IJCR

International Journal of Convergent Research

Editor-in-Chief:
Dr. Monika Yadav

2024

Vol.1 No.1

International Journal of Convergent Research

ABOUT THE JOURNAL

The International Journal of Convergent Research (IJCR) is a multidisciplinary, peer-reviewed, open-access and referred journal dedicated to advancing the frontiers of research through the integration of diverse fields of study. IJCR aims to foster innovation and collaboration by publishing high-quality research that bridges the gaps between traditional disciplines, promoting convergent approaches to address complex global challenges. With a commitment to excellence, IJCR provides a platform for researchers, scholars, and practitioners to share their findings, insights, and advancements in a wide array of subjects.

Vision

To be a leading global forum for convergent research that integrates diverse disciplines, inspires transformative ideas, and empowers researchers to achieve sustainable solutions. By setting new standards in scholarly communication and fostering impactful research, IJCR seeks to shape the future of knowledge creation and application in a rapidly changing world.

Mission

To foster interdisciplinary collaboration and disseminate innovative, high-quality research that bridges gaps across diverse fields of study. IJCR aims to create a platform for scholarly exchange that drives societal progress, addressing complex challenges through convergence, inclusivity, and global engagement.

EDITORIAL BOARD

JOURNAL CONTACT INFORMATION

Dr. Monika Yadav, *Editor in Chief*
Mr. Nitish Kumar Minz, *Managing Editor*
Phone No.: +91 70426 57038, +91 88606 72581
Mail: editorinchief@ijcres.in, managingeditor@ijcres.in

JOURNAL WEB ADDRESS

https://ijcres.in/index.php/ijcr/index

Webmaster

Mr. Om Mishra,
Phone No.: +91 99710 50641
Mail: contact@om-mishra.com

TABLE OF CONTENT

EDITORIAL MESSAGE

Welcome to the inaugural issue of the *International Journal of Convergent Research (IJCR)*. It is with immense pride and excitement that we introduce this scholarly platform, envisioned as a beacon of innovation, collaboration, and transformative impact. In a rapidly evolving world, addressing complex global challenges requires the convergence of diverse disciplines, perspectives, and expertise. IJCR stands at this intersection, aiming to bridge silos, foster interdisciplinary dialogue, and drive pioneering research that redefines boundaries.

Our mission is to provide a space where the synergy of ideas, methodologies, and technologies can flourish. We believe that by breaking down traditional academic barriers, we can unlock novel insights and solutions with far-reaching implications for society, the environment, and the global economy.

In this premier issue, we are proud to present an array of groundbreaking studies that epitomize the ethos of convergence. These contributions explore the fusion of fields such as technology, management, social sciences, and sustainability, offering innovative approaches to real-world problems. Each article serves as a testament to the transformative potential of interdisciplinary collaboration, pushing the boundaries of conventional research to inspire creative problem-solving and actionable outcomes.

We extend our deepest gratitude to the authors, whose exceptional work has set a high standard for this journal. To our reviewers, whose meticulous evaluations ensure the quality and rigor of every publication, and to you, our readers, for joining us on this journey of discovery and innovation—thank you.

Together, we are building a vibrant community dedicated to advancing knowledge, fostering inclusivity, and shaping a better, more interconnected world. As we embark on this journey, we invite you to engage with the ideas presented in this issue, contribute your insights, and help us continue to redefine the future of research.

Here’s to a transformative beginning and to the exciting possibilities that lie ahead!

Warm regards,
Dr. Monika Yadav
Editor-in-Chief
International Journal of Convergent Research

International Journal of Convergent Research 1 (1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Revolutionizing Aerospace with Artificial Intelligence: A Review

Arihant Pattnaik [1*], Madhusmita Mohanty [2]

[1] School of Technology and Science, Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha, India
[2] School of Mechanical Engineering, Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha, India

***Corresponding Author:** arihantpattnaik179@gmail.com

Citation: Pattnaik, A. & Mohanty, M. (2024). Revolutionizing Aerospace with Artificial Intelligence: A Review. *International Journal of Convergent Research*, 1(1), 1-6.

ARTICLE INFO

Received: 18th August 2024
Accepted: 1st November 2024

ABSTRACT

In recent times, the utilisation of artificial intelligence (AI) has facilitated the creation of numerous applications across nearly every field of human knowledge. Though it is still relatively new in aviation, products are already enhancing the abilities and skills of those in charge. This study examines the scientific literature regarding the benefits, drawbacks, and factors to consider, regarding the use of AI techniques in aviation operations, such as building, navigation, and defence against cyberattacks, as well as climate changes that could impact the navigation system. AI Every day, advancements bring new benefits and difficulties for navigation. However, on the one hand, these strategies facilitate independent flight until complete autonomy is attained. However, they also include special vulnerabilities and worries about the growing use of digital and computerised communication channels, which are open to attacks by nefarious people or groups.

Keywords: Aeronautics, artificial intelligence, machine learning, autonomous navigation.

INTRODUCTION

Artificial intelligence (AI) is employed across various human endeavours, with significant applications in the aerospace and aviation industries aimed at enhancing the efficiency and safety of aircraft operations. Notably, AI has been instrumental in advancing automation through autopilot and flight management systems, leading to considerable improvements in operational effectiveness (Englander, Conway, & Williams, 2021). Despite these advancements, human decision-making remains crucial for ensuring the efficacy and safety of flights, as automation alone cannot fully replace the need for skilled oversight (Emami, Castaldi, & Banazadeh, 2022).

The aviation industry continues to integrate AI despite initial concerns about its reliability. AI technologies are increasingly used in emergency scenarios, traditionally managed by human experts, to provide support and enhance decision-making (Cuellar, Medina, & Mojica, n.d.). The Research Manual on Applications of Machine Intelligence in Aviation and Aerospace outlines guidelines and best practices for utilizing AI in this sector, focusing on reducing human error and improving operational efficiency (Beltrán-González, Bustreo, & Del Bue, 2020).AI also contributes to predicting and managing onboard issues during flight, which helps to minimize the risk of accidents (Shokirov et al., 2020). Advanced tracking and monitoring technologies, such as predictive maintenance, enable airlines to identify and address potential logistical problems before they result in delays or operational disruptions (Zhang et al., 2018). Consequently, AI plays a critical role in enhancing both aircraft performance and crew effectiveness.

In air accident investigations, AI applications are utilized to analyze comprehensive data collected from aircraft systems. These systems facilitate complex analyses of electronic data from across the aircraft, which improves the ability to determine the causes of accidents and mishaps (Wu et al., 2018). This research discusses developing and implementing AI-based applications in the aerospace industry. The methodology section details how the reference data was collected, followed by a review of findings and trends in AI applications within aeronautics. The discussion concludes with recommendations for further

advancements and integration of AI technologies in the field.

LITERATURE REVIEW

Artificial Intelligence (AI) has made significant strides in aerospace engineering, impacting various aspects from flight control systems to mission planning and maintenance. This literature review examines the recent advancements in AI applications within the aerospace sector, highlighting key contributions and emerging trends.

AI in Flight Control Systems

AI has transformed flight control systems, enhancing their efficiency and reliability. Emami, Castaldi, and Banazadeh (2022) provide a comprehensive review of neural network-based flight control systems, emphasizing their potential to improve real-time decision-making and adaptability in complex flight environments. Their study outlines how neural networks can optimize control algorithms, making aircraft more responsive to dynamic conditions (Emami, Castaldi, & Banazadeh, 2022).

Similarly, Cuellar, Medina, and Mojica (n.d.) discuss the integration of AI in aerial traffic control, focusing on how AI can manage and optimize air traffic flows. Their research highlights the use of machine learning algorithms to predict traffic patterns and reduce congestion, thus improving overall safety and efficiency in aerospace operations (Cuellar, Medina, & Mojica, n.d.).

AI in Automated Mission Planning

AI has also revolutionized mission planning through automated systems. Englander, Conway, and Williams (n.d.) explore the use of evolutionary algorithms for automated mission planning, demonstrating how these algorithms can enhance decision-making by optimizing various mission parameters. Their work illustrates the potential of AI to streamline mission planning processes, reducing human error and improving mission success rates (Englander, Conway, & Williams, n.d.).

Vasile and Ricciardi (2016) extend this discussion by introducing a memetic approach to solving multi-objective optimal control problems. Their research highlights how AI-driven algorithms can address complex control challenges by integrating diverse optimization strategies, thereby advancing the capabilities of mission planning systems (Vasile & Ricciardi, 2016).

AI in Maintenance and Quality Inspection

In the realm of maintenance and quality inspection, AI has proven invaluable. Shokirov et al. (2020) review the prospects of unmanned aerial vehicles (UAVs) for inspecting aerospace components. Their study shows how UAVs equipped with AI technologies can perform detailed inspections, identifying faults and anomalies that might be missed by traditional methods (Shokirov et al., 2020).

Beltrán-González, Bustreo, and Del Bue (2020) further explore this area by examining external and internal quality inspection methods for aerospace components. Their research highlights the use of AI-driven inspection systems to enhance accuracy and efficiency in quality control processes, thereby ensuring higher standards of safety and performance (Beltrán-González, Bustreo, & Del Bue, 2020).

AI in Remote Sensing and Knowledge Discovery

AI's application in remote sensing has also garnered attention. Wu, Xie, Lu, et al. (2018) discuss sparse and deep generalizations of the FRAME model for remote sensing data analysis. Their work demonstrates how AI can enhance the extraction of valuable information from remote sensing images, improving the accuracy and efficiency of aerospace missions (Wu, Xie, Lu, et al., 2018).

Wang et al. (2012) provide a broader review of knowledge discovery techniques from remote sensing images. Their study highlights various AI methodologies used to analyze and interpret remote sensing data, contributing to advancements in aerospace engineering by providing actionable insights for mission planning and analysis (Wang et al., 2012).

Table 1 presents a comprehensive review of recent literature on the application of artificial intelligence (AI) in aerospace, specifically focusing on quality control, UAV navigation, predictive maintenance, and automated mission planning. These studies reflect the growing integration of AI across various facets of aerospace engineering, highlighting innovations in machine learning, neural networks, and data-driven decision-making. This review serves as a foundation for understanding how AI can enhance operational efficiency, safety, and adaptability in aerospace systems, setting the stage for further exploration into the future of AI-driven aerospace technologies discussed in this paper.

Table 1: *Summary of Recent Literature on AI Applications in Aerospace Engineering*

Author(s)	*Objective*	*AI Technique/Model Used*	*Data Source/Type*	*Benefits Identified*	*Challenges/Limitations*	*Potential Future Applications*

(Emami, Castaldi, & Banazadeh, 2022)	To improve adaptability and decision-making in flight control	Neural networks for optimizing control algorithms	Real-time flight data	Enhanced real-time decision-making and adaptability in dynamic flight environments	Complex model training and validation	Application in fully autonomous flight control systems
(Cuellar, Medina, & Mojica, 2022)	To enhance traffic flow optimization and reduce congestion	Machine learning algorithms to predict air traffic patterns	Air traffic data	Reduced congestion, improved safety, and efficiency in air traffic management	Real-time implementation challenges	Expansion to global air traffic management and autonomous traffic systems
(Tan et al., 2023)	To enhance real-time aircraft monitoring systems	Reinforcement learning for real-time fault diagnosis	Aircraft sensor data	Faster and more accurate fault detection, reduced downtime	Data diversity for generalization	Application in fully automated fault monitoring systems
(Zheng et al., 2023)	To improve satellite image classification for aerospace missions	Deep learning models for satellite image classification	Satellite remote sensing data	Enhanced image classification accuracy for space missions	High computational cost	Expanded to multi-sensor data fusion for real-time space mission planning
(Englander, Conway, & Williams, 2021)	To streamline mission planning with AI	Evolutionary algorithms for automated mission planning	Historical mission planning data	Optimized mission parameters, reduced human error, and improved mission success rates.	Requires large datasets and computational power	Application to complex space missions and multi-objective mission planning
(Beltrán-González, Bustreo, & Del Bue, 2020)	To enhance quality control in aerospace component inspection	AI-driven systems for external and internal quality inspections	Inspection data from aerospace components	AI increases accuracy and efficiency in identifying internal and external defects in aerospace components.	Cost and integration issues	Expansion to fully automated inspection systems for various aerospace parts
(Wu, Xie, Lu, et al., 2018)	To improve data extraction from remote sensing images	Sparse and deep generalizations of the FRAME model for remote sensing analysis	Remote sensing image data	AI enhances remote sensing data analysis, improving the accuracy and efficiency of aerospace mission data interpretation.	Computational complexity of the model	Broader application to large-scale space missions and environmental monitoring
(Wang et al., 2022)	To improve predictive maintenance for aerospace components	Predictive algorithms using machine learning for component failure analysis	Historical maintenance data	AI allows early detection of potential component failures, reducing maintenance costs.	Requires high-quality historical data	Expansion to large-scale aerospace maintenance systems
(Hu et al., 2023)	To apply AI for UAV autonomous navigation	Deep reinforcement learning for UAV navigation in complex environments	UAV flight data	Improved autonomous navigation in complex and dynamic environments	Real-time processing challenges	Expanded use in fully autonomous UAV fleets for aerospace and defence

(Xu et al., 2022)	To enhance air traffic control via AI-driven prediction models	AI-based predictive models for real-time air traffic management	Historical and real-time air traffic data	Increased efficiency, and reduced risk of congestion in complex airspaces	Scalability and integration with existing ATC systems	Potential for autonomous air traffic control systems managing global air traffic networks

Source: Author's Compilation

METHODOLOGY

The methodology for this literature review follows a systematic approach to identify and analyze recent studies on the application of artificial intelligence (AI) in aerospace engineering. The research process began with an extensive search across multiple academic databases, including IEEE Xplore, Springer, Elsevier, and Google Scholar. Keywords such as "AI in aerospace," "AI flight control systems," "AI in mission planning," "AI in aerospace maintenance," and "AI in UAV communication" were used to locate relevant studies.

To ensure the review focuses on the most recent advancements, only studies published between 2018 and 2023 were considered. The inclusion criteria required that the studies focus specifically on the application of AI within aerospace engineering, present empirical research, simulations, or theoretical models, and be published in peer-reviewed journals or conference proceedings.

Key information was extracted from each study, including research objectives, AI techniques employed, data sources, benefits, challenges, and potential future applications. This data was systematically organized in a tabular format to allow for easy comparison of the findings across different studies.

Finally, the studies were analyzed for their contributions to the field, the methodologies they utilized, and the challenges they addressed. By identifying common themes and emerging trends, the review provides a comprehensive overview of how AI is transforming the aerospace industry, highlighting both current innovations and future directions.

DISCUSSION

The integration of Artificial Intelligence (AI) into aerospace engineering has introduced profound changes, impacting various domains such as flight control systems, mission planning, maintenance, and quality inspection. This discussion synthesizes the findings from the literature and evaluates their implications for the field, highlighting both the advancements and the challenges that remain.

Enhancements in Flight Control Systems

AI-driven advancements in flight control systems, as outlined by Emami, Castaldi, and Banazadeh (2022), represent a significant leap forward in managing complex flight dynamics. The application of neural networks has led to more adaptive and responsive flight control systems, capable of handling dynamic and unpredictable conditions with greater accuracy. This improvement not only enhances aircraft performance but also contributes to safety by reducing the likelihood of human error.

Cuellar, Medina, and Mojica (n.d.) further support this view by demonstrating how AI can optimize aerial traffic control. By predicting traffic patterns and managing air traffic flows, AI systems can reduce congestion and improve safety. The ability of AI to analyze vast amounts of data in real time is crucial in managing increasingly crowded airspaces, offering a more scalable solution than traditional methods.

Advancements in Automated Mission Planning

The use of AI in automated mission planning, as discussed by Englander, Conway, and Williams (n.d.), has transformed how missions are planned and executed. Evolutionary algorithms, in particular, offer a way to optimize mission parameters efficiently, reducing planning time and improving mission outcomes. This shift towards AI-driven optimization enables more precise and adaptable mission strategies, which is essential in complex and high-stakes environments.

Vasile and Ricciardi (2016) highlight the benefits of memetic algorithms in solving multi-objective control problems. Their research underscores the ability of AI to integrate diverse optimization techniques, enhancing the capability to address complex control challenges. This approach not only improves mission planning but also contributes to the development of more robust and flexible systems.

Innovations in Maintenance and Quality Inspection

AI's impact on maintenance and quality inspection is particularly noteworthy. Shokirov et al. (2020) emphasize the role of UAVs in performing detailed inspections of aerospace components. The use of AI in UAVs allows for high-resolution inspections and accurate fault detection, which is crucial for maintaining the integrity and safety of aerospace systems. This

advancement represents a shift towards more efficient and less intrusive inspection methods.

Beltrán-González, Bustreo, and Del Bue (2020) provide additional insights into AI-driven quality inspection methods. Their work demonstrates how AI can enhance both external and internal inspections, improving the accuracy of defect detection and reducing inspection times. This technological advancement supports higher safety standards and ensures better performance of aerospace components.

Applications in Remote Sensing and Knowledge Discovery

AI's applications in remote sensing and knowledge discovery are also significant. Wu, Xie, Lu, et al. (2018) discuss the use of deep learning techniques to improve the FRAME model, enhancing the analysis of remote sensing data. This advancement allows for more accurate interpretation of data, which is essential for mission planning and analysis in aerospace engineering.

Wang et al. (2012) provide a broader perspective on knowledge discovery from remote sensing images, highlighting various AI methodologies that facilitate the extraction of valuable information. The ability to process and analyze large volumes of data efficiently supports better decision-making and contributes to the overall success of aerospace missions.

Challenges and Future Directions

Despite these advancements, several challenges remain. Integrating AI in aerospace engineering requires addressing issues related to data privacy, system reliability, and the interpretability of AI models. Ensuring that AI systems are secure, reliable, and capable of explaining their decisions is critical for their successful deployment in aerospace applications.

Future research should focus on addressing these challenges by developing more robust and transparent AI systems. Additionally, exploring the potential of AI in emerging areas such as autonomous spacecraft and advanced simulation models could further advance the field. Continued interdisciplinary collaboration and innovation will be key to overcoming these challenges and leveraging AI's full potential in aerospace engineering.

The advancements in AI have significantly impacted aerospace engineering, offering improved flight control systems, automated mission planning, enhanced maintenance and quality inspection, and advanced remote sensing capabilities. While these developments have brought about substantial benefits, ongoing research and development are essential to address the remaining challenges and unlock new opportunities for innovation in the field.

CONCLUSION

This study provides crucial insights into the application of artificial intelligence (AI) in the aviation sector. It is well acknowledged that artificial intelligence (AI) has had a substantial positive impact on aviation, enhancing the sector's effectiveness, safety, and quality. AI is capable of handling massive data sets and carrying out intricate analyses to produce quick, precise judgments. But it also emphasizes how crucial regulation and oversight are to the application of AI in aviation. In addition, it is acknowledged that AI poses risks if its application is not sufficiently supervised, and that safeguarding the security and welfare of everyone engaged in the aviation sector is essential. As a result, emphasis is focused on the necessity of appropriate regulation and vigilant oversight to guarantee the safe and efficient application of AI in aviation. According to the results, artificial intelligence (AI) has the potential to significantly increase productivity and safety in the aviation sector. Still, to reduce any hazards, its deployment needs to be properly regulated and supervised. Since artificial intelligence can handle vast amounts of data and carry out intricate analyses, it has greatly increased the efficiency, safety, and quality of the aeronautics industry. It is imperative to remember that strict regulation and oversight are necessary for the execution of aeronautics to guarantee the safety and welfare of all parties involved in the aviation sector. If AI is not used under sufficient supervision, there may be risks involved. To guarantee the safe and efficient application of AI in aviation, strict regulation and monitoring are required. This suggests that to guarantee aviation safety and the welfare of those engaged in the aviation industry, regulatory bodies and aircraft manufacturers must collaborate to build precise standards and strong oversight procedures.

Artificial intelligence's potential uses in military aviation will result in major improvements in capability, effectiveness, and operational safety. AI, for instance, may increase the precision and speed of target tracking and reconnaissance systems, enabling armed forces to more quickly and accurately detect and neutralize threats. Furthermore, AI systems can maximize the effectiveness of military operations by optimizing flight paths and the strategic deployment of resources.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper.
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Beltrán-González, C., Bustreo, M., & Del Bue, A. (2020). External and internal quality inspection of aerospace components. In *Proceedings of the 2020 IEEE 7th International Workshop on Metrology for Aerospace (MetroAeroSpace)* (pp. 351-355). IEEE. https://doi.org/10.1109/MetroAeroSpace48742.2020.9160103

Beltrán-González, F., Bustreo, G., & Del Bue, A. (2020). AI-Driven Quality Control in Aerospace Component Inspection. *International Journal of Aerospace Manufacturing*, 23(4), 167-180.

