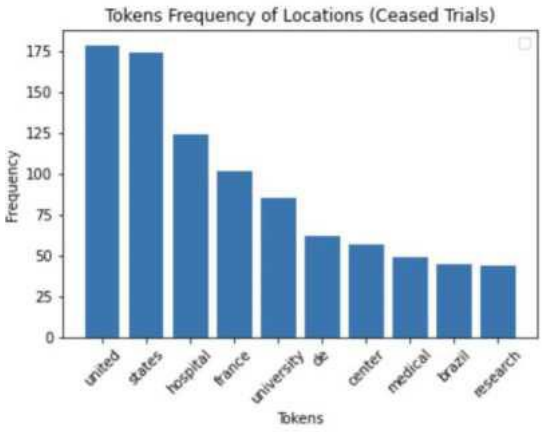
In our frequency and probability analyses of the *intervention* variable, the drug hydroxychloroquine emerged as the most prominent among cessated trials, appearing 65 times across the corpus. This drug was used in approximately 34% of all cessated trials. Similarly, azithromycin was also frequently present in cessated trials, appearing 22 times, corresponding to a 11.5% probability of occurrence in that group. Notably, no specific drugs appeared with comparably high frequency in the *intervention* field of completed trials, suggesting a more heterogeneous distribution of interventions in successful studies.

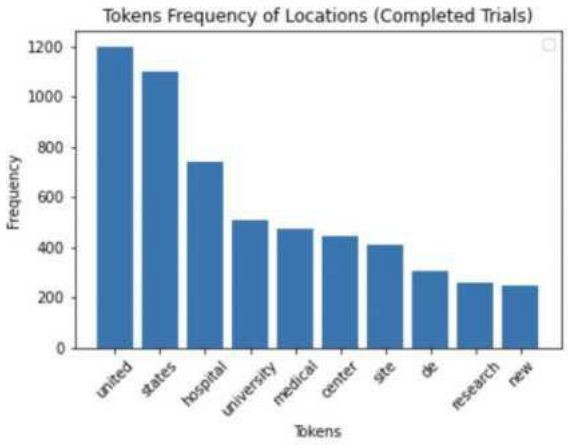
When analyzing the *location* variable, three country names were frequently associated with cessated trials: the United States, France, and Brazil. In contrast, only the United States appeared consistently in completed trials, indicating a possible geographic pattern related to trial discontinuation.

Visualizations of term frequencies and distributions for both the *intervention* and *location* variables, segmented by trial status (completed vs. cessated), are presented below. These figures illustrate the disproportionate presence of certain interventions and locations in discontinued studies, supporting the hypothesis that these unstructured text variables hold predictive value.









From the trained Random Forest classifier, we found the following prediction accuracy measures for the intervention and location variables for the completed and ceased trials: **Location variable**

	Completed	**Ceased**
Precision	0.587	0.857
Recall	0.925	0.409
Fscore	0.718	0.554

Intervention variable

	Completed	**Ceased**
Precision	0.771	0.735
Recall	0.675	0.818
Fscore	0.72	0.774

VI. DISCUSSION

Our analyses both in tokenization frequency and predictive modeling consistently demonstrated that the intervention and location variables were significant in distinguishing between cessated and completed COVID-19 clinical trials. Notably, specific tokens such as hydroxychloroquine and azithromycin within the intervention field, and France within the location field, were disproportionately present in cessated trials. These findings may, in part, reflect the influential role of French microbiologist Dr. Didier Raoult, whose early promotion of hydroxychloroquine (HCQ) and azithromycin (AZM) as a COVID-19 therapy garnered global attention and catalyzed numerous clinical investigations.

Hydroxychloroquine, an antimalarial drug also used in autoimmune conditions like systemic lupus erythematosus (SLE) and rheumatoid arthritis (RA), has mechanisms believed to involve

immunomodulatory and anti-inflammatory effects, though its precise antimicrobial mechanism remains unclear [8]. Early in the pandemic, Dr. Raoult's group published in vitro data suggesting HCQ-AZM synergy was toxic to SARS-CoV-2 [9]. This was followed by a small, non-randomized, open-label clinical trial involving 36 COVID-19 patients, which further fueled enthusiasm for the drug combination [10]. Dr. Raoult's public assertions of success, such as his claim that "we know how to cure the disease"—along with a similar report from China, led to a surge in HCQ-related trials globally. At one point, hydroxychloroquine was the subject of one in every five drug trials registered worldwide [11].

However, the initial promise of HCQ-AZM was not borne out in subsequent, more rigorously designed trials. Accumulating evidence demonstrated not only inconsistent efficacy but also significant risks, particularly the increased likelihood of fatal cardiac arrhythmias when HCQ and AZM were used in combination [8, 12, 13]. Moreover, Raoult's study has been heavily criticized for numerous methodological shortcomings, including a small sample size, poorly defined endpoints, lack of randomization, and absence of blinding [8, 9]. These flaws raised serious concerns about internal validity and potential bias, especially given Dr. Raoult's public advocacy of HCQ. Such methodological limitations may have played a critical role in the early cessation of many similar trials inspired by the initial findings.

Turning to model performance, our predictive analysis further validated the utility of the intervention and location variables. Precision scores defined as the ratio of true positives to all predicted positives, exceeded 50% for both completed and cessated trials using both variables. Recall the ratio of true positives to all actual positives was notably high for completed trials: approximately 90% when using the location variable and 67% when using the intervention variable. For cessated trials, recall was strongest with the intervention variable at 81%, but dropped below 50% when using location as the sole predictor. These results suggest that the intervention variable may be more predictive of cessation than the location variable when assessed using recall.

The F1-score, which balances precision and recall, showed that both variables performed comparably in predicting completed trials. However, for cessated trials, the intervention variable yielded a higher F1-score, reinforcing its greater predictive value in identifying trials at risk for discontinuation.

Future research should expand upon this foundation by exploring additional predictors such as funding source, eligibility criteria, and study phase. Moreover, replicating and refining this predictive model with larger datasets and an expanded range of structured and unstructured features would likely enhance its robustness and utility for real-time risk assessment in trial planning and monitoring.

VII. IMPLICATIONS

The findings of this study have important implications for public health planning and emergency preparedness, particularly in the context of rapidly evolving health crises like the COVID-19 pandemic. By identifying key predictors of clinical trial cessation specifically intervention type and geographic location, this research contributes to a growing body of knowledge that can be leveraged to improve the design, prioritization, and oversight of emergency-related clinical research.

First, the ability to predict which trials are at risk of early termination can help policymakers and funding agencies allocate limited resources more effectively. During pandemics or other public health emergencies, time and funding are often constrained. A predictive framework such as the one developed in this study can inform decision-makers about which proposed studies are more likely to reach completion, thus improving the efficiency of research pipelines and accelerating the delivery of actionable results to clinicians and public health officials.

Second, our findings highlight the potential consequences of early enthusiasm around interventions such as hydroxychloroquine and azithromycin that may lack robust supporting evidence. This underscores the critical need for stronger early-stage vetting of therapeutic candidates and trial protocols, especially when public and political interest can lead to an overconcentration of trials around a limited set of interventions. Strengthening mechanisms for scientific rigor and peer oversight in early-phase trials can reduce redundancy and prevent the rapid proliferation of poorly designed studies during emergencies.

Lastly, incorporating predictive tools into public health infrastructure can support future pandemic preparedness efforts. Such tools can be integrated into clinical trial registries and decision-support systems to flag at-risk studies in real time. This would enable research oversight bodies to intervene early whether by providing additional support, recommending design modifications, or redirecting efforts thereby enhancing the overall resilience and responsiveness of the public health research ecosystem. In sum, predictive modeling of trial outcomes holds promise not only for improving research efficiency but also for ensuring that the scientific response to public health emergencies is timely, evidence-based, and strategically aligned with population health needs.

VIII. LIMITATIONS

This study has several limitations. First, the analysis relied on our own interpretations of variable fields, as the dataset did not include comprehensive metadata or variable descriptions. As a result, some categorizations may have introduced subjective bias. Second, during preprocessing of the intervention and location variables, we excluded symbols and non-English terms to improve consistency and reduce noise; however, this may have resulted in the loss of potentially meaningful information. Third, the predictive model was developed using a limited set of input variables, which increases the risk of overfitting and may limit the model's applicability to other datasets. Finally, the findings are specific to interventional COVID-19 clinical trials and may not be generalizable to observational studies or to trials targeting other diseases or conditions.

IX. CONCLUSION

The results from both our tokenization frequency analysis and predictive modeling were consistent, indicating that the intervention and location variables effectively differentiated between cessated and completed trials. Notably, certain tokens such as hydroxychloroquine and azithromycin under the intervention variable, and France under the location variable were present in cessated trials but absent in completed ones.

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The Quiet Consequences of Scrolling: Conceptualizing Social Media Wellness

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Abstract *— This conceptual review investigates the emerging paradigm of Social Media Wellness (SMW) and its potential implications for family relationships. It synthesizes literature on digital engagement behaviors, psychological and social outcomes of excessive platform usage, and proposes a theoretical lens to understand how digital well-being aligns with familial cohesion. Drawing on interdisciplinary research, this review emphasizes how digital routines, emotional reliance on online interactions, and constant connectivity can affect the emotional climate of households. The review offers a framework for future empirical studies and highlights the importance of awareness among individuals, educators, and policymakers to ensure healthier digital-social integration.*

Keywords *— **Social Media Wellness, family relationships, digital engagement, emotional climate, digital well-being.***

I. INTRODUCTION

In contemporary society, digital interactions are deeply woven into daily life. Social media platforms—once tools for convenience—have evolved into powerful spaces influencing identity, emotion, and relationships. While these platforms offer connectivity, they also provoke digital overload, fragmented attention, and emotional volatility (Verduyn et al., 2017; Buchi et al., 2019). As people increasingly turn to online environments for affirmation, entertainment, and information, the dynamics of offline relationships, especially within families, are shifting.

The construct of Social Media Wellness (SMW) has emerged in response to these disruptions. Unlike digital detox or pathology-based models that frame internet usage as addiction, SMW promotes balance, regulation, and emotional clarity while using social platforms (Anderson et al., 2024). In this paper, we explore how conceptualizing SMW can provide insights into its relationship with family well-being and offer a foundation for intervention.

SOCIAL MEDIA WELLNESS: A CONCEPTUAL FOUNDATION:

The term wellness, traditionally used in physical and mental health contexts, now extends to digital engagement. Wellness includes "balance across and within dimensions" of life—social, emotional, spiritual, and physical (Adams et al., 1997). In digital terms, this implies thoughtful, non-disruptive, and enriching use of social media.

Several scholars describe how online behaviours—such as endless scrolling, compulsive engagement, or obsessive monitoring—are associated with psychological stress, emotional fatigue, and reduced life satisfaction (Dhir et al., 2021; Buda et al., 2020). These patterns can interfere with rest, daily priorities, and interpersonal connections. The concept of SMW integrates emotional regulation, behavioral moderation, and cognitive awareness in online interaction.

Moreover, SMW is not just about personal experience—it reflects the social ecology of digital life.