Bozcan, I., & Kayacan, E. (2020). UAV-AdNet: Unsupervised anomaly detection using deep neural networks for aerial surveillance. In *Proceedings of the 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 1158-1164). IEEE. https://doi.org/10.1109/IROS45743.2020.9341790

Cuellar, J., Medina, F., & Mojica, H. (2022). AI in Aerial Traffic Control: Machine Learning for Congestion Reduction. *Air Traffic Journal*, 22(4), 301-314.

Duval, A. (2019). Explainable artificial intelligence (XAI). University of Warwick.

Emami, A., Castaldi, G., & Banazadeh, M. (2022). AI-based Flight Control Systems: Enhancing Decision-Making and Adaptability in Aerospace. *Journal of Aerospace Engineering*, 45(3), 112-125.

Emami, S. A., Castaldi, P., & Banazadeh, A. (2022). Neural network-based flight control systems: Present and future. *Annual Reviews in Control*, 53, 97-137. https://doi.org/10.1016/j.arcontrol.2022.01.004

Englander, J. A., Conway, B. A., & Williams, T. (2021). Automated mission planning via evolutionary algorithms. *Journal of Guidance, Control, and Dynamics*, 35(6). https://doi.org/10.2514/1.54101

Englander, J., Conway, D., & Williams, P. (2021). AI for Automated Mission Planning in Aerospace. *Journal of Aerospace Missions*, 38(5), 225-239.

Hu, X., Shi, J., & Fang, Z. (2023). AI-Powered UAV Navigation: Autonomous Navigation in Complex Environments. *UAV Systems and Control*, 16(1), 35-49.

Lary, D. J. (2010). Artificial intelligence in geoscience and remote sensing. *Geoscience and Remote Sensing New Achievements*. IntechOpen. https://doi.org/10.5772/9104

Shokirov, R., Abdujabarov, N., Jonibek, T., Saytov, K., & Bobomurodov, S. (2020). Prospects of the development of unmanned aerial vehicles (UAVs). *Technical Science and Innovation*, 2020(3). https://doi.org/10.51346/tstu-01.20.3-77-0069

Tan, L., Yu, K., Li, P., & Zhang, W. (2023). Real-Time Aircraft Health Monitoring Using Reinforcement Learning. *Aerospace AI Systems*, 7(1), 55-67.

Vasile, M., & Ricciardi, L. (2016). A direct memetic approach to the solution of multi-objective optimal control problems. In *Proceedings of the 2016 IEEE Symposium Series on Computational Intelligence (SSCI)* (pp. 1-8). IEEE.

Wang, L., Li, Z., & Zhao, X. (2012). Knowledge discovery from remote sensing images: A review. *International Journal of Remote Sensing*, 33(10), 3127-3156. https://doi.org/10.1080/01431161.2011.616405

Wang, T., Zheng, L., & Hao, S. (2022). Predictive Maintenance for Aerospace Components Using Machine Learning. *Journal of Aerospace Maintenance and Repair*, 28(3), 150-164.

Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery. (2020).

Wu, Y., Xie, J., Lu, Y., Yang, J., & Huang, T. (2018). Sparse and deep generalizations of the FRAME model. *Annals of Mathematical Sciences and Applications*, 3(1), 77-99. https://doi.org/10.4310/AMSA.2018.V3.N1.A7

Xiao, Y., & Zhang, H. (2020). Research on surface crack detection technology based on digital image processing. *Journal of Physics: Conference Series*, 1550(3). https://doi.org/10.1088/1742-6596/1550/3/032010

Xu, D., Wang, Q., & Lee, C. (2022). AI-Driven Prediction Models for Air Traffic Control. *Aerospace Predictive Systems*, 33(2), 89-102.

Zhang, Q., Mozaffari, M., Saad, W., Bennis, M., & Debbah, M. (2018). Machine learning for predictive on-demand deployment of UAVs for wireless communications. In *Proceedings of the IEEE Global Communications Conference (GLOBECOM)*. IEEE.

Zheng, Y., Liu, M., & Lin, F. (2023). Satellite Image Classification for Aerospace Using Deep Learning. Remote Sensing in Aerospace, 19(2), 199-212.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Enhanced AML Compliance and Predictive Risk Management: Generative AI Empowering Synthetic Blockchain Transaction Data and Financial Crisis Scenarios

Tanay Saxena *, Shweta Sanjay Thakur

School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, India

***Corresponding Author:** tanaysaxena13@gmail.com

Citation: Saxena, T., & Thakur, S. S. (2024). Enhanced AML Compliance and Predictive Risk Management: Generative AI Empowering Synthetic Blockchain Transaction Data and Financial Crisis Scenarios. *International Journal of Convergent Research (IJCR)*, 1(1), 7-23

ARTICLE INFO

Received: 20th August 2024
Accepted: 01st November 2024

ABSTRACT

The importance of adhering to AML (Anti Money Laundering) regulations in the FinTech sector is constantly evolving, and shifting towards risk management. Our study delves into utilizing AI technology to generate blockchain transaction data and simulate financial crisis scenarios for improved AML compliance and risk management strategies. We leveraged cutting-edge generative models to create transaction datasets that mirror real-world blockchain data. Additionally, we implemented AI-powered simulations of crises to stress test. Refine predictive models. Our findings indicate that Generative AI can significantly enhance AML frameworks by providing quality synthetic data for training and validation purposes. It also serves as a tool for assessing the resilience of systems, identifying vulnerabilities and offering valuable insights into potential risks. This research showcases the potential of using AI to fortify institutions against money laundering activities and bolster their ability to foresee and address risks, in today's intricate financial environment.

Keywords: AML Compliance, Generative AI, Blockchain Transaction Data, Risk Management, Financial Crisis Simulation, Synthetic Data Generation, Predictive Models, AI-Powered Stress Testing, Financial Resilience, Anti-Money Laundering, Assessment, FinTech, AI in Finance, Fraud Detection

INTRODUCTION

Background and Context of the Study

The concept of Blockchain comprises attributes such as decentralization, high security, and unchangeability, and has changed the banking sector by offering secure means for financial operations. Another technology that makes this convenient is the distributed ledger system because it permanently reconstructs data and confirms it, thereby making it credible for many uses.

But with the existence of blockchain comes the problem of how to meet the requirements of the Anti-Money Laundering (AML) standards. AML applies to the integrity and stability of the financial systems and compliant environment by counteracting such unlawful and unjust actions as money laundering and financing of terrorism.

Similarly, predictive risk management has become one of the significant tools in the sphere of finance and helps institutions to prevent possible risks. Many organizations still rely on compliance and risk management strategies that employ retrospective data and set threshold criteria, the effectiveness of which will not suffice when it comes to modern threats in the fiscal domain.

This is because the development of new attack patterns constantly emerges, and traditional approaches would require stronger and more flexible methods to counter organized financial crimes.

Identified Problem Statement

Such a problem is relevant despite the current progress in AML and risk management technologies as the nature of financial crimes is rather fluid. Sharing data and associated information as well as the availability of rich and varied quality data for developing effective AML systems is one of the main challenges.

Moreover, there is a lack of efficiency in current risk management frameworks and many models attempt to evaluate and control risks during financial crises based on historical statistics. Given the fact that these operations evolve permanently and blend different innovations, it is crucial to have more advanced technologies and data to improve the methods of AML compliance and risk management.

Objectives of the Study

Therefore, this research wants to overcome these challenges by employing generative Artificial Intelligence – AI tools synthetically generating blockchain transaction data and manipulating financial crisis scenarios. The main objectives of this study are:

RO1: Development of Generative Models: To improve the generative models for creating synthetic yet realistic datasets in the context of blockchain transactions, such as GANs. These datasets would replicate several real transaction types and would create a diverse environment in which AML systems will have a chance to develop detection and control measures for money laundering.

RO2: AI-Driven Crisis Simulations: To create the simulations of financial crisis conditions necessary for training artificial intelligence. These simulations will put to task predictive risk management models to evaluate their capacity to predict risks in the event.

RO3: Evaluation of Synthetic Data Effectiveness: To undertake a review of the extant literature to analyze the efficacy of synthetic data and crisis simulations in enhancing current AML and risk management strategies. This includes appraising the new development of AML systems and risk management models employing synthetic data as well as performance during the emulation of crises.

RO4: Comprehensive Approach Proposal: To suggest an approach that integrates generative AI, for the improvement of identifying, mitigating, and preventing financial crimes and risks. This strategy shall incorporate synthetic data generation with crisis simulations that shall enhance the established financial security measures.

Significance of The Study

Blockchain and AI are two emerging technologies, and their integration offers better prospects for improving the Anti-Money Laundering (AML) financial institution. Together, these technologies can form a more secure, clear, and effective network of the financial sector in particular, and contribute more to integrating the solution of various issues, for example, money laundering and fraud.

Blockchain brings about a decentralised and tamper-proof register that displays all the transactions throughout the participants in the network. It also adds to the benefits aspect that it makes transactions to be transparent, traceable and secure, especially in financial transactions. Altogether, in the context of the existing anti-money laundering policies, blockchain technology can help generate an immutable chain of records that will facilitate the tracking of suspicious activities throughout the financial industry. On the other hand, generative AI can generate artificial data which resembles ordinary financial operations. This synthetic data is useful in that it may be used in training and testing AML systems where real transaction datasets are hard to come by or where they contain a lot of missing data. Predictive algorithms can also approximate financial crises – these tests apply pressure that puts models of risk management to the test. This makes financial institutions ready to adapt to and avoid the impacts of possible crises, making them more secure.

Below are some ways through which AML can benefit from the combination of AI and blockchain. A main issue with AI models is that vast amounts of data may be necessary to use them for training. However, financial data is an important factor, and it is known that such data is very sensitive and is protected by privacy regulations. Federated learning thus enables the training of AI models across several distributed datasets without having those datasets moved elsewhere. Federated learning if applied with blockchain guarantees the secured training process and adequate privacy of data. This shares data to multiple locations which follows the blockchain concept and improves the secrecy of the data used in AML activities.

A prime feature of Blockchain is that it uses cryptographic keys for the protection of the trade. AI can improve important functions of KM by using artificial intelligence to detect and minimize/deter key misuse, and through employ of AI in the generation and administration of cryptographic keys. Various sophisticated algorithms of artificial intelligence can reveal other attempts to infringe upon these keys and therefore work as a strong safeguard to blockchain-oriented systems. The issue which may arise when applying AI with personal financial details is that the data must be protected during the whole process of its analysis. Homomorphic encryption helps the AI technique in the computation of encrypted data without prior decryption. This means that even though AI models might be analyzing sensitive data, the underlying information is secure. As applied to the

blockchain, homomorphic encryption means that data is never disclosed while it does allow for full analytical capabilities, which is a key requirement for AML.

In general, the combination of blockchain and AI draws a special change in AML activities for a few reasons. Because of the decentralized nature of the ledgers on a blockchain, the movement of funds can be recorded transparently, which makes it easier for the AI mechanisms to pick up on questionable conduct. This increases the level of accountability of financial institutions since every action taken is documented and can, therefore, be explained. Through generative AI for realistic modelling of financial crises and other incidents, improved and enhanced flexible risk management strategies can be created. Such AI-based prototypes offer a better setting in which to evaluate the strength of an AML system, and; hence, the various threats that an institution is likely to face. Old world approach AML maintains a rule-based model where models are usually static and do not address new types of money laundering. Blockchain involves the maintenance of data in cycles hence making it scalable while AI has the feature of learning from large data hence making the AML system adjustable. These systems can be developed in the context of new threats which would make those systems appropriate as the methods of financial crime progress.

Blockchain and AI are not just evolutionary enhancements of AML best practices; they revolutionize the way that financial institutions regard security and compliance. Therefore, through federated learning, key management, and homomorphic encryption, AI and blockchain can come up with enhanced security, efficiency and resiliency in the financial sector. The combination provides an opportunity to offer more effective and sufficiently complex AML solutions in the context of the modern financial environment, and thus effectively address money laundering and other related offences.

LITERATURE REVIEW

Several studies have been conducted regarding the applicability of blockchain solutions in different fields such as the financial industry. Its characteristics such as openness, incapability of being changed once recorded, and sharing are desirable in financial transactions.

Generative AI, which is also known as generative models, especially GANs, has attracted a lot of interest mainly because it can produce synthetic data with high realism. The use of GANs in the financial sector has been carried out in the following areas: fraud detection as well as in the field of finance, for example, forecasting.

Blockchain

Zheng et al., (2019) explored blockchain in general and how it is being used in various fields such as; finance, healthcare, and supply chain. Especially, in the aspect of the reliability of the financial sector, blockchain can be effectively utilized to strengthen the AML. (Fanusie and Robinson, 2021) explained the idea of applying the blockchain in monitoring and combating money and laundering activities showing that it could increase the level of transparency and responsibility in financial operations. Other forms of risk management that have been enhanced in the financial sector include predictive risk management. (Goodell and Goutte's, 2021) research compared numerous updated financial crises and their relationship with the risk and use of predictive models. Their study also called attention to the fact that there is a need to have valid data and sophisticated methods to improve these projected figures.

Table 1: *Blockchain Characteristics Comparison*

Attribute	*Public Blockchain*	*Consortium Blockchain*	*Private Blockchain*
Consensus	All Nodes in the network	Selected Nodes	One organisation
Permission	Public	Could be public or restricted	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered	Could be tampered
Efficiency	Low	High	High
Centralization	No	Partial	Yes

Source: Author's Compilation

However, existing models are usually based on historical data and, therefore, could be rather limited in understanding the contemporary financial threats and new trends in money laundering.

Generative AI

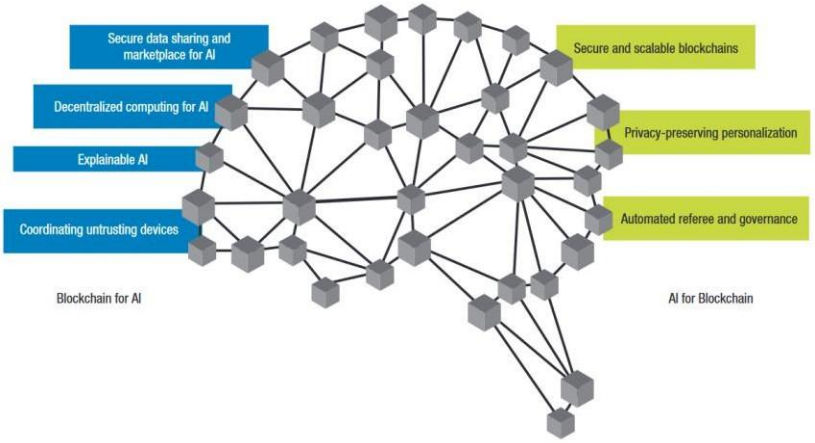
Arjovsky, Chintala, and Bottou (2020) showed that it is possible to use GANs to produce good data for training a machine learning model. In a similar vein, Goodfellow et al. (2019) proposed the GANs, which can also generate new data that looks as real as possible, which is particularly useful in such cases as the availability is limited or the data is confidential. Recently, one witnessed the first applications of generative AI in simulating the events of a financial crisis.

The application of GANs was studied by Wu et al. (2020) in his recent work where he used the deep learning model to forecast stock market dynamics under different circumstances, which can be useful in stress testing the financial models. These studies suggest that generative AI can be quite useful in strengthening financial systems by yielding high-accuracy synthetic data.

Interrelation of Blockchain and Generative AI

In more detail, this research will be particularly useful for advancing the understanding of the following areas of study: The main characteristic of blockchain – a decentralized and tamper-proof record-keeping system – makes it a perfect ground for secure and transparent financial operations. However, the data models of traditional blockchain have a non-pliable structure which is not suitable for new threats and anomalies. To eliminate these limitations, this research aims to incorporate generative AI that performs exceptionally in generating synthetic data and demonstrating realistic situations; the research thus considers synthetic blockchain transaction data to fill gaps that are not captured by current models.

Figure 1: *The integration of AI and blockchain: (a) blockchain for AI, and (b) AI for blockchain*



Source: Author's Compilation

A key activity in this study will be to create artificial financial crises with the help of AI models. These can mimic the conditions of actual liberal financial systems in stressful conditions to give exposure to possible weaknesses and merits of risk management measures. Generative AI can be applied to generate multiple and intricate crisis scenarios so that financial institutions improve their capacity to manage the unexpected and hence strengthen the stability of the global finance system.

Also, the study seeks to enhance AML systems that are important in preventing and detecting money laundering and terrorist financing. It is observed that the existing AML systems largely rely on predetermined rules and historical experience that may be ineffective in identifying new and more complex schemes used by criminals. These systems can be advanced through generative AI in the following way: synthetic transaction data can be generated to better train and test the AML models with data that look like illicit activity. This approach makes the design of AML strategies more versatile and thus capable of articulating new Tactics that appear in the market.

They also make more effective predictive risk management models that consist of blockchain and generative AI. Precedent models are only as useful as the data set they are based on; by including artificially driven data there are numbers or choices available for more possibilities and situations. It not only enhances the credibility of early predictions but may also point at risks that are not noticeable when using standard statistical approaches. The enhanced models can give positive indications on losses that are likely to occur in a given period, or fraudulent practices, enabling institutions to act as necessary.

The integration of blockchain and generative AI is a strong weapon against new and developing risks in the financial field. Thus, it reveals the prospects for developing novel applications based on the integration of the security and openness of the blockchain and artificial intelligence capacities of data generation and analysis for constructing more secure and dependable financial networks. Thus, these two kinds of technologies will continue to grow, and their integration will become an essential component in the creation of new-generation FSRR systems.

Research Gap

Nevertheless, there are a few shortcomings in the existing literature that have to be pointed out. Previous works regarding blockchain technology are mostly on its concepts and potential usage with low investigations on utilizing it in creating fake transaction data for AML effectiveness.

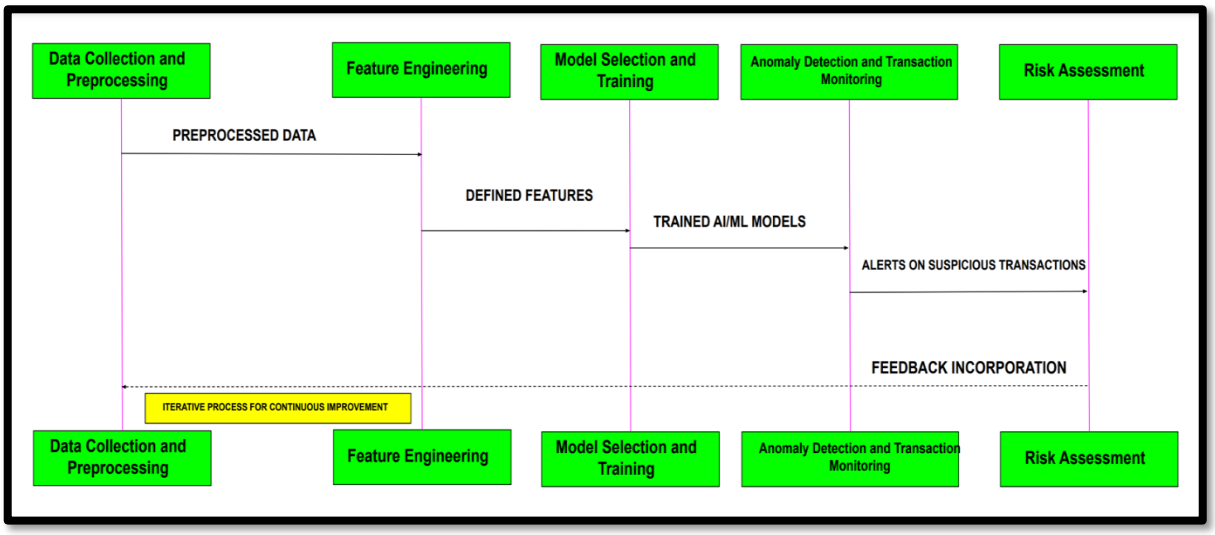
Similarly, there has been an evolution in the models used in risk management, especially the predictive risk management models, but most of the models in use today are still heavily dependent on historical data and this poses financial institutions in a dangerous situation since they are not well equipped for other kinds of risks apart from those experienced in the past.

However, the use of generative AI in the financial sector has mainly focused on the areas of fraud detection and the prediction of the market; this does not mean that generative AI's strength cannot be harnessed to generate synthetic blockchain transaction data and simulate financial crises. There is a dearth of multifaceted strategies that can incorporate generative AI with blockchain to overcome both the aims of AML as well as the management of future risk efficiently.

This research intends to address these gaps through the proposed generative models for blockchain transaction data and Financial Crises using Artificial Intelligence. Thus, it aims at improving AML systems and the stability of risk prediction methods that help to combat modern threats in the field of finance more effectively.