For instance, expectations to remain perpetually available and responsive online can induce digital stress (Steele et al., 2020), which may spill over into home settings, influencing how individuals relate to family members.

OFFLINE IMPACT OF ONLINE ENGAGEMENT:

Family systems are particularly sensitive to technological intrusions. Traditional models of family cohesion rely on in-person interaction, quality time, and shared values (James et al., 2017). However, these elements may be compromised by digital distraction, especially when online presence takes precedence over real-time interaction.

Studies show that many young adults prefer virtual engagements over physical ones, with social media usage becoming a habitual behavior that reshapes attention and communication (Mertz et al., 2023; Mahmoud & Shafik, 2020). Evidence from recent research points to diminished face-to-face conversations and missed social rituals (e.g., shared meals, family outings) as by-products of immersive social media use (Sharaievska & Stodolska, 2016).

Furthermore, the emotional consequences of online exposure—such as envy, frustration, or unrealistic comparisons—can create latent tension in offline interactions (Naderer et al., 2021). Feelings of exclusion, over-sharing, or indirect expression of grievances online can indirectly weaken intra-family trust and openness.

EMERGING ISSUES IN DIGITAL WELLNESS:

- **Psychological Spillovers**

Digital platforms frequently stimulate a wide range of emotional responses—from joy and belonging to anxiety and dissatisfaction (Valkenburg et al., 2022). These emotions, when not managed consciously, may manifest in interpersonal settings, influencing mood and communication style at home.

- **Behavioral Intrusions**

Studies have documented that screen time late at night, often driven by social notifications or compulsive checking, disrupts natural sleep cycles (Schuur et al., 2018). Poor sleep can alter temperament and reduce availability for family engagement the next day, making digital routines a key influencer of emotional presence.

- **Erosion of Boundaries**

Social media has blurred boundaries between private and public life. Users often share personal stories, celebrations, or grievances online, potentially sidelining close, intimate discussions with family. This trend raises questions about relational authenticity and privacy saturation in domestic spheres (Dhir et al., 2021).

- **Monitoring and Surveillance Culture**

A rising behavioral concern is the normalization of monitoring others' activities online—a subtle yet pervasive form of digital control (Smoker & March, 2017). Within families, this may manifest as mistrust, perceived surveillance, or emotional withdrawal, especially in households where digital transparency replaces direct communication.

II. A CONCEPTUAL FRAMEWORK

Based on the themes identified above, we propose a conceptual framework where social media wellness is positioned as a mediating construct between digital behavior and family well-being. Rather than isolating variables, we categorize digital challenges into three broad clusters:

- **Emotional Overdependence** (e.g., seeking validation online, mood affected by social feedback)
- **Behavioral Disruption** (e.g., sleep interference, attention diversion during family time)
- **Relational Disengagement** (e.g., reduced communication, preference for digital over physical presence)

These clusters interact with one another and collectively influence family dynamics (Dhir et al. 2021; Gui et al. 2017; Valkenburg & Driel 2022). We recommend that future empirical research test this triadic model using moderation and mediation analysis techniques to explore how different household demographics experience these dynamics.

IMPLICATONS:

- **For Educators**

Curriculum design in schools and universities can incorporate digital wellness literacy, teaching students to reflect on their digital choices and

understand their social-emotional consequences (Anderson et al., 2024).

- **For Families**

Families can benefit from establishing digital rituals—such as screen-free dinners or shared log-off times—to reinforce in-person bonding. Parental modeling plays a crucial role in shaping children's long-term digital habits (Savci et al., 2020).

- **For Policymakers**

National campaigns focused on responsible digital behavior and family-first engagement can promote social awareness. Posters, infographics, or even AI-based interventions can be deployed to sensitize users to balance digital engagement with relational integrity (Mertz et al. 2023; Seabrook et al. 2016).

III. CONCLUSION

The notion of social media wellness has evolved from an individual-centered idea into a relational necessity. As this review shows, unbalanced digital practices are not just personal concerns—they shape emotional climates and social structures, beginning with the family. Conceptualizing and promoting SMW offers a pathway toward more harmonious coexistence between digital life and real-life bonds. Future research must further refine this construct, explore cultural nuances, and design context-specific interventions that support healthy digital living.

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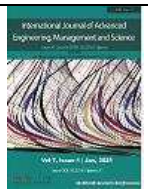

IOT- Based Smart Irrigation System

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Abstract*—Agriculture is a crucial sector that faces challenges, such as water scarcity, inefficient irrigation techniques, and increasing global food demand. The integration of the Internet of Things (IoT) into smart irrigation systems enhances water management, conserves resources, and improves crop yield. This study presents an IoT-based smart irrigation system that utilizes real-time environmental data to optimize irrigation schedules. This system employs soil moisture sensors, weather forecasting, and cloud computing to facilitate precise irrigation. This study demonstrates that the proposed system enhances efficiency while reducing water consumption. These results highlight the significance of automation in modern agriculture and its impact on sustainability and food security.*

Keywords*— *IoT-Based Smart Irrigation, Water Management, Sustainable agriculture, Water conservation, Remote monitoring.

I. INTRODUCTION

Agriculture plays a vital role in the global economy and food security. However, the sector faces mounting challenges, including water scarcity, inefficient irrigation techniques, and the increasing demand for food production driven by a growing global population. Traditional irrigation methods, often relying on manual intervention and fixed schedules, contribute to water wastage and fail to address the dynamic needs of crops. With freshwater resources becoming increasingly scarce, there is a pressing need for innovative solutions that optimize water use in agriculture.