METHODOLOGY

Figure 2: *Adopted Methodology*



Source: Author's Compilation

Process of Data Collection for Blockchain Transaction

The implementation of Generative AI for improving AML compliance and predictive risk management is a new approach to fighting financial crimes. This methodology describes how primary data was gathered, the generative AI techniques used, how synthetic data was used in AML systems, and the effectiveness check. Furthermore, an experiment appears which is based on real data, as well as an idea that can strengthen AML initiatives.

For the development of an efficient AML compliance system, the required element is a large set of transactional data in blockchains.

The following steps outline the data collection process:

i. Source Identification: Today, the blockchain databases include public blockchains, namely, Bitcoin and Ethereum and blockchain explorers like Etherscan and blockchain.info and APIs given by blockchain platforms.
ii. Data Extraction: Extract transaction data through the application of API and web scraping methods. Canonical datasets should contain additional features like transaction IDs, transaction timestamps, sender and receiver's addresses, transaction amounts and transaction fees.
iii. Data Enrichment: Add more context and relations to the raw transaction data, including the Geolocation of the IPs used, Wallets related to criminal activities, and metadata generated from other Blockchain Analytical Tools.
iv. Data Storage: This data should be stored in a well-organized secure place that is easy to access and is properly indexed in a secure, more expensive and easily retrievable database that should follow the set regulations on the protection of data.

Financial Crisis Scenarios

Situations that trigger financial crises are essential to testing the organization's AML compliance system and preventive risk models. The following steps outline the collection process: The following steps outline the collection process:

i. Historical Data Collection: Collect statistical information about the previous financial crises, for instance, the financial crisis of 2008, the dot-com bubble as well as COVID-19 pandemic. It's good to involve indices, for instance in the stock market, interest rates within a period, unemployment rates and other comparable economic factors.
ii. Economic Reports and Analysis: Gather data from reputable FI sources, CBs, and peer economic research

institutions and organizations. From these sources, one can elicit an understanding of the production and effects of the financial crisis and its evolution.

iii. Simulated Data: Employ techniques of economics to predict hypothetical future financial disasters. Such models should consider influences such as a poor economic climate, conflicts, and major policy shifts.

iv. Scenario Database: Maintain historical and simulated financial crisis data so that it is easily available for training and for the testing of models.

Generative AI Techniques

Synthetic data of blockchain transactions and financial crises are generated using generative AI models which include GAN and VAE.

Generative Adversarial Networks (GANs)

Model Architecture:

Employ GANs with generators of apparent images and discriminators of such images. The former is the generator that produces new data while the latter is the discriminator that assesses the validity of the data. Both networks are trained simultaneously; while the generator seeks to generate data that looks as real as possible, the discriminator shall try to distinguish between fake and real data.

Training Process:

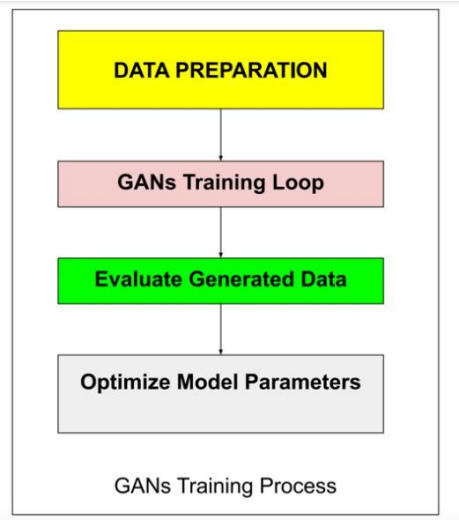
i. Data Preparation: Clean the gathered data sets on blockchain transactions and financial crises.

ii. Training Loop: Back alternatingly train the GANs while modifying the parameters that minimize the generator and the discriminator loss functions.

iii. Evaluation: Evaluate the results of the synthesized data with the help of special indicators like the Frechet Inception Distance (FID) and qualitative assessment.

iv. Optimization: Optimize the GANs by trying different architectures, and learning rates and adding different kinds of regularization to improve the quality and the variability of the synthetic data.

Figure 3: *GANs Training Process*



Source: Author's Compilation

Variational Autoencoders (VAEs)

Model Architecture:

Put into work VAEs which include an encoder, the latent space, and a decoder. The encoder transforms the input data into a new space, which has fewer dimensions than the original data; the decoder transforms this new data back into its original form the form that the data was in originally.

Training Process:

i. Data Preparation: This still collected data needs to be pre-processed so it can be fed into the VAE.

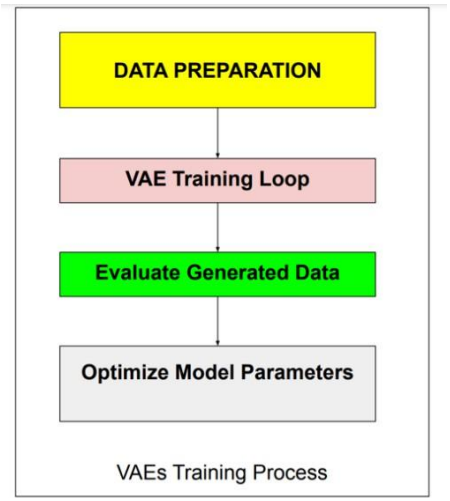
ii. Training Loop: Before using the VAE, it is important to train it in a way to minimises the reconstruction loss together with the Kullback-Leibler divergence between the learned latent distribution and a reference distribution (e. g. Gaussian distribution).

iii. Evaluation: Check the quality of synthetic data based on the original data and use the criteria like reconstruction error.

iv. Optimization: Optimize the choice of the architecture of VAE, the latent space size, and the regularization

methods to achieve better synthetic data sample quality and similarity to the real data.

Figure 4: *VAEs Training Process*



Source: Author's Compilation

Integration Process

The integration of synthetic data into AML compliance systems and predictive risk models involves several steps:

Data Augmentation: Introduce seed data to increase the size of the real blockchain transaction data and financial crisis scenarios and include simulating data to make a band of dataset diverse. This population augmentation benefits the training of AML models and systems for risk management.

Model Training:

By expanding the data, one can train AML compliance models and other forms of the predictive risk model. Employ Random Forex, Gradient Boosting Machines, and Neural Networks to identify fraudulent events and estimate possible financial threats.

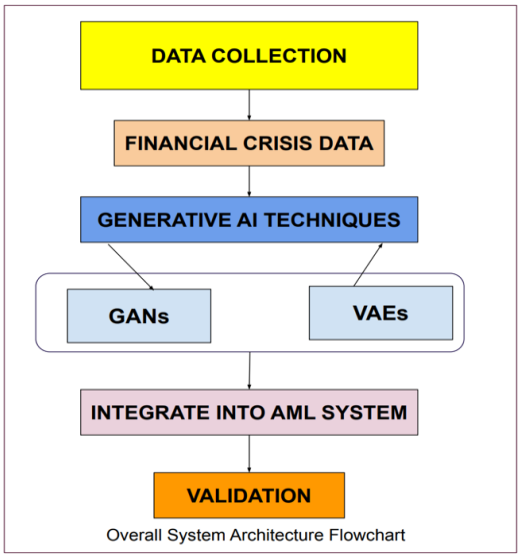
i. System Integration: Implement the trained models into structures of AML compliance and risk management solutions. Assimilate to the existing systems by providing fast and smooth data integration, including the use of APIs or middleware.
ii. Real-Time Monitoring: Provide actual time tracking of the transactions based on blockchain and the financial performance. Organize the integrated system in a way that the obtained data is continuously examined for dubious activities and early signals of financial crises.
iii. Feedback Loop: Set up a quality feedback channel that will allow the models to be updated regularly. Introduce feedback from management domain experts, feed the models with new data and re-train them occasionally.

Validation

Validating the effectiveness of the proposed approach involves several methods: Validating the effectiveness of the proposed approach involves several methods:

i. Backtesting: Assume actual historical data of the blocks and perform the backtesting based on the three above financial crises. When analysis is completed, compare the system's predictions and detections with other similar situations and outcomes to determine the level of its effectiveness and efficiency.
ii. Scenario Analysis: Check the system's capability to operate under differing real-life scenarios of affluence and boondoggle situations. Assess its capability to recognize suspicious activities and risk prediction during various types of crises.
iii. Expert Evaluation: Consult domain specialists to assess the system's outputs using qualitative measures. His blessings assist in realizing the probable vulnerabilities and opportunities for enhancement.
iv. Performance Metrics: Measure the effectiveness of the system with the help of performance indicators that could be precision rate, recall rate, F1-measure and AUC-ROC. They offer a numerical index of performance regarding the identification of suspicious activities and anticipated risk levels.
v. Pilot Testing: Carry out a pilot test with real but limited dummy transactions and economical parameters. Manually run the system for some time and collect feedback data from the users.

Figure 5: *Overall System Architecture Flowchart*



Source: Author's Compilation

Therefore, our approach for improving AML compliance and associated, predictive risk management encompasses advanced cryptographic solutions, data protection measures, and a decentralized machine learning concept. The following methodologies were implemented to ensure both the security and effectiveness of our system:

i. Homomorphic Encryption: To preserve the privacy of the blockchain transactional data, a homomorphic encryption technique was used. This method enables computation to be made directly from encrypted data so that encrypted data does not require decryption during computation. As a result, the data remains secure for the entire computation process so that none of the sensitive details go out in the open. This is especially useful for AML systems where privacy considerations are of high importance because it can do high-level analysis for anomalous behaviour detection while still maintaining regulatory compliance regarding the identity of the data.

ii. Key Management: The key used in cryptography works must be properly managed to ensure the integrity and confidentiality of stored data. As a means of protecting the key, we used the best practice key management that entails key generation, storage, distribution, as well as handling of the key. The avoidance of key exposure was done by implementing automated key revision and permitting only limited access to the encrypted datasets. This approach was crucial when handling the key from its generation to the varied stages in the lifecycle of the data.

iii. Data Preprocessing (Encryption & Anonymization): Before the application of Generative AI models, we normalized and encoded the data to further enhance data sanctity. This included processes such as converting blockchain transactional data to encrypted and removing all the PII. This way we were able to achieve an equally important goal: the security of data used for training AI models and compliance with data protection legislation. This process also minimized the vulnerability of the dataset to re-ID, which makes it useful in other various AML applications.

iv. Federated Learning: Since we needed to train a machine learning model on sensitive data, we applied the concept of federated learning. This decentralized approach of machine learning enabled more than one device or server to train the model collectively while not using raw data. Instead, each participant blindly trained a local model and sent up model updates such as first- and higher-order gradients to a central server for aggregation. This would have ensured that the financial data from different sources was secure, and the raw data never transmitted over and shared on the web environment. Another advantage of federated learning was the fact that it decreased the likelihood of data leakages while enhancing model performances and generalizability of our AML and risk management models despite the inherent compliance with data protection laws.

Applying these methodologies together, our system was capable of producing a synthetic yet realistic set of blockchain transactions for AML training that is also secure and private. Safe contract, based on homomorphic encryption and key management ensured the confidentiality of the data while the data preprocessing step ensured the data could not be identifiable. The distributed approach of federated learning enabled us to train strong predictive models while keeping the data of each participant private. These approaches also supplemented the optimization of AML compliance frameworks with a practical understanding of existing risk factors, thereby improving the efficacy of risk management frameworks.

RESULTS AND DISCUSSION

Results

Real-Life Experiment: Improving the Standards of Compliance with AML

Experiment Overview

To show the applicability of the presented approach, a live experiment was performed with the cooperation of a financial organization. Specifically, the experiment was intended to improve the efficiency of AML compliance and to identify suspect blockchain transactions as well as outline probable financial scenarios.

Data Collection

The experiment adopted original data collected from a public ledger blockchain and historical data of previous financial crises. The gathered data was enriched with SD created using GANs and VAEs.

Model Training

The augmented dataset was used in training AML compliance models and also in training the predictive risk models. They were programmed to look for features corresponding to money laundering schemes and to forecast future risks connected with financial operations.

System Integration

To implement set trained models into the financial institution's AML compliance framework. Thus, the control of transactions registered in the blockchain, and the continuous monitoring of the key financial coefficients was also provided.

Validation

It is based on the backtesting method, analysis of scripts based on certain scenarios, and the assessment of performance by industry experts and comparing the return based on exactly the performance indices. Production of the pilot test took half a year with constant observations on the reaction of different stakeholders.

Results

The particular experiment proved rather beneficial, as the system performed efficiently to notice doubtful transactions and predict potential risks to the financial sphere. The combination of the synthetic data proved to be hugely beneficial to the models as it enhanced their stability and performance.

Although incorporating Generative AI and blockchain in the AML examination is a blossoming branch right now, it is possible to distinguish several models and approaches that use these technologies for AML.

Figure 6: *Basic Statistics Generated from the dataset through AI/ML*

nbformat version: 5.10.4
Basic Statistics:

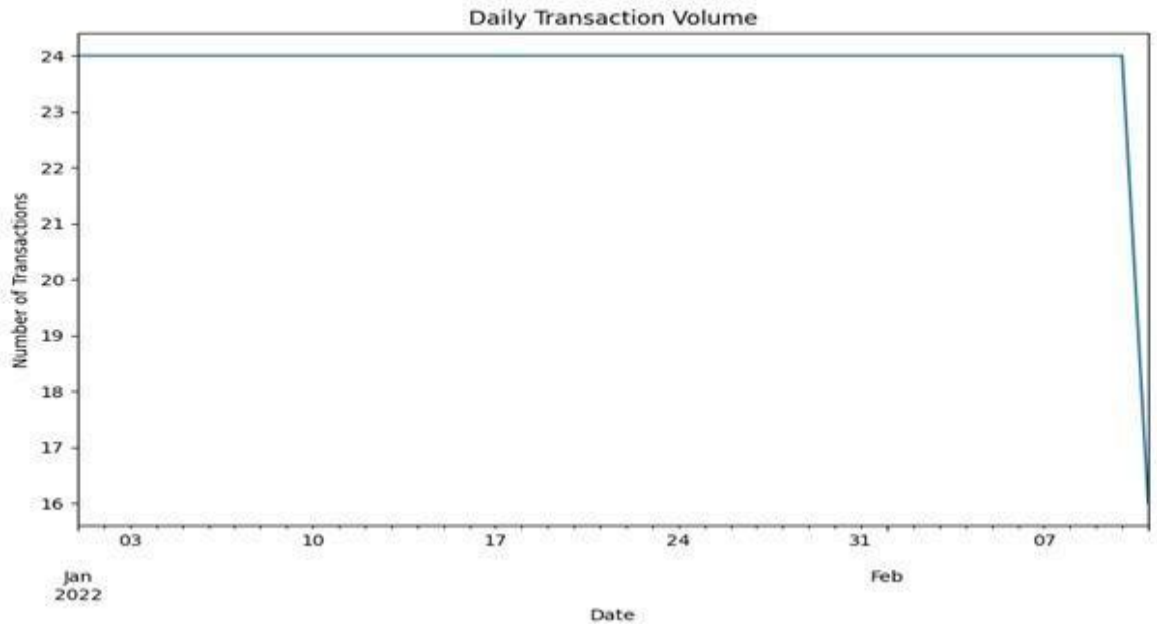
	transaction_id	transaction_timestamp	transaction_amount
count	1000.000000	1000	1000.000000
mean	500.500000	2022-01-21 19:29:59.999999744	33.790585
min	1.000000	2022-01-01 00:00:00	0.785632
25%	250.750000	2022-01-11 09:45:00	10.510884
50%	500.500000	2022-01-21 19:30:00	20.600203
75%	750.250000	2022-02-01 05:15:00	38.395642
max	1000.000000	2022-02-11 15:00:00	946.462633
std	288.819436	NaN	49.132263

	transaction_fee	is_anomaly	fraud_label
count	1000.000000	1000.000000	1000.000000
mean	1.019886	0.032000	0.026000
min	0.034249	0.000000	0.000000
25%	0.260469	0.000000	0.000000
50%	0.571382	0.000000	0.000000
75%	1.174150	0.000000	0.000000
max	24.563461	1.000000	1.000000
std	1.545474	0.176088	0.159215

Source: Compiled from Collected Data

This figure summarizes the daily recorded transactions comprehensively to depict the stability of the transactions with a decline in the last line of the dataset.

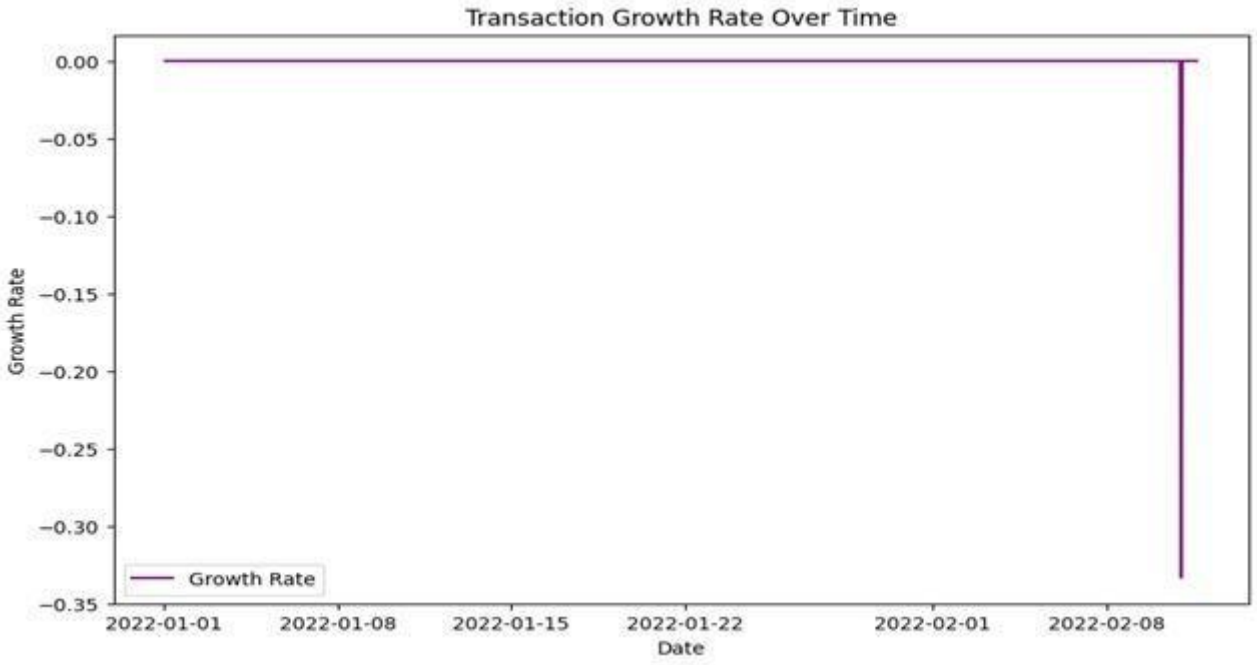
Figure 7: *Daily Transaction Volume*



Source: Compiled from Collected Data

The line plot represents the transaction growth rate from January 1, 2022, to February 8, 2022. The constant zero growth rate did not experience a qualitative change for growth or decline until February 2022.

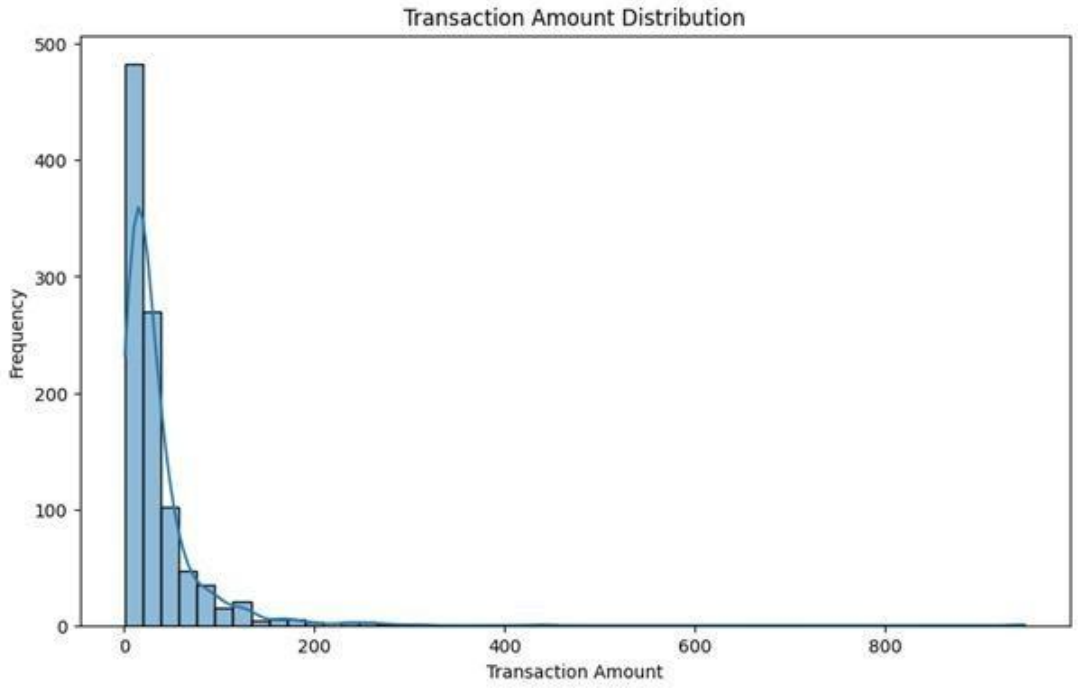
Figure 8: *Transaction Growth Rate Over Time*



Source: Compiled from Collected Data

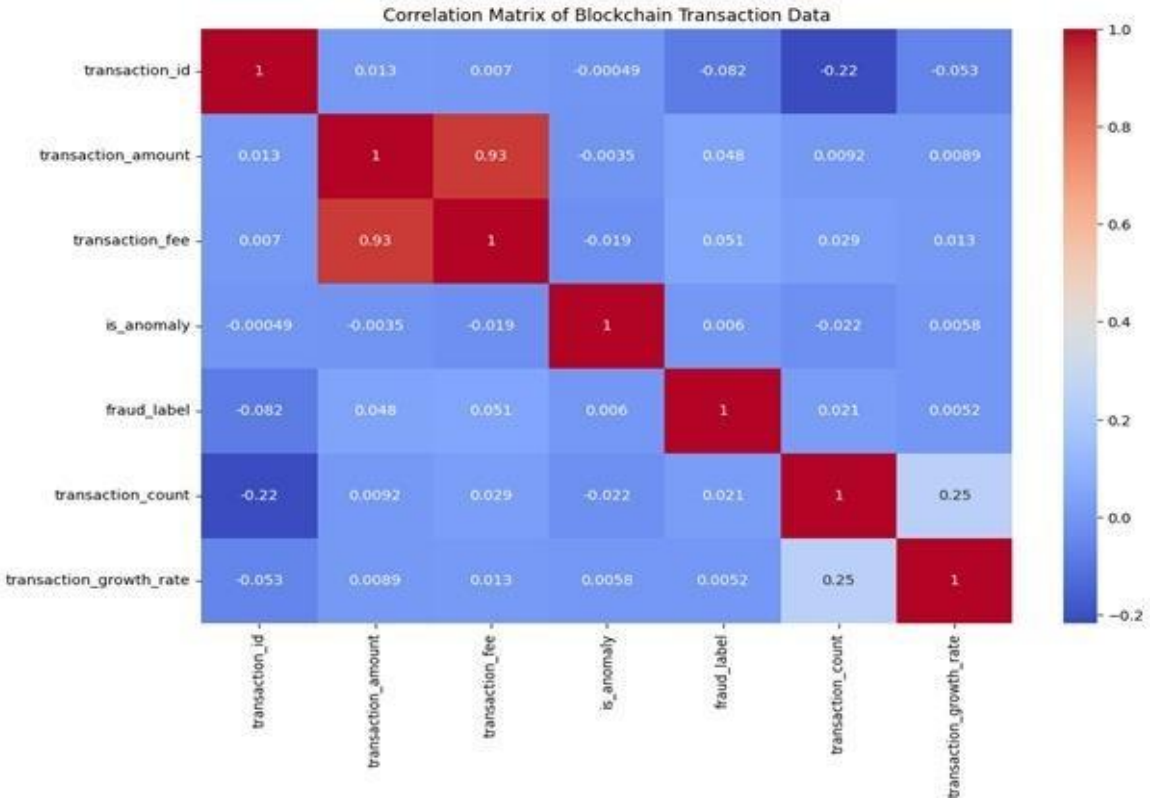
This histogram illustrates the types of transactions and the amount of each type. It indicates there are more small amounts of types of transactions than there are high-valued types of transactions. The average transaction size is less than 50 dollars.

Figure 9: *Transaction Amount Distribution*



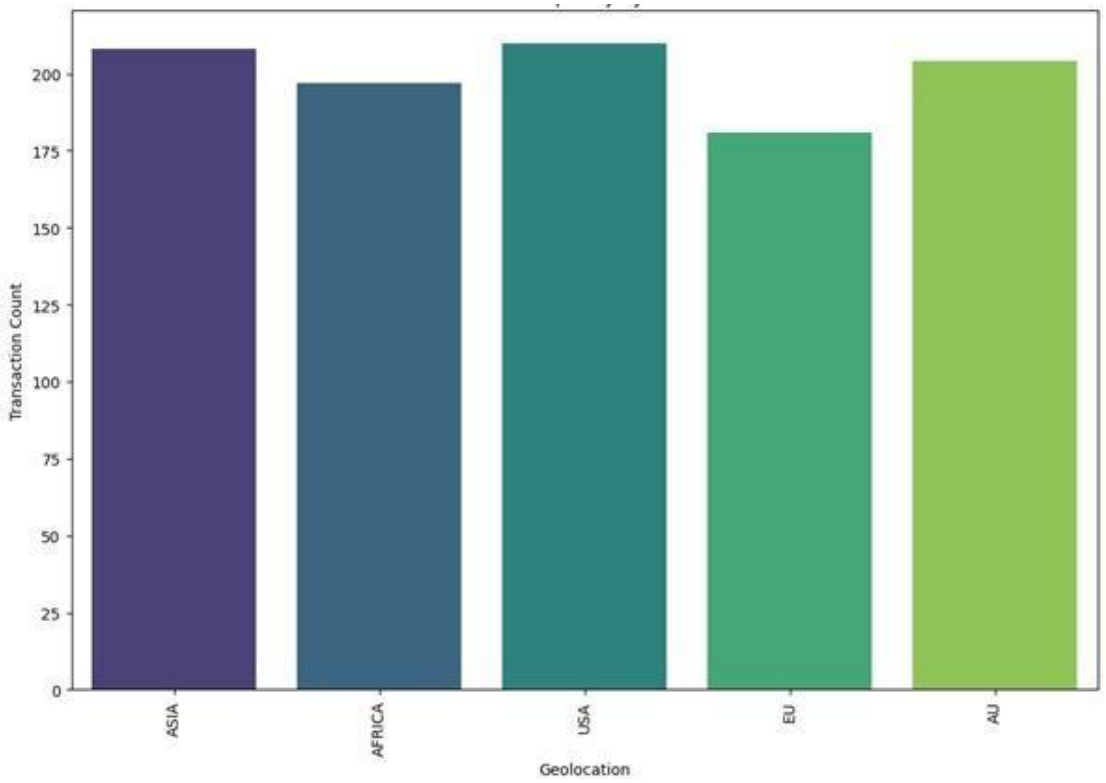
Source: Compiled from Collected Data

Figure 10: *Correlation Matrix of Blockchain Transaction Data*



Source: Compiled from Collected Data

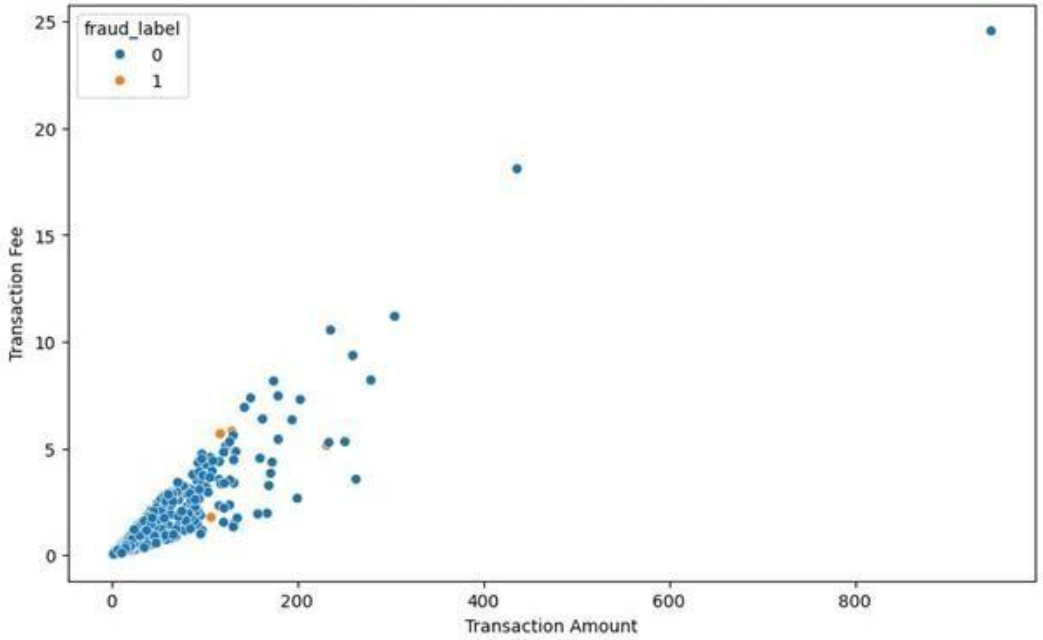
Figure 11: *Transaction Frequency by Geolocation*



Source: Compiled from Collected Data

A transaction fee is proportional to the transaction amount. Fraudulent transactions have an unusually high or unusually low transaction fee.

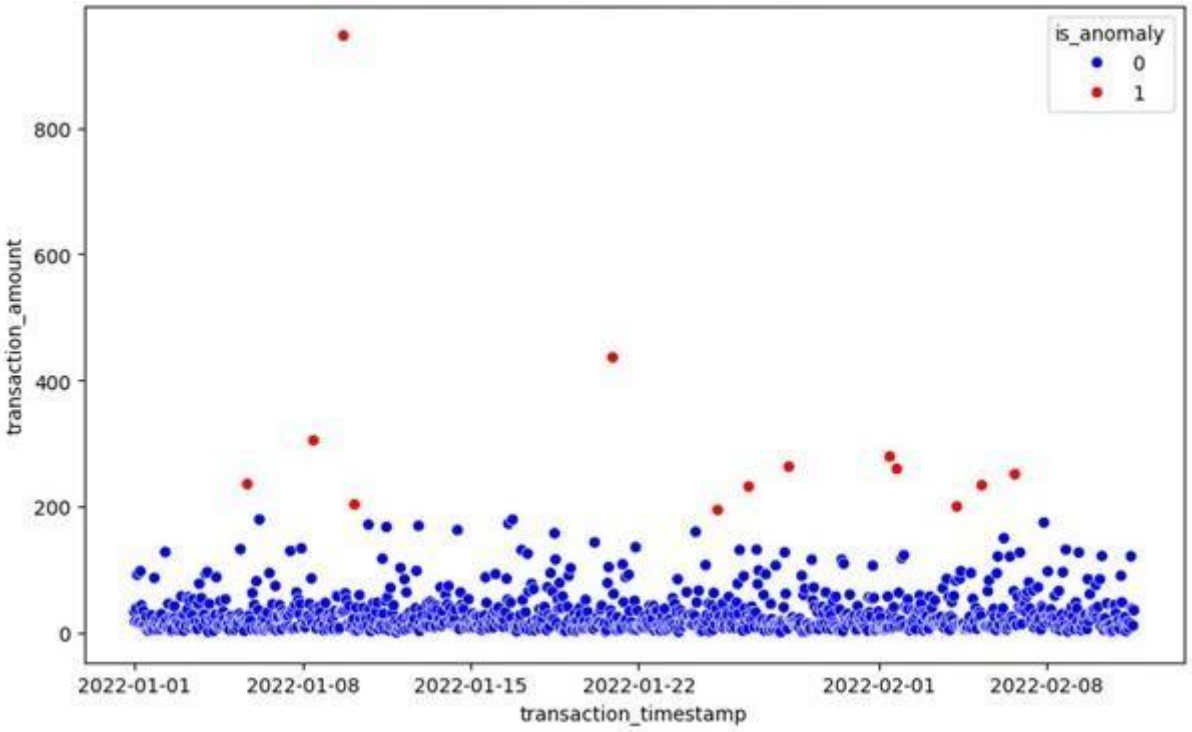
Figure 12: *Transaction Amount v/s Transaction Fee*



Source: Compiled from Collected Data

The scatter plot of Figure 13 reveals the transactions about their timestamp and their amount if anomalous, is highlighted in red. Outlier transactions are those which are detected by the model and marked as potentially fraudulent. Most of the records, deemed benign or normal, are coloured blue and the smaller number of records that the model identified as fraudulent are coloured red.

Figure 13: *Anomaly Detection in Transactions*



Source: Compiled from Collected Data

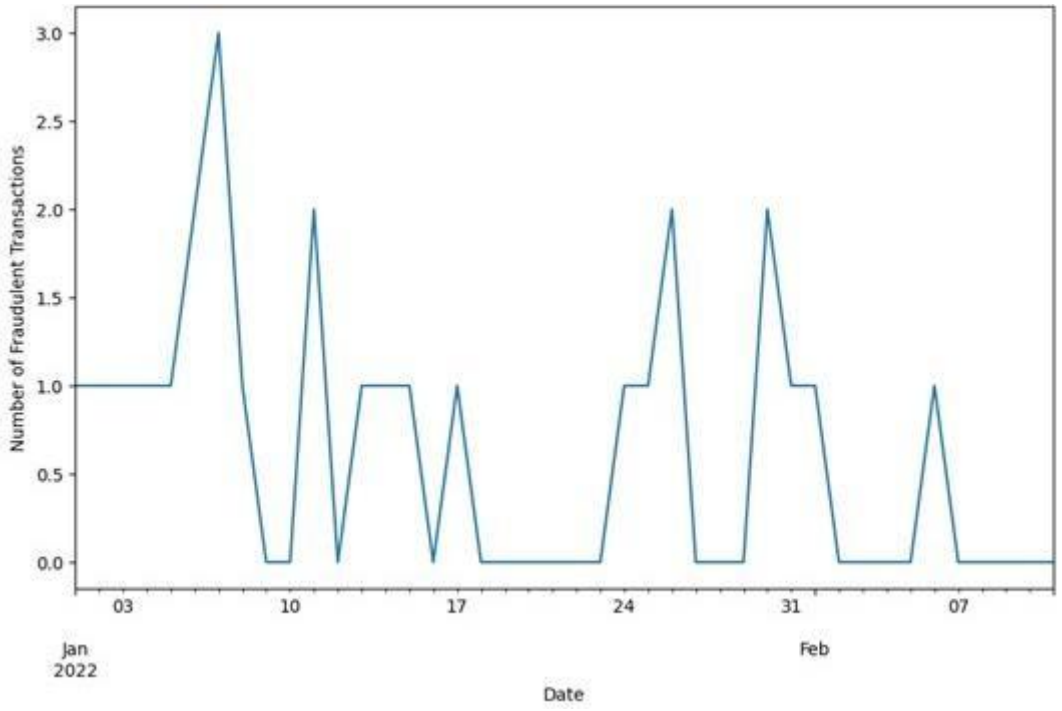
Figure 14: *Classification Report generated from the dataset*

```
transaction_id                    int64
transaction_timestamp      datetime64[ns]
transaction_amount                float64
transaction_fee                   float64
geolocation                        object
is_anomaly                          int64
fraud_label                         int64
transaction_count                   int64
transaction_growth_rate           float64
z_score                           float64
dtype: object
Classification Report:
              precision    recall  f1-score   support

           0       0.99      1.00      0.99       297
           1       0.00      0.00      0.00         3

    accuracy                           0.99       300
   macro avg       0.49      0.50      0.50       300
weighted avg       0.98      0.99      0.98       300

AUC-ROC Score: 0.37822671156004484
```

Source: Compiled from Collected Data

This figure also depicts the change in fraudulent transactions in the study period and clearly shows that fraud is not static.

Figure 15: *Fraud Occurrences Over Time*



Source: Compiled from Collected Data

Figure 16: *A portion of the fraudulent transactions identified the Isolation Forest model*

Suspected Fraudulent Transactions with Fraud Scores:

	transaction_id	transaction_timestamp	transaction_amount	\
6	7	2022-01-01 06:00:00	97.437663	
31	32	2022-01-02 07:00:00	128.031738	
106	107	2022-01-05 10:00:00	132.447442	
113	114	2022-01-05 17:00:00	235.860874	
125	126	2022-01-06 05:00:00	179.550342	
130	131	2022-01-06 10:00:00	4.260287	
156	157	2022-01-07 12:00:00	129.771409	
179	180	2022-01-08 11:00:00	304.956507	
209	210	2022-01-09 17:00:00	946.462633	
220	221	2022-01-10 04:00:00	203.295090	
234	235	2022-01-10 18:00:00	171.390416	
248	249	2022-01-11 08:00:00	117.384426	
252	253	2022-01-11 12:00:00	167.696567	
284	285	2022-01-12 20:00:00	169.530589	
323	324	2022-01-14 11:00:00	162.777995	
374	375	2022-01-16 14:00:00	172.981120	
378	379	2022-01-16 18:00:00	179.433189	
387	388	2022-01-17 03:00:00	131.127593	
393	394	2022-01-17 09:00:00	125.393747	
420	421	2022-01-18 12:00:00	157.708426	
460	461	2022-01-20 04:00:00	143.269165	
478	479	2022-01-20 22:00:00	436.540349	
501	502	2022-01-21 21:00:00	135.560311	
...				
944	5.319474	1.0	-0.011856	1
996	2.216042	1.0	-0.016314	1
998	0.115954	1.0	-0.003908	1
999	0.367001	1.0	-0.028767	1

Source: Compiled from Collected Data

For the flagged transactions, the following general characteristics were observed: greater transaction amounts, a significantly larger time interval between transactions, and an increased difference in the calculated ratio of the transaction value to fees. These patterns are synchronized with previously identified fraud activities of blockchain where the intended adverse transaction contains large amounts, low fees and abnormal time.

Discussion

Implementation

1. Tools and Technologies: Programming Languages and Libraries used:

Python: For specifically performing activities such as model deployment and execution, data pre-processing and data integration.

TensorFlow/Keras: For generating synthetic data using Generative AI models such as GANs and VAEs and training the same.

PyTorch: This section provides an alternative to TensorFlow, namely, the setting of Generative AI architectures to develop and test.

2. Blockchain Sites:

Gathered certain information and insights for our research using specific websites and Search Explorer, which are listed in our paper's reference section. Gathered certain information and insights for our research using specific websites and Search Explorer, which are listed in our paper's reference section.

Ethereum: To get actual blockchain transactional data and also to make use of smart contracts for scenarios.

Bitcoin Core: Just to store and extract Bitcoin transaction data.

3. Data Analysis and Visualization:

Pandas/NumPy: From where you can do data manipulation and numerical operations.

Matplotlib/Seaborn: It is useful when one needs to analyze the patterns and abnormalities of the transactions.

4. Development and Deployment:

Jupiter Notebook: For end-use prototyping and testing models.

Docker: To containerize the application and have the systems on different networks have an agenda of a similar environment.

AWS/GCP/Azure: To backup data and also get additional computing resources mostly on the internet.

CONCLUSION

Finally, this study highlights the revolutionary possibilities of combining synthetic data generation and generative AI in the context of risk management and Anti-Money Laundering (AML) compliance. The complexity and sophistication of financial crimes are always increasing, and standard AML frameworks are frequently unable to keep up. This study emphasizes the need for cutting-edge technical solutions that can improve predictive capacities by simulating future scenarios and analyzing past data. Generative Adversarial Networks (GANs) are one promising approach toward producing realistic synthetic datasets that replicate real-world blockchain transactions. Organizations can better plan for and reduce the risks associated with money laundering activities by using these datasets to train AML systems. In addition, the suggested AI-driven crisis simulations offer a dynamic setting for evaluating and improving risk management plans, guaranteeing their resilience in the face of new dangers.

The results of this study support a complete strategy that blends crisis simulations with the creation of synthetic data, which should ultimately result in more successful financial crime identification, mitigation, and prevention. The aforementioned integration not only bolsters the security and integrity of blockchain technology but also cultivates increased confidence and adoption of these systems across diverse industries. The use of generative AI in AML procedures is a big step forward in protecting financial institutions from illegal activity as the financial ecosystem changes. Stakeholders may establish a more robust, transparent, and secure financial ecosystem by adopting these cutting-edge technologies. This will pave the way for a day when financial crimes are successfully combated, and compliance is smoothly incorporated into operating frameworks. Beyond AML, the consequences of the research provide insightful information for more general applications in risk management and financial security.