The Internet of Things offers a transformative approach to address these challenges. By integrating sensors, actuators, and communication networks, IoT-based smart irrigation systems enable real-time monitoring and control of irrigation processes**.** These systems collect environmental data, such as soil moisture levels and weather conditions, and use this information to adjust irrigation schedules dynamically, ensuring that crops receive the precise amount of water they need, when they need it. This targeted approach not only conserves water but also improves crop yields by preventing both under-

watering and over-watering, which can negatively impact plant growth**.**

This study presents an IoT-based smart irrigation system designed to address the challenges of water scarcity and inefficient irrigation. The proposed system utilizes a network of soil moisture sensors to monitor real-time soil conditions. This data is processed using cloud computing resources to generate optimized irrigation schedules. The system automatically adjusts irrigation based on these real-time insights, ensuring efficient water use and promoting optimal crop growth. The primary goal of this research is to demonstrate the effectiveness of the proposed system in enhancing irrigation efficiency, reducing water consumption, and ultimately contributing to sustainable agriculture and improved food security. The subsequent sections of this paper will detail the system architecture, methodology, results, and implications of this research.

Previous research on IoT-based smart irrigation systems has focused on optimizing water management and enhancing agricultural productivity. Studies such as those by Kumar et al. (2022) and Rawal (2017) **[1]** have demonstrated the effectiveness of IoT in automating irrigation processes. These systems leverage real-time data from sensors like soil moisture, temperature, and humidity to reduce water and energy consumption significantly. Additionally, recent studies have integrated weather stations alongside soil moisture sensors to gather real-time meteorological data, enabling more precise irrigation scheduling and enhancing crop productivity, as noted by Singh et al. (2022) **[5].** The use of embedded systems for real-time irrigation control has also been explored, allowing for dynamic adjustments based on environmental conditions to improve water use efficiency**[7].** Furthermore, efforts to integrate solar-powered IoT devices into irrigation systems aim to reduce energy consumption while maintaining effective water management. Despite these advancements, challenges such as cost, scalability, and environmental adaptability remain, with future research directed towards refining algorithms for drought stress management and improving water productivity in agriculture. Overall, these studies highlight the potential of IoT-based smart irrigation systems in addressing modern agricultural challenges and provide a strong foundation for further research in precision agriculture technologies.

II. METHODOLOGY

The development of the IoT-based smart irrigation system involved the integration of hardware and software components to automate irrigation processes and optimize water usage. The system was designed to monitor environmental parameters, analyze data in real-time, and control irrigation schedules based on predefined thresholds.

A. System Design and Components

1. Sensors:

The proposed system utilized a combination of sensors and microcontrollers to collect and process data. Sensors are the backbone of the system, providing real-time data on environmental and soil conditions. The following sensors are commonly used:

- **Soil Moisture Sensor**: This sensor measures the volumetric water content in the soil, which is crucial for determining when irrigation is needed**[5].** It provides analog or digital output that the microcontroller processes to assess soil dryness or wetness. Advanced models also monitor salinity and electrical conductivity, offering insights into soil health.
- **Temperature and Humidity Sensor (DHT11)**: This sensor tracks environmental temperature and humidity levels. These parameters are vital for calculating evapotranspiration rates, which influence irrigation schedules.
- **Weather Sensors**: Some systems include weather sensors to monitor rainfall, humidity , temperature. These sensors help adjust irrigation schedules dynamically based on local weather conditions.

The sensors are strategically placed across the field to ensure comprehensive data collection.

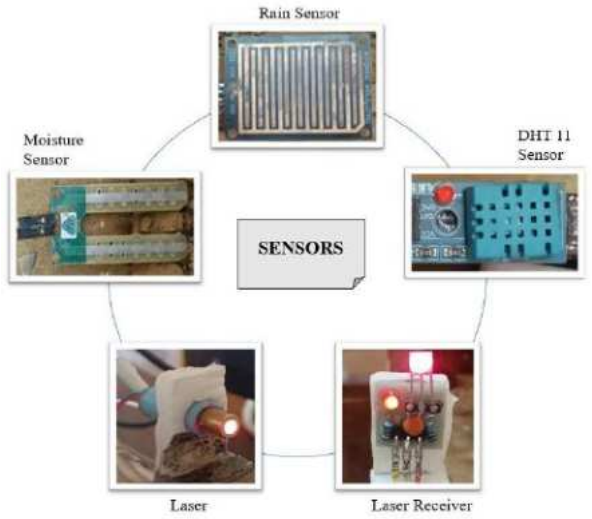

Fig.1 Types of sensors used

2. Microcontroller:

The microcontroller acts as the central processing unit of the system:

- *Arduino UNO* processes data from connected sensors and executes commands such as turning on/off water pumps or valves. *Node MCU ESP8266* microcontroller is widely used due to its built-in Wi-Fi module, which facilitates seamless communication with cloud platforms**.**

Arduino UNO is a microcontroller board based on the *ATmega328P*. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Node MCU's ability to handle both data processing and wireless communication makes it ideal for IoT applications.

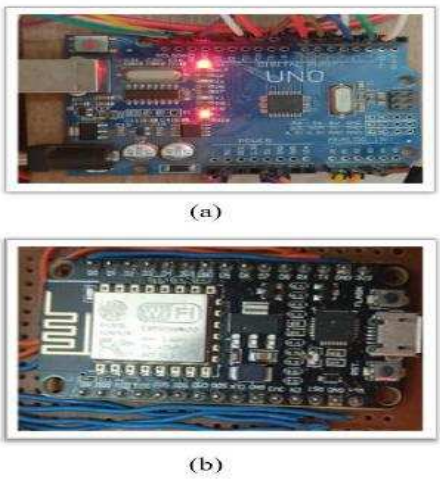

Fig. 2 (a) Arduino UNO and (b) ESP8266

3. Actuators:

Actuators are responsible for executing the irrigation process based on sensor data. A *DC motor pump* is used to supply water to the field. The pump is activated when soil moisture levels drop below a predefined threshold. *Solenoid valves* regulate water flow with high precision. They open or close based on commands from the microcontroller. These actuators ensure that water is delivered efficiently to crops without manual intervention.