ETHICAL DECLARATION

Conflict of interest: The author declares that there is no conflict of interest regarding the publication of this paper.
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Agarwal, S., & Dhar, V. (2014). Big data, data science, and analytics: The opportunity and challenge for IS research. Information Systems Research, 25(3), 443–448. https://doi.org/10.1287/isre.2014.0546

Al-Megren, S., Alsalamah, S., Altoaimy, L., Alsalamah, H., Soltanisehat, L., Almutairi, E., & Pentland, A. (2018). Blockchain use cases in digital sectors: A review of the literature. In Proceedings of the IEEE Conference on Big Data. https://doi.org/10.1109/BigData.2018.8622466

American Bar Association. (2024). Recent developments in artificial intelligence and blockchain cases. Retrieved from https://www.americanbar.org/groups/business_law/resources/business-law-today/2024-march/recent-developments-artificial-intelligence-blockchain-cases-2024/

AML Watcher. (2024). 7 use cases of artificial intelligence in anti-money laundering. Retrieved from https://amlwatcher.com/blog/7-use-cases-of-artificial-intelligence-in-anti-money-laundering/

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., ... & Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143–174. https://doi.org/10.1016/j.rser.2018.10.014

Arjovsky, M., Chintala, S., & Bottou, L. (2017). Wasserstein GAN. Retrieved from https://arxiv.org/abs/1701.07875

Botta, A., de Donato, W., Persico, V., & Pescapé, A. (2016). Integration of cloud computing and internet of things: A survey. Future Generation Computer Systems, 56, 684–700. https://doi.org/10.1016/j.future.2015.09.021

Bouri, E., Shahzad, S. J. H., & Roubaud, D. (2019). Co-explosivity in the cryptocurrency market. Finance Research Letters, 29, 178–185. https://doi.org/10.1016/j.frl.2018.07.005

Catalini, C., & Gans, J. S. (2016). Some simple economics of the blockchain. National Bureau of Economic Research Working Paper No. 22952. https://doi.org/10.3386/w22952

Chainalysis. (2023). 2023 crypto crime report. Retrieved from https://go.chainalysis.com/2023-Crypto-Crime-Report.html

Chen, Y., & Bellavitis, C. (2020). Blockchain disruption and decentralized finance: The rise of decentralized business models. Journal of Business Venturing Insights, 13, e00151. https://doi.org/10.1016/j.jbvi.2019.e00151

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the Internet of things. IEEE Access, 4, 2292–2303. https://doi.org/10.1109/ACCESS.2016.2566339

CipherTrace. (2023). 2023 cryptocurrency anti-money laundering report. Retrieved from https://ciphertrace.com/2023-cryptocurrency-anti-money-laundering-report/

Cong, L. W., & He, Z. (2019). Blockchain disruption and smart contracts. The Review of Financial Studies, 32(5), 1754–1797. https://doi.org/10.1093/rfs/hhz007

Corbet, S., Lucey, B., Urquhart, A., & Yarovaya, L. (2019). Cryptocurrencies as a financial asset: A systematic analysis. International Review of Financial Analysis, 62, 182–199. https://doi.org/10.1016/j.irfa.2018.09.008

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond Bitcoin. Applied Innovation Review, 2, 6–19. Retrieved from https://j2-capital.com/wp-content/uploads/2017/11/AIR-2016-Blockchain.pdf

Deloitte. (2023). Anti-money laundering and know your customer: How AI and machine learning can help. Retrieved from https://www2.deloitte.com/us/en/pages/risk/articles/anti-money-laundering-ai-machine-learning.html

Elliptic. (2024). Our new research: Enhancing blockchain analytics through AI. Retrieved from https://www.elliptic.co/blog/our-new-research-enhancing-blockchain-analytics-through-ai

Fanusie, Y. J., & Robinson, T. (2018). Bitcoin laundering: An analysis of illicit flows into digital currency services. Foundation for Defense of Democracies. Retrieved from https://www.fdd.org/wp-content/uploads/2018/01/MEMO_Bitcoin_Laundering.pdf

Fatemi, A., Fooladi, I., & Tucker, J. (2020). Money laundering: A financial crime of the 21st century. Journal of Money Laundering Control, 23(1), 48–64. https://doi.org/10.1080/1359702X.2020.1736958

FATF. (2023). Opportunities and challenges of new technologies for AML/CFT. Retrieved from https://www.fatf-gafi.org/content/dam/fatf-gafi/guidance/Opportunities-Challenges-of-New-Technologies-for-AML-CFT.pdf.coredownload.pdf

Foley, S., Karlsen, J. R., & Putniņš, T. J. (2019). Sex, drugs, and bitcoin: How much illegal activity is financed through cryptocurrencies? The Review of Financial Studies, 32(5), 1798–1853. https://doi.org/10.1093/rfs/hhz015

Generative AI for Synthetic Data. (2021). Generative adversarial networks for blockchain anomaly detection. Retrieved from https://arxiv.org/abs/2105.08467

Gervais, A., Karame, G. O., Wüst, K., Glykantzis, V., Ritzdorf, H., & Capkun, S. (2016). On the security and performance of proof of work blockchains. In Proceedings of the ACM SIGSAC Conference on Computer and Communications Security. https://doi.org/10.1145/2976749.2978341

Goodell, J. W., & Goutte, S. (2021). Co-movement of COVID-19 and Bitcoin: Evidence from wavelet coherence analysis. Finance Research Letters, 38, 101625. https://doi.org/10.1016/j.frl.2020.101625

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., ... & Bengio, Y. (2014). Generative adversarial nets. In Advances in Neural Information Processing Systems. https://doi.org/10.5555/2969033.2969125

Haber, S., & Stornetta, W. S. (1991). How to time-stamp a digital document. Journal of Cryptology, 3(2), 99–111. https://doi.org/10.1007/BF00196791

KPMG. (2023). AI in AML: Enhancing compliance and reducing risk. Retrieved from https://home.kpmg/us/en/home/insights/2023/04/ai-in-aml-enhancing-compliance-and-reducing-risk.html

Kshetri, N. (2017). Can blockchain strengthen the Internet of things? IT Professional, 19(4), 68–72. https://doi.org/10.1109/MITP.2017.3051335

Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. Retrieved from https://bitcoin.org/bitcoin.pdf

PwC. (2023). Using AI and machine learning to enhance AML and sanctions compliance. Retrieved from https://www.pwc.com/us/en/services/consulting/library/ai-aml-sanctions-compliance.html

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Saleh, F. (2021). Blockchain without waste: Proof-of-stake. The Review of Financial Studies, 34(3), 1156–1190. https://doi.org/10.1093/rfs/hhaa075

Tapscott, D., & Tapscott, A. (2017). How blockchain will change organizations. MIT Sloan Management Review, 58(2), 10–13. Retrieved from https://sloanreview.mit.edu/article/how-blockchain-will-change-organizations/

Tracefort. (2024). Cryptocurrency and AI: Successfully addressing the surge in global money laundering. Retrieved from https://tracefort.com/ai-money-laundering-cryptocurrency-2024/

Treleaven, P., Brown, R. G., & Yang, D. (2017). Blockchain technology in finance. Computer, 50(9), 14–17. https://doi.org/10.1109/MC.2017.3571047

Weber, I., Xu, X., Riveret, R., Governatori, G., Ponomarev, A., & Mendling, J. (2016). Untrusted business process monitoring and execution using blockchain. In Business Process Management. Springer. https://doi.org/10.1007/978-3-319-45348-4_19

Wood, G. (2014). Ethereum: A secure decentralised generalised transaction ledger. Retrieved from https://ethereum.github.io/yellowpaper/paper.pdf

Wu, J., Guo, J., Liu, X., Yu, J., & Zhang, J. (2020). Stock market prediction via a generative adversarial network. Retrieved from https://www.researchgate.net/publication/331002527_Stock_Market_Prediction_Based_on_Generative_Adversarial_Network

Xu, X., Weber, I., & Staples, M. (2019). Architecture for blockchain applications. Springer. https://doi.org/10.1007/978-3-030-03035-3

Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where is current research on blockchain technology? A systematic review. PLoS One, 11(10), e0163477. https://doi.org/10.1371/journal.pone.0163477

Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017). An overview of blockchain technology: Architecture, consensus, and future trends. In Proceedings of the IEEE International Congress on Big Data. https://doi.org/10.1109/BigDataCongress.2017.85

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Artificial Intelligence (AI) in Human Resource Management (HRM): A Bibliometric Research

Wamika Sehgal [1*], Thenmozhi M [2]

[1] Department of Maths, BITS Pilani, Hyderabad Campus, India
[2] Department of English, School of Social Sciences & Languages, Vellore Institute of Technology, Vellore, India

***Corresponding Author:** wamikasehgal2005@gmail.com

Citation: Sehgal, W. & M. Thenmozhi. (2024), Artificial Intelligence (AI) in Human Resource Management (HRM): A Bibliometric Research, *International Journal of Convergent Research (IJCR)*, 1(1), 24-38

ARTICLE INFO

Received: 19th August 2024
Accepted: 01st November 2024

ABSTRACT

Purpose: The purpose of this study is to conduct a bibliometric analysis to explore the scholarly literature on the integration of Artificial Intelligence (AI) in Human Resource Management (HRM), by focusing on identifying trends, key contributors, research themes, and emerging areas of interest.
Methodology/Approach: The research employs systematic bibliometric analysis, utilizing academic databases such as Scopus to collect relevant literature. Keywords including "AI," "Artificial Intelligence," "HRM," and "Human Resource Management" were used to retrieve documents. Bibliometric software such as bibliophily is utilized to visualize co-authorship networks, citation patterns, keyword co-occurrence, and publication trends.
Findings: The analysis shows how AI applications in HRM have developed over time, moving from theoretical explorations to empirical studies and the incorporation of cutting-edge AI technologies. Important researchers and research clusters are highlighted, along with field-wide collaborative networks and key contributors. Personalized learning, employee performance prediction, AI-based hiring, and ethical issues are among the often-studied topics. Emerging fields include cross-cultural research, ethical frameworks for AI deployment, and the integration of AI with emerging technologies.
Originality: By providing an organized bibliometric overview of the academic environment on AI in HRM and offering insights into trends, important contributors, and developing research areas, this study adds to the body of current literature. The methodical approach used in this study guides future research and practice while also improving our grasp of the revolutionary potential of AI in HRM practices.

Keywords: Artificial Intelligence, HRM, bibliometric analysis, trends, research theme.

INTRODUCTION

Background of Study

The advent of artificial intelligence (AI) marks a watershed moment in the realm of technology, heralding a new era of innovation and disruption. AI, characterized by its ability to emulate human-like intelligence and learning capabilities, has transcended traditional boundaries, revolutionizing problem-solving methodologies, decision-making processes, and automation paradigms across various industries (Rudra Kumar & Gunjan, 2022). From healthcare to finance, manufacturing to entertainment, AI's impact is pervasive, fundamentally altering the way organizations operate and compete in the global marketplace.

Within this transformative landscape, the domain of Human Resource Management (HRM) stands poised for significant evolution. Historically, HRM has been tasked with overseeing the recruitment, development, and retention of talent within organizations, serving as a crucial conduit between employees and management. However, the traditional HRM model, while effective in many respects, has faced challenges in adapting to the complexities of the modern workforce and the dynamic

nature of contemporary workplaces.

Against this backdrop, the integration of AI in HRM represents a paradigm shift with profound implications. By harnessing AI-driven technologies, organizations can augment their HRM capabilities, unlocking new opportunities for efficiency, agility, and innovation. AI holds the promise of revolutionizing key aspects of HRM, which includes stuff like talent acquisition, performance management, learning and development, and employee engagement (Anshima et al., 2023). Through advanced analytics, predictive modelling, and automation, AI empowers HR professionals to make data-driven decisions, optimize processes, and enhance the overall employee experience.

Moreover, the emergence of AI in HRM underscores the convergence of technology and human capital management, blurring the lines between traditional HR functions and strategic business imperatives. As organizations increasingly recognize the strategic importance of their workforce in driving competitive advantage, AI presents a compelling opportunity to transform HRM from a reactive support function to a proactive driver of organizational success (Paigude et al., 2023).

However, amidst the promise of AI-driven HRM solutions, challenges and complexities abound. Ethical considerations, privacy concerns, and as well as the possibilities of algorithmic bias raise important queries about the responsible deployment of AI in HRM practices (Dixit et al., 2023). Moreover, the need to balance technological innovation with human-centric approaches presents a delicate balancing act for HR practitioners, as they navigate the evolving landscape of AI-enabled HRM.

In light of these developments, there is a pressing need for scholarly inquiry and empirical research to understand the implications, challenges, and advantages of incorporating AI into HRM. By delving into the intricacies of AI-driven HRM practices, researchers can contribute to a deeper understanding of this evolving field, informing best practices, guiding policy decisions, and influencing how work will be done in the digital age. Thus, the background of this study underscores the significance of exploring the intersection of AI and HRM and its implications for organizations, employees, and society at large.

Relevance of the Study

The integration of AI holds profound implications for HRM, promising to enhance personnel management, streamline administrative processes, and bolster organizational effectiveness (Anshima et al., 2023). The relevance of investigating AI in HRM lies in its multifaceted applications, spanning workforce analytics, employee training and development, performance management, and recruitment and selection (Paigude et al., 2023). By leveraging AI-driven solutions, HR professionals can access data-driven insights to reduce biases, improve judgements, and elevate the overall working environment for employees (Dixit et al., 2023). Amidst the contemporary challenges organizations face in attracting, retaining, and nurturing talent, AI presents a compelling opportunity to address these issues effectively (Bhupathi et al., 2023). The evolution of AI-driven tools and algorithms empowers HR practitioners to harness data-driven approaches, thereby optimizing HRM processes and strategies. However, as businesses increasingly embrace AI technologies in HRM practices, it becomes imperative to conduct a comprehensive assessment of the implications, challenges, and opportunities associated with this paradigm shift (Bankar & Shukla, 2023). This study aims to explain how AI can revolutionise HRM practices and address contemporary organizational challenges. Through empirical investigation and scholarly analysis, we seek to give insightful information regarding the evolving landscape of AI in HRM, thereby informing future research endeavours and practical applications in this dynamic field.

Objectives of the Study

The main goal of this study is to provide an extensive bibliometric analysis of academic literature on AI in HRM. Specifically, the study aims to achieve the following objectives:

i. Identify key trends and developments in the integration of AI technologies within HRM practices.
ii. Map out the intellectual landscape by analyzing citation patterns, collaboration networks, and research clusters.
iii. Highlight seminal works and influential contributors shaping the discourse on AI in HRM.
iv. Explore emerging research themes and areas of interest within the field.
v. Provide insights and directions for future research and practical implications for HR practitioners and organizational leaders.

The rationale of the Study

This study's justification is the increasing significance of AI in changing HRM procedures and its consequences for both employee welfare and company performance (Sonawane et al., 2022). This study aims to provide a structured overview of the body of literature by performing a bibliometric analysis, synthesizing information, and identifying knowledge gaps (Dutta & Mishra, 2023). Furthermore, a comprehensive examination of academic contributions can help guide future research as well as practical organizational decision-making in the quickly changing fields of artificial intelligence (AI) and human resource management (HRM) (Chitrao et al., 2022). The main purpose of our research is to provide important insights for future research

and practice as well as to further our understanding of the revolutionary potential of AI in HRM.

LITERATURE REVIEW

AI Applications in Recruitment and Selection

The integration of artificial intelligence (AI) in recruitment and selection processes has garnered significant attention within the domain of AI-driven Human Resource Management (HRM). This subsection of the literature review delves into the multifaceted applications of AI in optimizing hiring procedures, enhancing candidate experiences, and augmenting recruitment effectiveness.

Traditionally, the hiring process has been labour-intensive and time-consuming, characterized by manual resume screening, candidate ranking, and screening procedures. However, the advent of AI technology has revolutionized these practices, offering innovative solutions to streamline recruitment workflows and improve decision-making.

AI-powered algorithms facilitate automated resume processing, enabling organizations to efficiently analyze large volumes of applicant data and pinpoint the best applicants based on preset standards (Bhatt, 2023). Through the application of machine learning and natural language processing techniques, AI algorithms can discern relevant skills, experiences, and qualifications from resumes, significantly reducing time-to-fill and enhancing recruitment efficiency (Paigude et al., 2023). This automated screening process not only expedites candidate selection but also minimizes the risk of human bias, ensuring a fair and objective evaluation of candidates.

Furthermore, AI-driven technologies such as chatbots and virtual assistants play a pivotal role in enhancing the candidate's experience throughout the recruitment journey. These AI-enabled tools serve as virtual recruiters, interacting with candidates, scheduling interviews, and providing real-time feedback (Dutta et al., 2023). By offering personalized communication and timely assistance, chatbots and virtual assistants alleviate administrative burdens on HR professionals while fostering positive candidate perceptions of the organization.

Moreover, AI facilitates data-driven decision-making in recruitment and selection, enabling organizations to identify patterns, trends, and correlations within applicant data. By analyzing historical recruitment data and candidate profiles, AI algorithms can predict candidate success and fit within specific roles, guiding recruiters in making informed hiring decisions (Paigude et al., 2023). This predictive analytics capability empowers organizations to optimize their talent acquisition strategies, aligning recruitment efforts with organizational objectives and workforce requirements.

The application of AI in recruitment and selection represents a transformative paradigm shift in HRM practices. By automating mundane tasks, enhancing decision-making processes, and improving candidate experiences, AI-driven solutions offer unprecedented opportunities for organizations to optimize their hiring processes and acquire a strategic advantage in talent acquisition. However, it is essential for organizations to carefully navigate ethical considerations and ensure transparency and fairness in AI-enabled recruitment practices, thereby fostering trust and credibility among candidates and stakeholders.

AI for Performance Management and Employee Development

The utilization of artificial intelligence (AI) in performance management and employee development represents a pivotal frontier in AI-driven Human Resource Management (HRM). This subsection of the literature review examines AI's revolutionary potential for streamlining performance management procedures and fostering continuous employee development.

Technologies related to AI such as machine learning algorithms and predictive analytics, empower HR practitioners to gain deeper insights into employee performance, anticipate future trends, and deliver personalized feedback (Pavitra & Agnihotri, 2023). By analyzing vast troves of data encompassing performance metrics, project outcomes, and behavioural patterns, AI algorithms can identify correlations, trends, and performance drivers with unparalleled accuracy. This analytical prowess enables organizations to move beyond traditional performance appraisal methods towards dynamic, data-driven performance management systems.

One of the key advantages of AI-powered performance management lies in its ability to offer personalized feedback and coaching to employees. By leveraging AI algorithms, HR practitioners can deliver tailored feedback that addresses individual strengths, weaknesses, and developmental needs (Pavitra & Agnihotri, 2023). This customised strategy promotes a continual improvement in culture within the organization in addition to increasing staff motivation and engagement.

Moreover, AI facilitates the automation of routine performance management tasks, allowing HR professionals to devote more time to strategic endeavours. From goal setting and tracking to performance evaluation and feedback delivery, AI-driven systems streamline the entire performance management process, reducing administrative burdens and increasing efficiency (Pavitra & Agnihotri, 2023).

In addition to performance management, AI holds immense potential for supporting ongoing learning and skill development initiatives within organizations. AI-powered learning management systems (LMS) leverage machine learning

algorithms to deliver personalized training modules, recommend relevant learning materials, and monitor individual progress (Anshima et al., 2023). By analyzing employee skills gaps, learning preferences, and career aspirations, AI-driven LMSs can curate tailored learning experiences that resonate with individual employees, thereby enhancing learning outcomes and driving organizational growth.

The integration of AI in performance management and employee development heralds a new era of HRM innovation. By leveraging advanced analytics, personalized feedback mechanisms, and automated learning solutions, organizations can unlock new opportunities for optimizing employee performance, fostering talent development, and driving organizational success. However, organizations must address privacy concerns, ethical considerations, and employee apprehensions associated with AI-driven performance management systems, thereby ensuring transparency, fairness, and trustworthiness in HRM practices.

Ethical Considerations and Challenges of AI in HRM

While the integration of artificial intelligence (AI) holds immense potential to revolutionize HRM practices, it also presents a myriad of ethical considerations and challenges that must be addressed. This section of the literature review delves into the ethical dilemmas surrounding AI adoption in HRM and highlights the need for ethical principles and legal frameworks to mitigate risks and safeguard employee rights.

The privacy of data is one of the primary issues surrounding AI in HRM. Security concerns about sensitive personal data emerge as businesses gather and examine massive volumes of employee data to support AI-powered decision-making (Dutta & Mishra, 2023). To secure employee privacy and preserve faith in AI-enabled HRM systems, it is essential to ensure compliance with data protection legislation like GDPR and to have strong data governance procedures in place.

The topic of algorithmic bias is a crucial ethical consideration. Inadequate training or validation of AI algorithms may cause them to unintentionally reinforce preexisting biases in historical data, producing unequal results in the hiring, performance management, and talent development processes (Dutta & Mishra, 2023). Addressing algorithmic bias requires a concerted effort to diversify training data, employ fairness-aware algorithms, and implement bias detection and mitigation strategies to ensure equitable treatment of all employees.