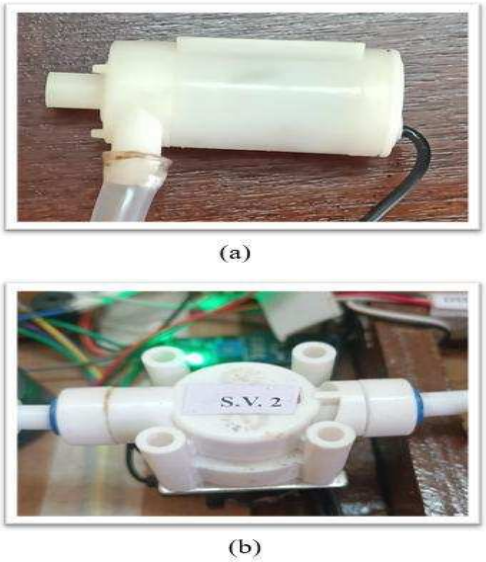

Fig. 3 (a) Water Pump and (b) Solenoid Valve

4. Relay Module:

The relay module acts as an intermediary between the low-power microcontroller and high-power devices like water pumps. It allows the microcontroller to control devices operating at higher voltages (e.g., 5V–12V). A transistor circuit within the relay ensures safe operation when switching high-power devices on or off. The relay module's role is critical in enabling automation while protecting sensitive components from power surges.

Fig. 4 Relay Module

5. Power Supply:

A reliable DC power supply is essential for uninterrupted operation. The Node MCU, Arduino UNO and sensors typically operate at 3.3V or 5V DC, provided by a regulated power source. This combination of power sources ensures efficiency and reliability in remote agricultural settings.

6. Communication Module:

The communication module facilitates data exchange between system components and cloud platforms. The built-in Wi-Fi module of Node MCU ESP8266 enables real-time data transmission to IoT platform ThingSpeak**.**

Data collected by sensors is uploaded to the cloud for storage, analysis, and visualization. Farmers can access this data remotely, allowing them to monitor field conditions and control irrigation operations in real time. This seamless communication ensures that users stay informed about their fields' status at all times.

7. System Integration:

All components are integrated into a cohesive system through careful circuit design. The soil moisture sensor connects to the analog input pins (e.g. A0,A1,A2 and so on) of Arduino UNO. Other sensors (e.g., DHT11) connect to digital GPIO pins (e.g., D1). The relay module connects to another GPIO pin (e.g., D0) for controlling actuators like pumps or valves.

Custom algorithms programmed into the Arduino UNO process sensor data and make decisions based on predefined thresholds**[4][5].** For instance: If soil moisture falls below a set threshold, the pump is activated until optimal moisture levels are restored. Weather data can be factored in to delay irrigation if rainfall is expected.

This modular design allows scalability, enabling additional features like advanced weather forecasting or solar integration to be added as needed.

B. Circuit Diagram

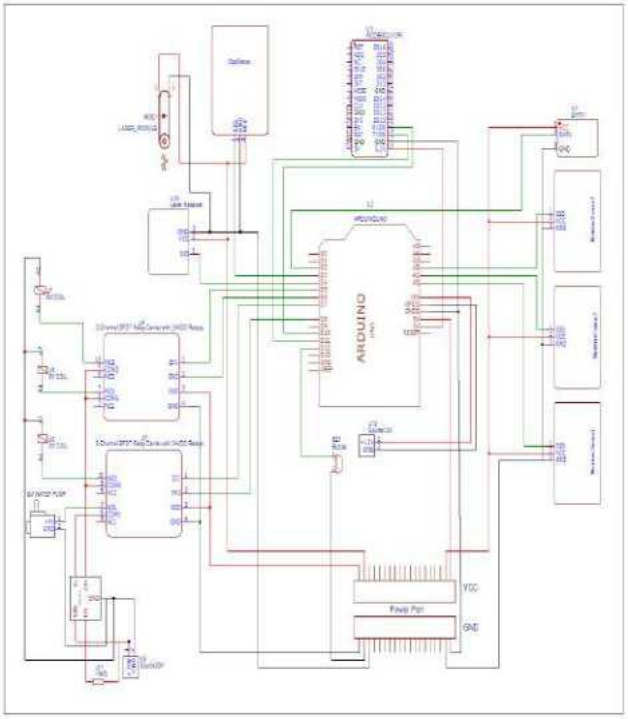

Fig. 5 Circuit Diagram

The circuit schematic for the Smart Irrigation System was designed and developed using *Easy EDA software*. This schematic represents the complete

hardware architecture of the system, integrating multiple electronic components for automated irrigation based on environmental conditions.

The circuit diagram presents a detailed IoT-enabled environmental monitoring and smart irrigation system, orchestrated by an Arduino Uno microcontroller at its core. The Arduino collects data from a network of sensors, including three soil moisture sensors strategically placed at different locations (labeled Moisture Sensor 1, 2, and 3), each directly connected to individual analog input pins on the Arduino for precise moisture level readings. For security, a laser diode and receiver are implemented for intruder detection, with the receiver connected to a digital input pin to signal any interruptions in the laser beam. Although not explicitly labeled, connections suggest integration of additional sensors for temperature and humidity, critical for a comprehensive environmental overview. Actuation is managed through three 2-channel SPDT relay carriers configured to control solenoid valves, enabling targeted irrigation to specific areas based on the corresponding moisture sensor readings. These relays are linked to digital output pins on the Arduino, allowing precise control over water flow. A separate relay is dedicated to controlling a water pump, ensuring a broader irrigation response when overall moisture levels are low. An auditory alarm, in the form of a buzzer, is connected to a digital output pin to provide immediate alerts upon intruder detection. Power is delivered via a power port, distributing the necessary voltage to the Arduino, sensors, and actuators, with appropriate voltage regulation implemented where needed to ensure component compatibility and stability. The intricate arrangement allows the system to continuously monitor environmental conditions, and autonomously respond with targeted irrigation and security measures, making it highly suitable for smart agriculture and automated greenhouse applications.

C. Flow Chart

The flowchart illustrates a detailed process for an automated environmental control system, likely used in applications like smart agriculture or greenhouse management. The system initializes by setting up the necessary sensors (temperature, humidity, moisture, rain, and potentially a laser sensor), along with an LCD for local display and configuring the required pins for controlling external hardware. It then proceeds to read data from all the initialized sensors, gathering comprehensive environmental information. This data is then displayed on the LCD screen, providing immediate feedback to anyone present. Following this, the system checks for specific conditions to trigger automated actions. First, it assesses if it is raining; if it is, the system bypasses the intruder detection step, presumably because rain might interfere with accurate detection. If no rain is detected, the system checks for potential intruders, likely using the laser sensor; if an intruder is detected, a buzzer is activated to provide an alert, otherwise, the buzzer remains off. Subsequently, the system delves into moisture management. It evaluates moisture levels at three distinct locations (Moisture1, Moisture2, Moisture3), and if the moisture level at any of these locations is below a threshold of 500, the corresponding solenoid valve is opened, enabling targeted irrigation to that specific area; otherwise, the valve remains closed. A more general moisture check is then performed; if the overall moisture level is below 600, a pump is activated to provide broader irrigation, otherwise, the pump is turned off. Finally, all the collected sensor data is transmitted to an ESP8266 module, enabling data logging, remote monitoring, or integration with other smart systems. The system then enters a delay period before repeating the entire process, effectively creating a continuous loop of environmental monitoring and automated control. This continuous feedback loop allows for real-time adjustments and ensures optimal conditions are maintained automatically.