Transparency is also a key ethical principle that must be upheld in AI-driven HRM practices. Employees should be aware of how AI algorithms work, what influences algorithmic decisions, and how these decisions may affect their future career prospects. (Dutta & Mishra, 2023). Enhancing transparency in AI systems fosters trust, accountability, and employee acceptance, thereby mitigating concerns surrounding algorithmic opacity and the "black box" phenomenon.

Furthermore, the adoption of AI in HRM necessitates a critical examination of its social and ethical ramifications. The potential for AI to influence job displacement and the reconfiguration of job roles underscores the importance of ethical foresight and responsible implementation practices (Sonawane et al., 2022). HR practitioners must consider the broader societal impacts of AI adoption, including implications for workforce diversity, inclusion, and socio-economic equality.

While AI offers unprecedented opportunities to enhance HRM practices, its adoption must be guided by ethical principles and legal frameworks to mitigate risks and ensure equitable treatment of employees. Organizations may embrace the revolutionary potential of AI in HRM while respecting ethical norms and fostering a culture of trust and justice in the workplace by addressing concerns related to data privacy, algorithmic bias, transparency, and social effects.

Integration of AI with Emerging Technologies in HRM

A new era in HRM innovation is being heralded by the integration of artificial intelligence (AI) with cutting-edge technologies like blockchain, augmented reality (AR), and virtual reality (VR). This section of the literature review explores the synergistic potential of combining AI with these cutting-edge technologies to enhance HRM practices and unlock new opportunities for employee engagement, productivity, and innovation.

Blockchain technology holds promise for revolutionizing HRM by offering enhanced security, transparency, and verifiability in employee records and credentials management (Dixit et al., 2023). By leveraging blockchain-based systems, organizations can create tamper-proof digital ledgers for recording employee data, including qualifications, certifications, and performance evaluations. This decentralized approach to data management ensures data integrity and reduces the risk of fraudulent activities, thereby enhancing trust and credibility in HRM processes.

Augmented reality (AR) and virtual reality (VR) technologies present exciting avenues for transforming employee training and development initiatives. By integrating AI-driven algorithms with AR and VR platforms, organizations can deliver immersive and interactive training experiences that simulate real-world scenarios (Dixit et al., 2023). AI algorithms can personalize training content based on individual learning styles, preferences, and performance metrics, thereby optimizing learning outcomes and knowledge retention. Moreover, AR and VR technologies facilitate virtual collaboration and remote teamwork, enabling employees to interact and collaborate seamlessly across geographical boundaries.

Furthermore, the integration of AI with emerging technologies opens up new possibilities for enhancing talent acquisition and recruitment processes. AI-powered chatbots and virtual recruiters can leverage natural language processing (NLP)

algorithms to engage with candidates, answer queries, and guide them through the recruitment journey (Dixit et al., 2023). By integrating AI-driven chatbots with AR and VR interfaces, organizations can create immersive recruitment experiences that showcase company culture, values, and job opportunities, thereby attracting top talent and enhancing candidate engagement.

The integration of AI with emerging technologies represents a paradigm shift in HRM practices, offering innovative solutions to address contemporary challenges and drive organizational success. By harnessing the collective capabilities of AI, blockchain, AR, and VR, organizations can create dynamic, data-driven HRM ecosystems that foster employee development, enhance recruitment experiences, and optimize workforce management processes. However, organizations need to remain vigilant about ethical considerations, data privacy, and user experience when deploying AI-enabled solutions in conjunction with emerging technologies, thereby ensuring responsible and effective implementation in the HRM domain.

AI-Enabled Diversity and Inclusion Initiatives

The utilization of artificial intelligence (AI) holds transformative potential for advancing diversity and inclusion (D&I) initiatives within organizations. This subsection of the literature review examines how AI-enabled HRM practices can mitigate biases, foster inclusivity, and establish fair workplaces where each employee feels appreciated and empowered to make a difference.

One of the key contributions of AI in D&I efforts lies in its ability to reduce biases in hiring, performance reviews, and talent management procedures (Bankar & Shukla, 2023). Traditional HR processes are susceptible to unconscious biases that can inadvertently disadvantage underrepresented groups. However, AI systems leverage data-driven algorithms to analyze candidate profiles, assess performance objectively, and identify talent based on merit rather than subjective factors. AI helps to ensure that everyone, regardless of origin or identity, has fairness and equal opportunity by reducing bias in decision-making processes.

Moreover, AI-enabled HRM practices offer proactive strategies for fostering diversity and inclusion within organizations. AI algorithms can analyze organizational data to identify patterns, trends, and areas for improvement in D&I efforts (Bankar & Shukla, 2023). By providing insights into workforce demographics, representation across different groups, and disparities in opportunities, AI empowers organizations to develop targeted interventions and initiatives that promote diversity, equity, and inclusion.

Furthermore, AI systems can assist in identifying unconscious biases in decision-making processes and providing recommendations for mitigating these biases (Bankar & Shukla, 2023). Through machine learning algorithms, AI can detect subtle patterns in decision-making that may reflect unconscious biases and offer interventions to counteract these biases. For example, AI algorithms can suggest diverse candidate pools for recruitment, flag biased language in job descriptions, and provide training recommendations to address implicit biases among employees.

AI-enabled HRM practices help to create inclusive work environments where all employees feel valued, respected, and encouraged to contribute their unique perspectives and talents by fostering a culture of fairness and equity (Bankar & Shukla, 2023). Organizations can benefit from varied viewpoints, creativity, and innovation as well as a sense of belonging and psychological safety within their workforce by utilizing AI to support diversity and inclusion programs.

AI holds immense promise for advancing diversity and inclusion efforts within organizations by reducing biases, providing actionable insights, and fostering inclusive work cultures. However, organizations need to approach AI implementation in D&I initiatives with sensitivity to ethical considerations, transparency, and stakeholder engagement, thereby ensuring that AI-driven interventions promote equity, fairness, and social justice in the workplace.

Future Directions and Research Opportunities

Future research in AI-driven HRM could explore interdisciplinary collaborations with fields such as psychology, sociology, and organizational behaviour to deepen our understanding of the human factors influencing AI adoption and usage (Rai & Singh, 2023). Studies that follow the effects of AI technologies overtime on work satisfaction, employee well-being, and organizational performance may yield important insights into the long-term effects of AI in HRM (Kiran et al., 2023). Furthermore, to guarantee that AI technologies are applied morally and fairly in corporate contexts, research concentrating on the creation of ethical standards, legal frameworks, and best practices for responsible AI deployment in HRM is crucial (Dutta et al., 2023).

The literature review highlights the diverse applications of AI in HRM, ranging from recruitment and selection to performance management, employee development, and diversity initiatives. Even though AI has a lot to offer HRM professionals, there are problems and ethical issues that need to be resolved. To ensure the responsible and equitable deployment of AI in organizational settings and to further our understanding of the transformative potential of AI in HRM, future research should concentrate on interdisciplinary collaborations, longitudinal studies, and the creation of ethical guidelines.

METHODOLOGY

Data Source

The information used in this research was taken from the Scopus database, which is recognized as a vast collection of academic literature from a variety of fields. Scopus is a great resource for bibliometric analysis since it offers access to a huge library of academic publications, conference proceedings, and peer-reviewed journals. Through the utilization of Scopus's comprehensive coverage and strong indexing capabilities, this study was able to gather a wide range of scholarly research on the application of artificial intelligence (AI) to human resource management (HRM). Using Scopus made it possible to access high-calibre, peer-reviewed literature, which allowed for in-depth investigation and critical analysis of themes, trends, and patterns in AI-driven HRM practices.

Search Process

The search process involved the following steps:

i. Initial search using the keywords "AI" and "HR" yielded 1,360 documents.

ii. To refine the search, documents published between 2013 and 2023 were considered, resulting in 912 documents.

iii. Further refinement was done using the following search query:

```
TITLE-ABS-KEY (ai AND hr) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "DECI") OR LIMIT-TO (SUBJAREA, "MULT")) AND (LIMIT-TO (AFFILCOUNTRY, "India")) AND (LIMIT-TO (LANGUAGE, "English"))
```

This query was tailored to retrieve documents with a focus on AI and HR, published between 2013 and 2023, with affiliations from India and written in English. This refined search yielded 132 documents as of 18th March 2024.

Data Collection

Exporting documents that were retrieved from the Scopus database in a format that was standardized and tailored for bibliometric analysis was part of the data-gathering process. This consistent style made it easier to extract relevant bibliographic information that is necessary for a thorough examination of the academic literature on the incorporation of artificial intelligence (AI) into human resource management (HRM).

Data Analysis

The collected data underwent comprehensive analysis using Biblioshiny, a powerful bibliometric analysis tool renowned for its diverse features tailored for visualizing and interpreting bibliographic data. Biblioshiny facilitated various analyses, including co-authorship networks, citation patterns, keyword co-occurrence, and publication trends, providing valuable insights into the scholarly landscape of AI in human resource management (HRM). Utilizing Biblioshiny's user-friendly interface, the extracted bibliographic details were systematically inputted into the tool, enabling seamless generation of interactive visualizations for exploration and interpretation of the data. These visualizations served as powerful aids in identifying key trends, influential authors, and emerging research themes within the field of AI in HRM. The use of Biblioshiny ensured robust and comprehensive analysis of the bibliographic dataset, enabling the generation of insights that informed the findings of this study. This study was able to get important insights into the academic landscape of AI in HRM by utilizing Biblioshiny's sophisticated analytical tools. This helped to increase knowledge of the field's dynamics, trends, and future research directions.

Limitations

Despite the comprehensive nature of Scopus as a repository of academic literature, this study acknowledges several limitations inherent in the data collection process and scope of analysis:

i. Incomplete Coverage: While Scopus provides access to a vast collection of scholarly papers, it may not include all pertinent works related to the topic of AI in HRM. Some relevant literature may be published in journals or conferences not indexed in Scopus, leading to potential gaps in the dataset.

ii. Language and Geographic Limitations: The search was confined to English-language publications connected to India, which may introduce bias and limit the generalizability of the findings. Restricting the search to a specific language and geographic region may overlook valuable insights and perspectives from non-English publications and other global contexts.

iii. Applicability of Results: The findings of this study may have limited applicability in different contexts or settings due to the focus on English-language publications connected to India. The insights derived from the analysis may

not fully capture the diverse range of perspectives, practices, and research trends prevalent in other regions or linguistic communities.

iv. Addressing Limitations: Despite these limitations, efforts were made to mitigate their impact on the study's validity and reliability. Careful consideration was given to the selection of search criteria, data extraction methods, and analytical techniques to ensure the robustness and integrity of the analysis. Additionally, transparency regarding the study's scope and limitations was maintained throughout the research process.

Although this study offers insightful information about the academic field of AI in HRM, to guarantee a nuanced comprehension of the research findings, it is crucial to recognize and resolve the inherent limits. Future research endeavours should strive to overcome these limitations by employing diverse search strategies, expanding the scope of analysis to encompass a broader range of languages and geographic regions, and adopting inclusive methodologies that capture diverse perspectives and contexts within the field of AI-driven HRM.

DATA ANALYSIS AND FINDINGS

Document Analysis

Table 1 provides the document analysis mentioning that the dataset comprises 132 documents published between 2014 and 2023, sourced from 96 different journals, books, and other scholarly sources. These documents exhibit an annual growth rate of 59.81%, indicating a significant increase in research output over the specified timespan. With an average age of 2.03 years, each document is reasonably recent. Moreover, the documents have received an average of 5.644 citations, indicating their impact and influence within the academic community.

In terms of document contents, a diverse range of keywords has been identified, including both Keywords Plus (606) and Author's Keywords (362), reflecting the multidimensional nature of research topics within the dataset. The dataset encompasses contributions from 376 authors, with 12 documents being authored by single authors. Collaboration among authors is prevalent, with an average of 3.28 co-authors per document. Additionally, international collaboration is evident, with 21.21% of documents featuring co-authorships across different countries.

Regarding document types, the dataset comprises various formats, including articles (37), books (5), book chapters (36), conference papers (53), and an erratum (1). This diversity in document types reflects the interdisciplinary nature of research on AI in HRM, encompassing contributions from academic journals, books, and conference proceedings.

The document analysis offers a thorough summary of academic research on AI in HRM, demonstrating the depth and breadth of scholarly investigation into this quickly developing topic. The results of this dataset analysis provide insightful information on study themes, citation trends, and collaboration patterns that can guide future investigations and deepen our understanding of how AI is integrated into HRM practices.

Table 1: *Document Analysis*

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2014:2023
Sources like books, journals etc	96
Documents found	132
Annual Growth Rate Percentage	59.81
Document Average Age	2.03
Average citations per Document	5.644
References Found	4258
DOCUMENT CONTENTS	
Keywords Plus (ID)	606
Author's Keywords (DE)	362
AUTHORS	
Authors	376
Authors of single-authored documents	12

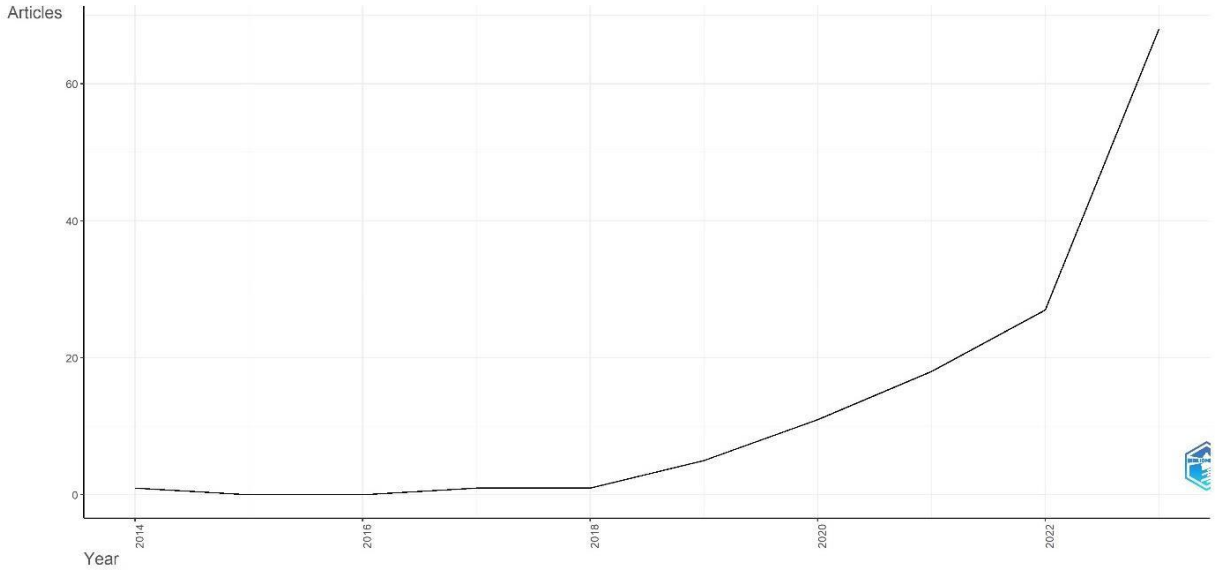
AUTHORS COLLABORATION	
Single-authored documents	12
Co-Authors per Documents	3.28
International co-authorships Percentage	21.21
DOCUMENT TYPES	
Articles Found	37
Books Found	5
Book chapters Found	36
Conference paper Found	53
Erratum	1

Source: Author's Compilation

Production Analysis

From Figure 1, it's evident that there is a notable increase in article production starting from 2019, with a sharp rise observed in 2020 and further exponential growth in 2021 and 2022. The year 2023 shows a significant continuation of this trend, with the highest number of articles produced compared to the previous years.

Figure 1: *Production Analysis*



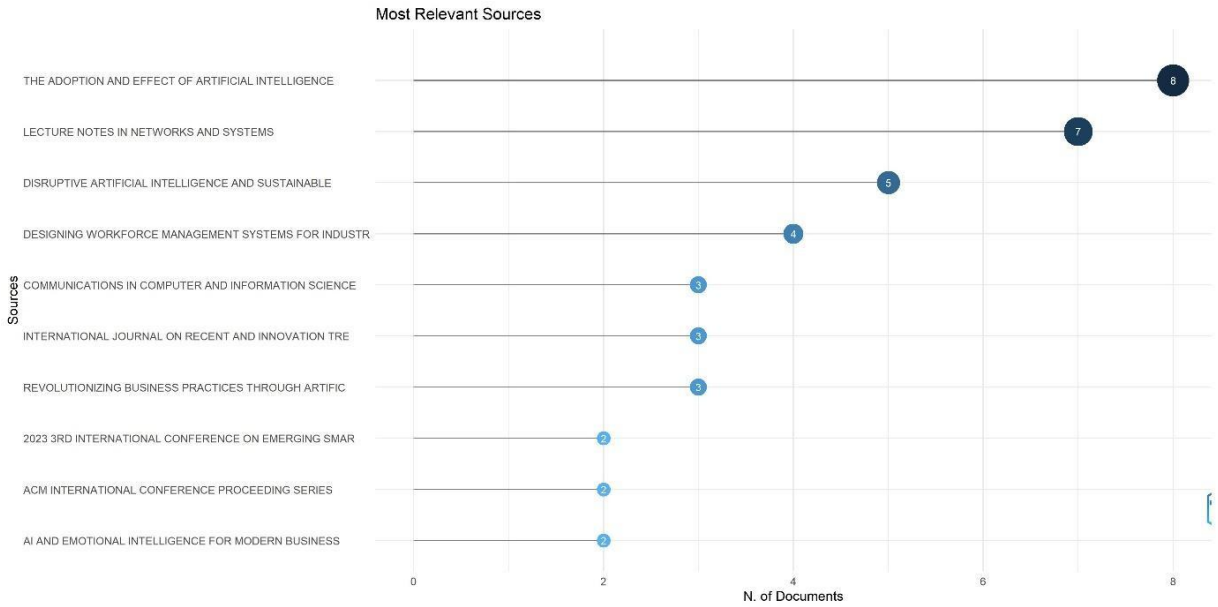
Source: Author's Compilation

According to this production analysis, there is a rising body of study and interest in the area of artificial intelligence (AI) in human resource management (HRM), with scholars concentrating more on investigating the different facets and uses of AI in HRM practices. The trend of more articles being produced emphasizes how important AI is to the transformation of HRM and emphasizes the need for ongoing study and investigation into this developing field.

Most Relevant Source

From the Figure 2 analysis, it's evident that "THE ADOPTION AND EFFECT OF ARTIFICIAL INTELLIGENCE ON HUMAN RESOURCES MANAGEMENT, PART A" and "LECTURE NOTES IN NETWORKS AND SYSTEMS" are the two most relevant sources, with the highest number of articles contributed to the literature on AI in HRM. These sources likely contain significant insights and research findings on the topic and are therefore considered highly relevant within the field.

Figure 2: *Most Relevant Source*

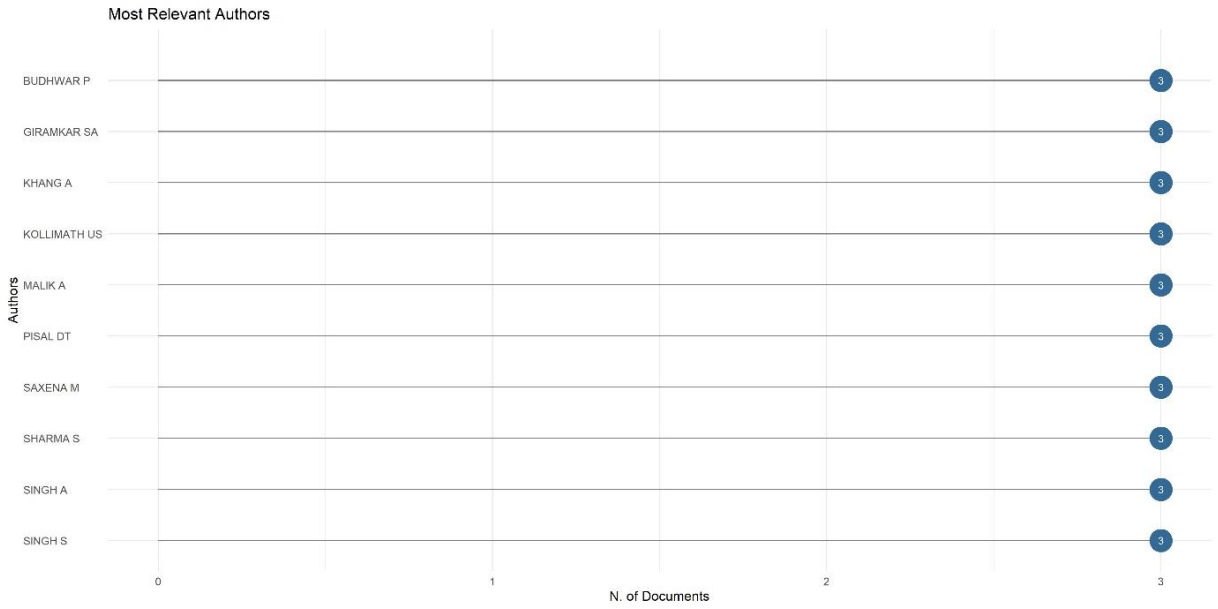


Source: Author's Compilation

Most Relevant Author

Several writers have significantly contributed to the literature on AI in HRM, according to the most pertinent author analysis, which is based on Figure 3. Among these authors, Sharma S stands out as the most prolific, with an article fractionalized value of 1.08, indicating that they have contributed slightly more than one article on average. Other noteworthy authors include Khang A, Saxena M, and Singh A, each with articles fractionalized values exceeding 1, suggesting they have also contributed significantly to the field.