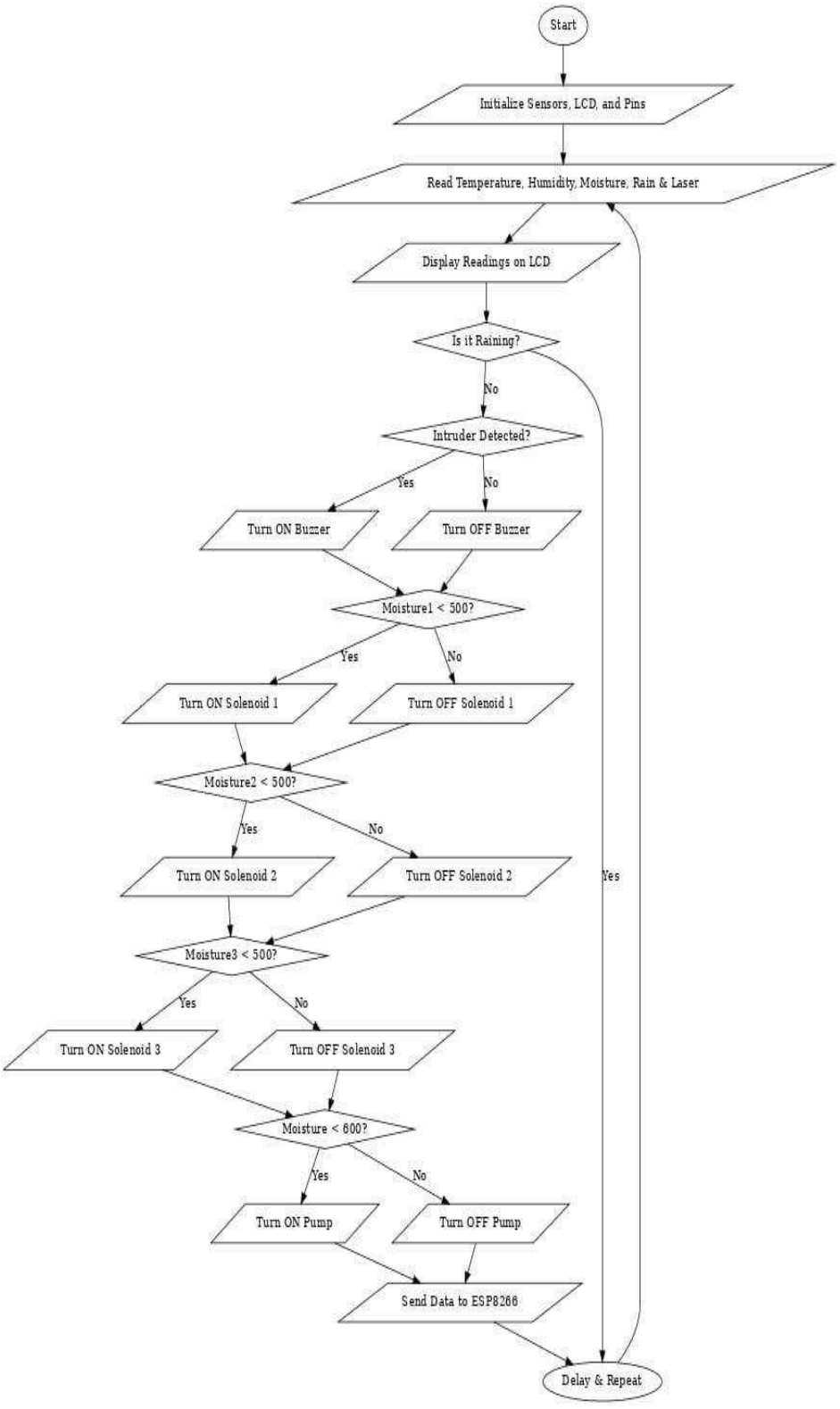

Fig. 5 Flow Chart of the process

III. ANALYSIS

The analysis of the IoT-based smart irrigation system focuses on evaluating its performance, reliability, and efficiency in managing water resources and optimizing agricultural productivity. This section outlines the key findings derived from data processing, system testing, and performance evaluation.

1. Data Analysis and Decision-Making

The system collects real-time data from sensors, including soil moisture, temperature, humidity, and weather conditions. The collected data is analyzed using predefined threshold values and intelligent algorithms to make irrigation decisions:

- **Threshold-Based Analysis**: Soil moisture levels are continuously monitored and compared against predefined thresholds**[3].** When moisture levels drop below the lower limit, irrigation is initiated; when they reach field capacity, irrigation is stopped**[5].**
- **Weather Data Integration**: Real-time weather data (e.g., rainfall predictions) is incorporated into the decision-making process to avoid unnecessary irrigation during rainy periods**[2].**
- **Edge Computing**: In some systems, data analysis is performed at the edge (e.g., on the microcontroller), reducing latency and ensuring faster decision-making.

This analytical approach ensures precise water distribution, minimizing wastage while maintaining optimal soil conditions for crop growth.

2. Performance Metrics

The system's performance was evaluated using various metrics:

- **Accuracy**: Machine learning models applied to analyze sensor data achieved high accuracy levels (e.g., 89%–98%), ensuring reliable irrigation decisions.
- **Water Savings**: Studies reported significant reductions in water usage—up to 35% compared to traditional methods—by stopping irrigation when soil moisture reached field capacity.
- **Energy Efficiency**: Solar-powered systems demonstrated sustainable operation by reducing dependency on external electricity sources.

These metrics highlight the system's ability to conserve resources while maintaining agricultural productivity.

3. Visualization and Monitoring

The analyzed data is visualized on IoT platform ThingSpeak. Users can monitor real-time sensor readings (e.g., soil moisture, temperature) through mobile or web applications. Historical data trends are displayed for better understanding and optimization of irrigation schedules.

Notifications or alerts are sent to users for critical events, such as low soil moisture or pump malfunctions. This visualization enhances user interaction with the system, enabling informed decision-making and remote control of irrigation processes.

4. System Reliability

The reliability of the system was assessed through field tests under varying environmental conditions. The system consistently maintained soil moisture within optimal ranges for crops like corn and brinjal. Fail-safe mechanisms (e.g., stopping pumps during sensor malfunctions) ensured uninterrupted operation. These results demonstrate that IoT-based smart irrigation systems are robust and adaptable to diverse agricultural settings.

5. Challenges Identified

Despite its advantages, certain challenges were observed during analysis:

- **Scalability**: Expanding the system for larger fields requires additional sensors and communication modules, increasing costs.
- **Environmental Adaptability**: Extreme weather conditions (e.g., heavy rainfall) may affect sensor accuracy or communication reliability.
- **Data Security**: Protecting sensitive agricultural data from cyber threats remains a concern in IoT systems.

IV. RESULTS

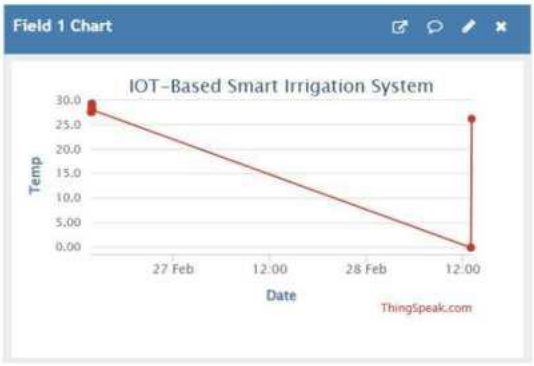

Fig. 6 Field 1: Temperature

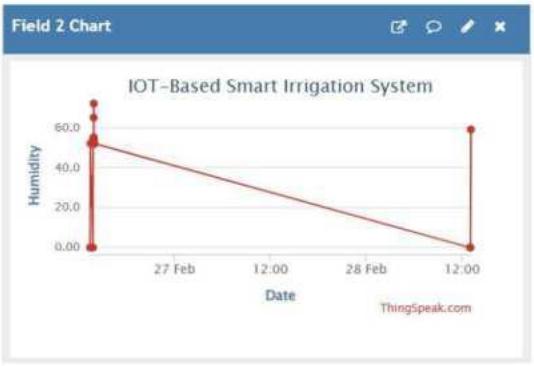

Fig. 7 Field 2: Humidity

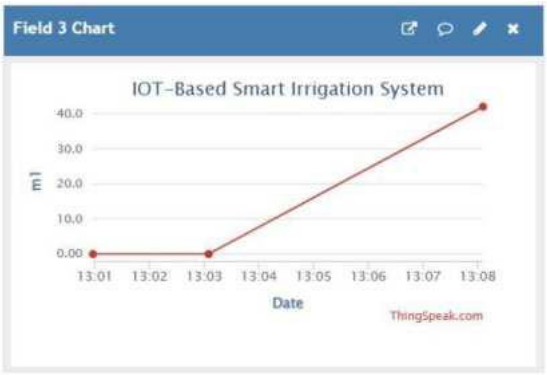

Fig. 8 Field 3: Moisture Sensor 1

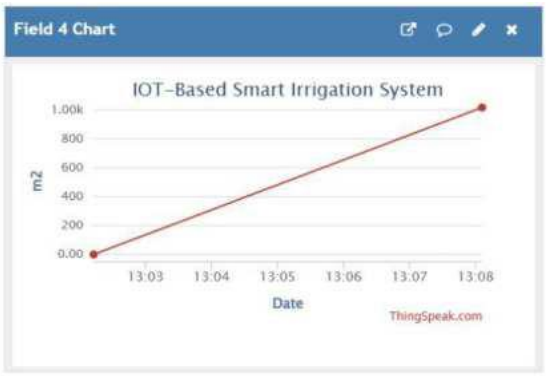

Fig. 9 Field 4: Moisture Sensor 2

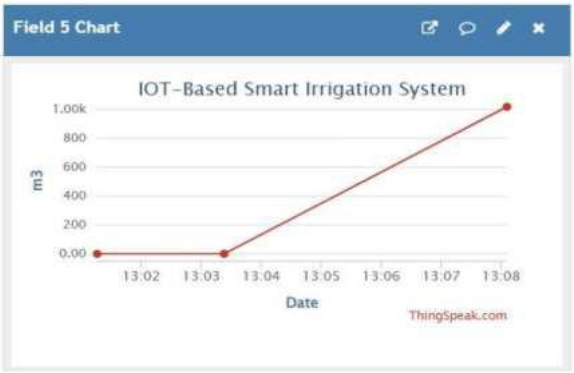

Fig. 10 Field 5: Moisture Sensor 3

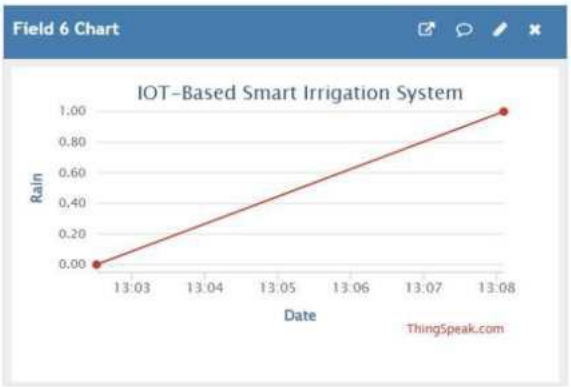

Fig. 11 Field 6: Rain Sensor

Fig. 12 Field 7: Laser Sensor

The results of the environmental monitoring and control system were successfully recorded and analyzed using the ThingSpeak IoT platform. The system utilized multiple sensors to measure environmental parameters such as temperature, humidity, soil moisture levels, rain detection, and intruder detection**.** The data collected from these sensors was transmitted to the ThingSpeak platform via the ESP8266 module for real-time visualization and analysis. The graphical representation of the sensor data on ThingSpeak provided valuable insights into the system's performance and environmental conditions.

The results are presented in a series of graphs which display the trends and variations in the collected data over time. Each field on the ThingSpeak platform corresponds to a specific sensor parameter**.** *Fig.6* shows that in field 1, the *temperature* readings showed consistent variations throughout the monitoring period, reflecting environmental changes. The graph highlights the system's ability to accurately track temperature fluctuations. *Fig.7* shows that in field 2, *humidity* levels were recorded and displayed, demonstrating the system's capability to monitor atmospheric moisture effectively. *Fig.8,9 and 10* shows that in fields 3, 4, and 5, the *soil moisture* levels at three different locations were monitored. The graphs indicate when irrigation was triggered based on predefined thresholds. For instance, when soil moisture dropped below 500 units, the corresponding solenoid valve was activated to irrigate that specific area. *Fig.11* shows that in field 6 , *rain* events were detected using the rain sensor, with corresponding data points logged on ThingSpeak. This feature allowed the system to bypass irrigation during rainy conditions. *Fig.12* shows that in field 7, *intruder* alerts were logged whenever the laser sensor detected movement. This functionality ensures security in agricultural or greenhouse environments.

The ThingSpeak platform provided a centralized interface for monitoring all sensor data in real time, enabling remote access and analysis of environmental conditions. This integration not only facilitated efficient irrigation management but also ensured optimal resource utilization by preventing overwatering during rain or when sufficient soil moisture was detected.

The results demonstrate that the proposed IoT-based smart irrigation system is highly effective in automating environmental monitoring and control processes. The results highlight the significance of IoT-based systems in automating irrigation processes while conserving resources and improving agricultural productivity**[5].** The accurate detection of sensor data and its seamless transmission to ThingSpeak highlight the reliability and scalability of this system for smart agriculture applications.

V. CONCLUSION

The IoT-based Smart Irrigation System is a significant step toward modernizing agriculture by integrating advanced technologies to address traditional irrigation challenges. This project demonstrates the potential of IoT to revolutionize farming practices, ensuring efficient use of water and other resources, improving crop yields, and reducing manual labour. The system optimizes water usage by monitoring real-time soil moisture levels and environmental conditions. By automating the irrigation process, it prevents over-irrigation and under-irrigation, contributing to sustainable water management. Automating irrigation reduces labour costs and minimizes water and energy wastage, offering long-term economic benefits for farmers, especially in water-scarce regions. By conserving water and reducing resource wastage, the project aligns with global efforts toward sustainable farming and addresses critical issues like water scarcity and climate change.

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