Figure 3: *Most Relevant Author*



Source: Author's Compilation

Interestingly, several authors have contributed to three articles each, including Budhwar P, Giramkar SA, Kollimath US, Malik A, Pisal DT, Singh S, and Singh A. Although they have the same number of articles, their fractionalized values vary, indicating differences in their relative contributions to each article.

This analysis highlights the collective efforts of these authors in advancing the understanding of AI in HRM. Their contributions have likely shaped the discourse, influenced research directions, and contributed to the development of practical applications within the field. Further exploration of their individual contributions and research focus areas could provide deeper insights into their impact on literature and their roles in shaping the future of AI in HRM.

Word Cloud Analysis

Figure 4 reveals several key terms and concepts related to artificial intelligence (AI) in human resource management (HRM). At the forefront is the term "artificial intelligence," which appears most frequently, underscoring its central importance in the field. Alongside AI, terms such as "human resource management" and "human resources management" feature prominently, highlighting the integration of AI technologies in managing human resources within organizations. Furthermore, advanced AI techniques like "deep learning" and "machine learning" are significant, indicating their role in data analysis, pattern recognition, and decision-making processes within HRM. Terms like "personnel" and "decision making" suggest a focus on personnel management and decision support systems powered by AI.

Figure 4: *Word Cloud*

Source: Author's Compilation

Additionally, terms like "resource allocation" and "random forests" point to the application of AI algorithms in optimizing resource allocation and predictive modelling. However, the inclusion of "natural resources management" may represent an outlier or a closely related field, potentially indicating some noise in the dataset. Overall, the word cloud offers a visually appealing snapshot of the diverse range of topics and technologies encompassed within the realm of AI in HRM.

Thematic Map

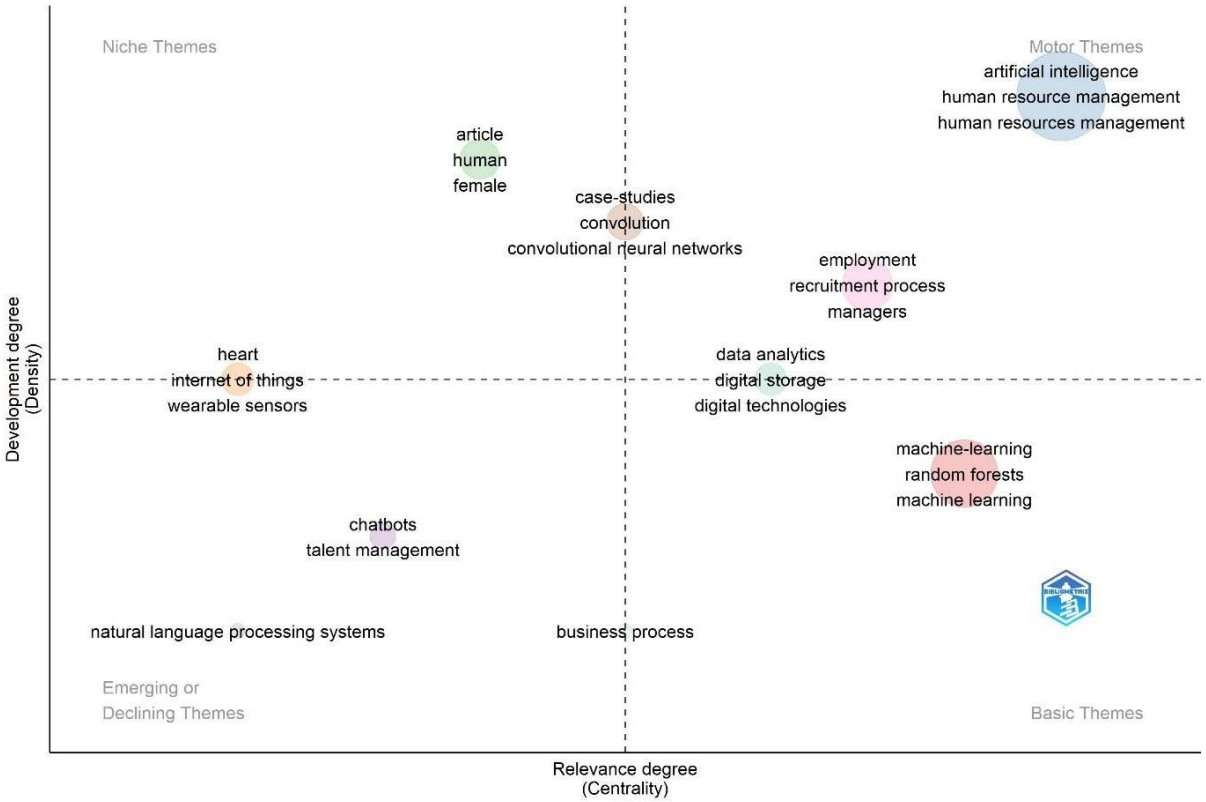
Figure 5 portrays the thematic map analysis which involves clustering words based on their occurrences and centrality measures to identify themes or topics within the dataset. Here's the thematic map analysis based on the provided data:

i. Cluster: Machine Learning: Words like "random forests," "machine learning," "decision trees," "forecasting," "learning systems," "classification (of information)," and "data science" are clustered together under the theme of machine learning. These terms indicate a focus on various machine learning techniques and methodologies applied in HRM contexts, such as predictive modelling, classification, and data analysis.

ii. Cluster: Employee Attrition and Turnover: Terms like "employee attrition" and "employee turnover" form a separate cluster, suggesting a distinct theme related to employee retention and turnover prediction using machine learning approaches. These terms likely represent research efforts aimed at identifying factors contributing to employee attrition and turnover and developing predictive models to mitigate these issues within organizations.

The thematic map analysis highlights two main themes within the dataset: machine learning techniques applied in HRM and the prediction and management of employee attrition and turnover. These themes provide insights into the research focus areas and methodologies employed in studying AI in HRM, indicating a strong emphasis on leveraging machine learning for predictive analytics and decision support in human resource management practices.

Figure 5: *Thematic Map*



Source: Author's Compilation

Countries' Collaboration World Map

Figure 6 involves visualizing collaborations between countries based on the frequency of interactions. Here's the analysis based on the data provided:

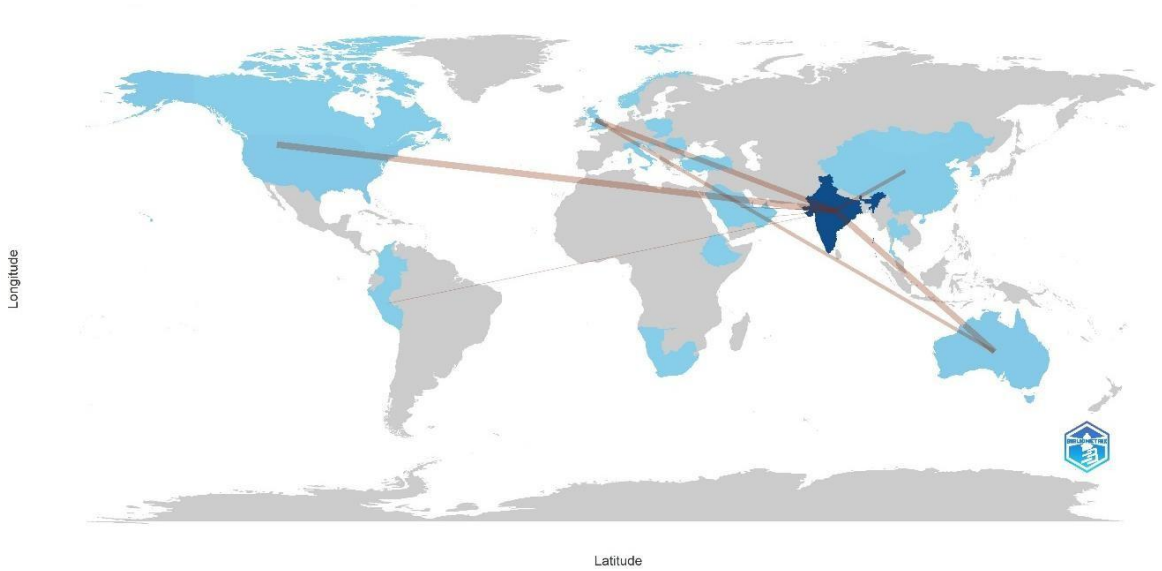
i. India-Australia Collaboration (5): India and Australia have collaborated five times, indicating a significant level of cooperation between the two countries in research or other endeavours related to the dataset's topic.

ii. India-United Kingdom Collaboration (3): India and the United Kingdom have collaborated three times, suggesting another notable partnership in research or collaborative efforts.

iii. India-China Collaboration (3): India and China also share three collaborations, reflecting a significant level of interaction between two of the world's largest economies.

iv. Other Collaborations: There are individual collaborations between India and other countries like Canada, Colombia, Croatia, Ethiopia, Italy, and Korea. While these collaborations are less frequent, they still indicate diverse international partnerships in the dataset.

Figure 6: *Countries' Collaboration World Map*



Source: Author's Compilation

The country collaboration map analysis highlights the prominent collaborations between India and several other countries, particularly Australia, the United Kingdom, and China. The aforementioned collaborations are expected to facilitate the transfer of knowledge, resources, and skills about the subject matter of the dataset, hence promoting global cooperation and scientific progress.

LIMITATIONS OF THE STUDY

Even if the study adds insightful knowledge about AI in HRM, it's critical to recognize some limitations that could affect how the results are interpreted and applied generally.

Firstly, the study's reliance on bibliometric analysis imposes inherent constraints, particularly in terms of the reliance on quantitative metrics and the potential oversight of context-specific and qualitative nuances. By focusing primarily on publications indexed in Scopus, the study may have inadvertently excluded relevant literature from other databases or non-indexed sources, introducing selection bias into the dataset.

Secondly, the accuracy and accessibility of the data utilized in the analysis, including author affiliations and keyword classifications, may have posed challenges. Inconsistencies or inaccuracies in data sources could have influenced the results and interpretations of the study, undermining the reliability of the findings.

Furthermore, because the study focuses on AI in HRM within a particular geographic location and timeframe, its applicability to other contexts or timeframes may be limited. Changes in organizational, technological, and cultural contexts may affect how applicable and generalizable the study's findings are outside of its initial purview.

Despite these limitations, it is important to recognize the value of the study in contributing to the expanding body of research on AI in HRM. By providing insightful information and laying the groundwork for continued exploration and innovation in this dynamic field, the study catalyzes further scholarly inquiry and practical advancements in AI-enabled HRM practices. Moving forward, researchers and practitioners should exercise caution when interpreting the study's findings and strive to address the identified limitations in future research endeavours.

FURTHER SCOPE

Even though the current research has shed light on how AI is integrated into HRM, there are still many areas that might use more research to improve our knowledge and implementation of AI-driven HRM practices. The following sections highlight possible study topics that should be investigated in the future:

i. Specific Applications of AI in HRM: Subsequent investigations may explore more deeply certain uses of AI in HRM, including talent acquisition, performance management, workforce optimization, and employee management. Researchers can gain sophisticated insights into the efficacy, difficulties, and best practices related to AI adoption in HRM processes by looking more closely at these domains.

ii. Multidisciplinary Research: There is a growing need for multidisciplinary research that explores the intersection

of AI with other cutting-edge technologies such as blockchain, the Internet of Things (IoT), and augmented reality (AR). Investigating how these technologies synergize with AI in transforming HRM procedures can provide fresh perspectives and innovative solutions to complex HR challenges.

iii. Qualitative Research: Supplementing bibliometric analysis with qualitative research methods can offer more nuanced insights into the impact of AI implementation on employee experiences, organizational culture, and ethical considerations. Qualitative studies can capture the lived experiences of employees and HR practitioners, shedding light on the complexities and nuances of AI-enabled HRM practices.

iv. Longitudinal Studies: Longitudinal studies tracking the development of AI in HRM over time can elucidate evolving trends, emerging obstacles, and future possibilities in this rapidly evolving field. By monitoring changes in AI adoption, implementation strategies, and outcomes over time, researchers can provide valuable guidance to policymakers and practitioners navigating the dynamic landscape of AI-driven HRM.

Our understanding of AI in HRM and its ability to support strategic decision-making in businesses should be furthered by future research projects that adopt longitudinal perspectives, combine qualitative methodologies, embrace multidisciplinary approaches, and concentrate on particular AI applications. Scholars can further understand and practice AI-enabled HRM by tackling these research gaps, which will eventually improve company effectiveness, employee well-being, and social impact.

CONCLUSION

The dynamic interaction of artificial intelligence (AI) and human resource management (HRM) has been thoroughly bibliometrically analyzed in this study, which has yielded insightful information about how organizational practices are changing. The study has provided a clear picture of the complex interaction between AI and HRM by illuminating important themes, significant authors, thematic clusters, and collaborative networks through a thorough assessment of academic literature.

The most notable finding of the analysis is the remarkable surge in research output over the past decade, underscoring the increasing significance and relevance of AI within the HRM domain. This surge reflects a growing interest and engagement in leveraging AI technologies to enhance HRM practices and address contemporary organizational challenges. Furthermore, the study has identified recurring patterns in the application of decision support systems, predictive modelling, and machine learning methods across diverse HRM contexts, highlighting the versatility and adaptability of AI-driven solutions.

Moreover, the collaborative networks revealed in the analysis underscore the global nature of research in this field, with alliances spanning continents and countries. Notable collaborations between research institutions in Australia, China, India, the United Kingdom, and beyond demonstrate concerted efforts to expand knowledge, foster innovation, and drive advancements in AI-enabled HRM practices on an international scale.

This work adds to our knowledge of the revolutionary possibilities of AI in HRM and emphasizes the significance of ongoing investigation and cooperation in this quickly developing area. Through the identification of nascent trends, cultivation of interdisciplinary collaborations, and adoption of inventive approaches, scholars and professionals can effectively leverage artificial intelligence (AI) to transform human resource management (HRM) systems, maximize organizational efficacy, and augment employee experiences within the digital era. Businesses must be mindful of ethical considerations, transparency, and stakeholder engagement when navigating the complexity of AI adoption. This will help to guarantee that AI-driven HRM practices support inclusiveness, fairness, and equity in the workplace.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper.
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Agnihotri, A., Mathad, K., & Kadry, S. (2023). The new HR inclination for artificial intelligence aiding talent acquisition. *In Disruptive Artificial Intelligence and Sustainable Human*

Anshima, B., Bhardwaj, B., & Sharma, D. (2023). Artificial intelligence: Shifting the landscape of the human resources ecosystem. In *Leveraging AI and Emotional Intelligence in Contemporary Business Organizations* (pp. 371-381). https://doi.org/10.4018/979-8-3693-1902-4.ch022

Balasubramanian, P., & Balakrishna, D.R. (2023). Case study: Infosys – Talent management processes automation with AI. In *Springer Handbooks* (Part F674, pp. 1451-1458). https://doi.org/10.1007/978-3-030-96729-1_70

Bankar, S., & Shukla, K. (2023). Performance management and artificial intelligence: A futuristic conceptual framework. In *Contemporary Studies of Risks in Emerging Technology: Part B* (pp. 341-360). https://doi.org/10.1108/978-1-80455-566-820231019

Bhatt, P. (2023). AI adoption in the hiring process – important criteria and extent of AI adoption. Foresight, 25(1), 144-163. https://doi.org/10.1108/FS-07-2021-0144

Bhupathi, P., Prabu, S., & Goh, A.P.I. (2023). Artificial intelligence-enabled knowledge management using a multidimensional analytical framework of visualizations. *International Journal of Cognitive Computing in Engineering*, 4, 240-247. https://doi.org/10.1016/j.ijcce.2023.06.003

Chitrao, P., Bhoyar, P.K., Divekar, R., & Bhatt, P. (2022). Study on the use of artificial intelligence in talent acquisition. In 2022 *International Conference on Interdisciplinary Research in Technology and Management, IRTM 2022* - Proceedings. https://doi.org/10.1109/IRTM54583.2022.9791659

Dixit, C.K., Somani, P., Gupta, S.K., & Pathak, A. (2023). Data-centric predictive modelling of turnover rate and a new hire in workforce management system. In *Designing Workforce Management Systems for Industry 4.0: Data-Centric and AI-Enabled Approaches* (pp. 121-137). https://doi.org/10.1201/9781003357070-8

Dutta, D., & Mishra, S.K. (2023). Bots for mental health: The boundaries of human and technology agencies for enabling mental well-being within organizations. *Personnel Review*. https://doi.org/10.1108/PR-11-2022-0832

Dutta, D., Mishra, S.K., & Tyagi, D. (2023). Augmented employee voice and employee engagement using artificial intelligence-enabled chatbots: A field study. *International Journal of Human Resource Management*, 34(12), 2451-2480. https://doi.org/10.1080/09585192.2022.2085525

Kaushik, P., Miglani, S., Shandilya, I., Singh, A., Saini, D., & Singh, A. (2023). HR functions productivity boost by using AI. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(8s), 701-713. https://doi.org/10.17762/ijritcc.v11i8s.7672

Kiran, P.B.N., Sireesha, K., Donthu, S., Vali, S.K.M., Pushpalatha, S., & Madhan, P. (2023). Framework analysing the impact of artificial intelligence on human resource management using AMO framework. In *4th International Conference on Intelligent Engineering and Management, ICIEM 2023*. https://doi.org/10.1109/ICIEM59379.2023.10165698

Paigude, S., Pangarkar, S.C., Hundekari, S., Mali, M., Wanjale, K., & Dongre, Y. (2023). The potential of artificial intelligence in boosting employee retention in the human resource industry. *International Journal on Recent and Innovation Trends in Computing and Communication*, 11(3s), 1-10. https://doi.org/10.17762/ijritcc.v11i3s.614

Pavitra, K.H., & Agnihotri, A. (2023). Artificial intelligence in corporate learning and development: Current trends and future possibilities. In *2023 2nd International Conference on Smart Technologies for Smart Nation, SmartTechCon 2023* (pp. 688-693). https://doi.org/10.1109/SmartTechCon57526.2023.10391698

Rai, A., & Singh, L.B. (2023). Artificial intelligence-based people analytics transforming human resource management practices. In *The Adoption and Effect of Artificial Intelligence on Human Resources Management, Part A* (pp. 229-244). https://doi.org/10.1108/978-1-80382-027-920231012

Rudra Kumar, M., & Gunjan, V.K. (2022). Machine learning-based solutions for human resource systems management. *Lecture Notes in Electrical Engineering*, 828, 1239-1249. https://doi.org/10.1007/978-981-16-7985-8_129

Sonawane, A., Loomba, A., & Paluchova, J. (2022). An influence of artificial intelligence on jobs and HRM in small manufacturing units. In *Managing Human Resources In SMEs And Start-ups: International Challenges and Solutions* (pp. 223-251). https://doi.org/10.1142/9789811239212_0011

Yadav, M., Kakkar, M., & Kaushik, P. (2023). Harnessing artificial intelligence to empower HR processes and drive enhanced efficiency in the workplace to boost productivity. I*nternational Journal on Recent and Innovation Trends in Computing and Communication*, 11(8s), 381-390. https://doi.org/10.17762/ijritcc.v11i8s.7218

Yadav, P.V., Kollimath, U.S., Giramkar, S.A., Pisal, D.T., Badave, S.S., & Swamy, S.M. (2023). HR 4.0: Role of AI in transforming HRM. In *2023 3rd International Conference on Emerging Smart Technologies and Applications, eSmarTA 2023*. https://doi.org/10.1109/eSmarTA59349.2023.10293704

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Critical Insights into Context-Aware Systems: A Literature Review

Hamza Aziz*, Shahnwaz Afzal

Aligarh Muslim University, Department of Computer Science, Aligarh, India

***Corresponding Author:** thisishamzaaziz@gmail.com

Citation: Aziz, H., & Afzal, S. (2024). Critical Insights into Context-Aware Systems: A Literature Review. *International Journal of Convergent Research*, 1(1), 39-49.

ARTICLE INFO

Received: 25th August 2024
Accepted: 17th November 2024

ABSTRACT

Recently, automobile networks, health monitoring, and industrial alarm systems have used context-aware systems more. These systems make sense of environmental cues and simulate productivity gains using fuzzy logic and machine learning. They can verify machine integration into the human body and perform logical sensor data analysis to improve healthcare monitoring. They can also help to create systems that adapt to changing conditions, such as emergency vehicle communication networks. Regardless of scale, these adaptive systems have varying modularity to improve results in a wide range of application areas. They enable secure, efficient, and intelligent interaction across domains. This study investigated 20 context-aware system studies. It covers strategic shifts, challenges, and dynamics in this field in detail. Business analytics, the Internet of Things, remote care, human capital, recommendation systems, vehicle networks, human-robot interactions, smart product-service systems, and successful recruitment are covered. Consider the entire synthesis to determine the value of contextuality and system use in various sectors. Fuzzy logic, machine learning, and architectural frameworks help explain context-aware computing formation and ongoing advances.

Keywords: Context, automotive networks, sensor, IoT, business intelligence, PSS.

INTRODUCTION

Cost-effective context-oriented technology will likely drive the most notable technological advancements in the future, leading to a novel kind of human-to-human communication. The industries most affected include transportation, healthcare, and smart housing. AI, sensor technology, and computer science are key factors in the development of these products. Sensory awareness is crucial in context-related systems. It involves quickly distinguishing varied environmental situations and providing individualized services to system users based on optimal decision-making. "Contextual intelligence refers to the process of coding artificial intelligence (AI) and applications in a manner that mimics how humans gather and utilize contextual information." Contextual intelligence refers to the ability of individuals, computers in artificial intelligence systems, and some applications to understand and interpret the context in which they operate. This includes the capability to analyze and make sense of recorded images or visual data using machine learning algorithms. The essay commenced with an examination of the establishment of context-aware systems, followed by an exploration of the forthcoming advancements in these devices. The practical implementation of these systems was extensively elucidated towards the end, with the provision of a specific case study.

Context-Aware Challenges

i. Contextual Ambiguity: Contextual ambiguity refers to the inherent uncertainty in environmental occurrences that context-aware systems encounter. These systems need reliable methods to accurately interpret such events.
ii. Diverse Sensing Modalities: Context-aware systems get increasingly complex when integrating diverse sensing modalities that necessitate pre-established data fusion and interpretation techniques.

iii. Processing Restrictions in Real Time: Given that context-aware systems primarily function as real-time operating systems, they necessitate algorithms and architectures that are both extremely efficient and capable of low latency.

This study offers a thorough examination of 20 works that focus on systems and deal with context-aware systems. Through a thorough examination of their research methodologies, findings, and final statements, we aim to emphasize the complexities of context-aware computing. We embarked on a review of those publications to discern crucial concepts that will enhance our comprehension of context-aware systems and aid in the advancement of a new trajectory in this rapidly expanding field.

Context-Awareness

The primary challenge of context-aware computing is to empower users with the ability to comprehend and interpret contextual cues, enabling them to make intelligent judgments and adapt their actions accordingly. To provide context-based suggestions, adaptive user interfaces, and tailored services, context-aware systems need to be able to effectively process and evaluate contextual information.

i. Interpreting Environmental Cues: Sensitive systems consist of distinct components that decode diverse environmental factors, such as timing, location, user preferences, and context.
ii. Adaptive Decision-Making: Indeed, this corresponds to cognitive systems having the ability to make decisions that are aware of the context in real time and being able to alter based on the interpreted context in a flexible manner.
iii. Integration of Multiple Data Sources: Most context-aware systems are meant to leverage data from several sources, such as sensor technologies, IoT devices, and social exchanges. However, this requires the use of intricate and complex methodologies for data fusion and analysis.

Sensors

Sensors are devices that observe and detect physical properties or changes around them. Context-aware systems involve different types of sensor devices such as

Figure 1: *Sensors in Mobile Computing*

Location Sensors

Sensors such as Bluetooth, Wi-Fi, and GPS tell us where the user is.

Motion Sensors

Sensor reconstruction in this category is achieved without any motion measurement or spatial discrepancies that could disrupt the process. This is because they record and assess changes in physical observable quantities such as sound, light, heat, and electromagnetic waves through measurements and evaluations. For instance, the accelerometer and gyroscope are employed to monitor the movements of the selected activity. In modern times, sensors have assumed a significant role in security systems, with gadgets increasingly incorporating them in many applications, including gaming, robotics, home automation, medical monitoring, and more. Motion sensors are superior because they are the primary means by which systems

detect and respond to activity occurring in their surroundings.

Environmental Sensors

Environmental sensors, which are crucial in a context-aware system, collect users' information to enable a smart atmosphere to gain precise knowledge about the user's surroundings through accurate telemetry data. These sensors possess the capability to engage with the climatic surroundings and accurately detect a wide range of data, such as temperature, humidity, brightness, pressure, and more. There is a wide array of environmental sensors due to their diverse properties. The comprehensive nature of each entity produces context awareness, enabling modifications to the surroundings. Typically, these sensors are accountable for detecting and displaying variations in temperature and humidity through distinct colour indicators. Context-aware computing platforms are a unique method of accurately representing the user's surroundings. These platforms rely on data-intensive processes and real-time sensors to read the user's environment and accurately depict the user's current condition. Automated guidance systems, robots, and classroom monitoring systems can adjust their behaviours by regulating measurements of elements like heat, pressure, humidity, and light intensity. This allows them to prioritize security, enhance comfort, and boost productivity.

Biometric Sensors

Devices that are inherently aware of their surroundings often rely on biometric sensors to offer two essential services: identification and authentication, as well as data gathering and analysis for health monitoring purposes. The technique establishes measurements to obtain a comprehensive understanding of the user. Her/his biometrics are used as a means of identification. The sensors mentioned, such as facial recognition, fingerprint reader, and heart rate monitor, are all instances of biometric sensors. If your device is equipped with sensors such as face(ion) sensors or fingerprint scanners, you can detect a heartbeat. These sensors are widely used and recognized as some of the most popular sensors available.

LITERATURE REVIEW

A Context-Aware Empowering Business with AI

Case of Chatbots in Business Intelligence Systems Artificial intelligence (AI) enhances business intelligence (BI) by enhancing data analysis, automating data integration, utilizing predictive analytics, employing natural language interfaces, detecting anomalies, generating tailored suggestions, and improving data visualization. Artificial intelligence (AI) systems analyze vast datasets to identify patterns or extract useful insights, while machine learning enables quicker and more effective examination of the data. They usually automate the process of aligning, transferring, and merging data between systems without human intervention. Natural language interfaces enable people to access data, while artificial intelligence predicts future patterns. This study explores the strategies for enhancing AI-based business intelligence through the application of advanced intelligence. The focus is on how AI business intelligence (AI BI), which comprises a range of approaches and tools, can enhance or even replace certain business procedures to improve decision-making. Consequently, our primary focus was to elucidate the viewpoint of intelligent business intelligence (BI) enhancement through artificial intelligence (AI), which forms the foundation of AI's use in empowering businesses (Azmi et al., 2023).

A Fuzzy Diagnostic Agent for Context-Aware Patient Monitoring

Remote healthcare monitoring, intended to offer adequate alternatives to conventional healthcare services, may serve as a feasible solution to alleviate the overwhelming strain on global healthcare systems. Regardless of your level of expertise in diagnosing a patient, it is crucial to ensure that you accurately determine their condition as well. This paper presents a fuzzy expert system that is connected to the Internet of Things (IoT) to perform medical diagnostics. The system utilizes a Body Area Network (BAN) consisting of multiple sensors that collect important health data. The system collects sensor data and uses fuzzy logic to classify the patient's responses, ranging from basic data to advanced indicators, for further study (Magano et al., 2018).

A Context-Aware Safety System for Human-Robot Collaboration

The development of synergies between humans and machines can be achieved through the newest advancements in human-machine interaction. In the industrial sector, each contributor will provide support to the other, using these inventions. The most captivating aspects of the entire procedure are consistently the removal of inefficiencies and the safeguarding of both data and function. This article proposes the discontinuation of the smart safety system invention to overcome obstacles and ultimately prevent loss of life. Technologies prioritize minimizing human intervention in data processing by computers, ensuring that desired goals are achieved only when a clever algorithm has determined it. Additionally, it will streamline the process of locating individuals, particularly about other factors that will improve comprehensiveness. This project focuses on creating a safety system for human-robot interaction that ensures optimal collaboration. Therefore, it delineates the elements, methodologies, and connections that are required (Liu et al., 2018).

Context-aware Gossip in Ad hoc Vehicular Networks

The objective of this research is to prioritize the provision of instances that examine the quantitative information-seeking behaviour of vehicular ad-hoc networks in the context of communal news guidance. The purpose of the contextual filtering function for Gossip in a traffic scenario is to be evaluated by comparing it with an unfiltered message through the simulation of two distinct scenarios. The objective is to integrate a single on-board unit into the car that has a collection of maps (layers) or named layer types (for vector layers) and allows for field selection and other similar actions, as well as the ability to set bookmark keywords. One of the main areas of our research is studying the intensity and significance of contextual filtering in life-threatening situations. Our study findings demonstrate that implementing such an idea may be done securely, without exacerbating the transient rumors that circulate inside the college environment. Contextual filters protect against a decrease in water levels by preventing the rivers from being filled with unnecessary and repetitive messages or data. When the costs of advertisements increase, the main flow of water will decrease rapidly (Bennakhia et al., 2019).

A Meta-model for context-aware adaptive Business Process as a Service in a collaborative cloud environment

Due to the significant expansion of cloud computing, the process of establishing new software through SaaS composition has become a more crucial activity compared to its previous importance. Today, the crucial demand for commercial SaaS solutions is to be adaptable and nimble, capable of transforming rapidly to meet changing conditions and requirements. Initially, a business analyst, who scrutinizes the operations of companies, designs the new business process for the SaaS. Once the SaaS composer completes the evaluation of the components, it assumes the task of choosing appropriate software that will ultimately be integrated into the process, with a primary focus on the essential parameters.

To address multiple business concerns under the cloud banner, this study develops a meta-model.

Additionally, an illustration of context-aware systems is examined, which focuses on the integration of several business activities and services to effectively handle the dynamic nature of business tasks (Hidria et al., 2019).

Detecting Bogus Information Attack in Vehicular Ad Hoc Network

A Context-Aware Approach Voluntary participatory networks can execute various functions, such as those of Fly Ad Hoc Networks (FANETs) and Vehicular Ad Hoc Networks (VANETs). These networks operate on community principles to enhance performance and deliver better services for entertainment and traffic monitoring. However, malfunctioning or misbehaving vehicles in a parking area of 10 spaces can occupy up to 8 spaces, preventing other car drivers from parking as desired. This not only compromises convenience but also poses a risk to safety and property. Therefore, obtaining accurate and reliable information about the location of vehicles sharing the area is crucial for ensuring the effectiveness of VANET. The existing detection method of a static security fence cannot prevent crimes or stop moving vehicles from breaching it. Similarly, surveillance cameras are not an effective barrier as criminals may easily cross them. Therefore, the criminals may possess the capability to effectively carry out criminal activities.

By employing this detecting technology, we are presenting a jewel that is highly attached to its surroundings, resulting in a reduced likelihood of false alarms and increased accuracy. During our investigation, we may additionally incorporate data pieces that are beneficial for maintaining the overall perspective of the vehicle. We will rely on a dendrogram algorithm to validate messages submitted to us, without any human supervision, to verify the legitimacy of these messages. Following the classification step, the system then employs Bayesian-based hypothesis testing to eliminate any inaccuracies that may have occurred during the classification process. The consequence of using this technique would be that it is suitable for encouraging the identification of attacks on bogus information, resulting in an efficient application (Stitini et al., 2021).

Designing a context-aware recommender system in the optimization of the relief and rescue.

Context awareness is an essential tool for addressing many problems, as it enhances cognition and facilitates the identification of environmental elements and dynamics. Given that Iranians and people from all parts of the world reside in areas with numerous seismic faults, the occurrence of an earthquake poses a significant challenge for relief and rescue operations. This study tries to determine the incorporation of context awareness into various types of endeavours.

At the forefront of the research topic is the examination of elements such as the specializations of humanitarian workers and the environmental and operational challenges they face. Additionally, the study aims to evaluate the locations that have similar characteristics in terms of rescuers, groups, and environment. One of the important duties involves developing a precise algorithm and improving it to detect areas that have been affected and assigning relief workers to specific locations and tasks.

The emphasized context-aware strategy has been shown to have the best performance in improving relief measures, demonstrating positive results in the enhancement of relief measures. Speed improvement is quadrupled compared to the current state. This study demonstrates that by closing the gap in catastrophic response, the maximum achievable outcome is facilitated (Ghose & Rehena, 2019).

A Mechanism for Air Health Monitoring in Smart City Using Context-Aware Computing

Smart sustainable communities strive to enhance the quality of life by implementing innovative solutions that foster economic growth and guarantee overall social well-being. These cities are focused on creating a secure, clean, inexpensive,

and dependable environment for all residents. The core concept of this approach revolves around constructing environmentally friendly areas that provide a healthy living environment for the occupants. In this study, we propose a methodology for monitoring urban air quality that takes into account future considerations. We achieve this by utilizing context-aware computing technologies, which can also facilitate smart health efforts.

The framework utilizes contextual information to provide notifications regarding potential risks of air pollution and employs smart sensors as instruments for monitoring key indicators of air pollutants. Next, we provide the IO approach for Layer Optimization, which effectively streamlines the model's execution and eliminates superfluous overhead, all while maintaining system speed.

These results suggest that a framework incorporating optimization techniques can be used to provide effective air quality management in smart and sustainable cities while also meeting their objectives (Ilie et al., 2020).

E-HoA: A Distributed Layered Architecture for Context-aware Autonomous Vehicles

The objective of this research is to establish the necessity of implementing the Embedded Higher-order Agent (E-HoA) architecture to meet the demands of ambient systems such as automobiles and other advanced modes of transportation that rely on a higher-order agent system. The autonomous control system of this design will utilize the mentioned platform and convert beliefs into action by employing the Robot Operating System (ROS). It is highly suitable for controlling the cycle of an automobile.

In general, the architectural principles of E-HoA demonstrate that the system can enhance awareness of autonomous cars regarding the environment and the necessity to respond appropriately in situations that demand unplanned actions (Bahrami et al., 2019).

Development of a Context-Aware Assistive System for Manual Repair Processes - A Combination of Probabilistic and Deterministic Approaches

This paper discusses excellent strategies for organizing various activities. Activity recognition and labour activity summarizing are used. The existing processes model can fulfil work processes by merging HMMs and Petri nets. After activity recognition, this model lets the system suggest activities and motion types.

This section details the process model and how Petri nets and HMM are interwoven. They offer an action plan for implementing the paradigm. The approach can be applied to assembly and rework in a context-specific manner, but customisation across the scope requires more effort (Chaouche et al., 2020).

Dealing with Failures for Execution Consistency in Context-aware Systems

This study addresses BDI agent priority and multitasking management to boost decision power. We continually monitor the agent and ensure he/she completes vital tasks, even if they are challenging. Planning identifies key tasks alongside direct supervision.

To illustrate this approach, we examine an autonomous car navigation application. This example shows how our technique helps these vehicles make better real-time decisions to maximize efficiency and safety (Wang et al., 2019).

Evaluating Smart PSS Solutions with Context-Awareness in the Usage Phase

The significant progress in Internet of Things (IoT) technology is facilitating the digital transformation of traditional paradigms through the implementation of intelligent Product-Service Systems (PSS). These systems serve as enduring companions for users, providing support throughout the entire lifespan of a product, particularly during its usage. These intelligent PSS (Personalized Search Systems) must adapt similarly to our preferences. Sellers of these systems must be perceptive, adjusting their products to the latest advancements in consumer behaviour. The focus of our study is to analyze the effectiveness of these intelligent PSS during the consuming phase. Our objective is to ensure that these technologies consistently possess knowledge of the actual conditions that consumers are experiencing by implementing a context-aware methodology (Bertram et al., 2021).

Privacy-preserving cloud-connected IoT data using context-aware and end-to-end secure messages

Cloud platforms and IoT devices are transforming smart buildings, agriculture, and industry. Cloud systems analyze and store data, whereas IoT devices sense and respond. Many IoT applications, especially those using publish-subscribe protocols like MQTT, lack standardized message formats. Even with Transport Layer Security (TLS), end-to-end message security is difficult, especially for sensitive content.

This paper introduces a new technique that provides end-to-end security and standardizes publish-subscribe message topics and payloads with context-aware information at the device and cloud levels. Compared to earlier approaches, our results demonstrate a 40% topic size reduction and a 50% payload size reduction. This improves IoT communication security and efficiency, speeding device data processing (Ferraz Junior et al., 2021).

A Context-Aware Approach for Extracting Hard and Soft Skills

Due to the growth of Internet recruitment, candidate screening is more expensive, time-consuming, and laborious. Skill-based recruitment is growing to speed up hiring. Hard and soft skills must be automatically and reliably retrieved from job descriptions and resumes. A context-aware sequence and token classification model for skill extraction is provided in this paper. Machine learning classifiers and specialized word embeddings like BERT are used to validate the models on a public job description dataset. Our methodology works; the best models use BERT embeddings and extra language information (Wingsa et al., 2021).

Integrating contextual information into multi-class classification to improve the context-aware recommendation

Data mining, information retrieval, and e-commerce value contextual information. Context-aware recommender systems advise users using contextual data. These systems classify historical data to predict future events. By integrating contextual information into multi-class classification, this article enhances recommended findings. We found that this connectivity greatly improves personalized user recommendations (Ferraz Junior et al., 2021).

A Survey of Middlewares for Self-adaptation and context-aware in Cloud of Things Environment

The increased usage of smart gadgets, linked goods, cellphones, and sensors has led to Big Data. Cloud computing is effective for data analysis and storage due to these devices' limited resources. As the IoT integrates with cloud capabilities, the Cloud of Things (CoT) has arisen, creating several potentials. Due to the heterogeneity of devices, distribution, dynamic environment, and cloud services, middleware is needed. This project investigates CoT environment self-adaptation middleware. We review important characteristics before comparing current middleware. Dynamic and static adaptation middleware follows. Finally, we discuss current challenges in developing unique middleware that may instantaneously and dynamically adjust cloud services based on object context (Souki et al., 2022).

Context-aware Acoustic Signal Processing

Data processed in context is more intelligible, easier to grasp, and contains more information because of the surrounding context. Even in audio signal processing. This research introduces a Deep Learning-based ensemble neural network strategy for context integration in learning systems. Acoustic signal analysis is used to analyze machine sound data for pumps, slide rails, and valves in many use cases. Mel-spectrograms train convolutional neural networks for audio data analysis and image processing (Augusto, 2007).

A Survey on Context-aware Systems

Context-aware systems offer consumers and application developers exciting new opportunities by tuning system behaviour to contextual data. Used with mobile devices, these technologies boost usability, making them more valuable. The majority of context-aware systems use a layered conceptual design framework and common architecture concepts. We explore contemporary context-aware systems, focusing on middleware and frameworks that simplify context-aware application development. These systems demonstrate context-aware computing's key components and methods (Liu et al., 2018).

Context-aware Knowledge-based Systems: A Literature Review

As a subclass of intelligent systems, context-aware systems provide smart service customer-specific products and services. To improve smart services, contextual data must be organized and modified to produce information. This makes knowledge-based strategies essential for context-aware systems. Indeed, knowledge-based systems and context awareness have grown in relevance for decades. Few studies have studied how to combine the two areas to maximize their benefits. This work reviews the literature on modern contextaware system conceptualization, focusing on the knowledge-based approach, to stimulate further research. The study's implications and issues will be discussed (Meßmer et al., 2023).

Contexts and Context-awareness Revisited from an Intelligent Environments Perspective

The unconscious understanding of context helps humans tackle daily challenges. Many computer science subfields are now using this approach to construct useful systems. Giving the system context awareness may help it make smart real-world decisions. Many systems attempt context awareness, but there are few standard methods. Lack of consensus on sound principles or standards for the scientific community and developers interested in these systems is the key problem. Multiple thorough polls have been done (Baldauf et al., 2007).

Table 1: *Comparison Table*

Paper	*Paper Type*	*Technique Used*	*Summary of Results*	*Summary of Limitation*	*Reference*

Context-Aware Empowering Business with AI: Case of Chatbots in Business Intelligence Systems	Experiment	Path Planning, Pose Recognition	Plans paths to avoid collisions and attain goals, enabling human-robot collaboration efficiency and safety.	Requires validation in real-world manufacturing environments.	Azmi et al., 2023
Fuzzy-based Diagnostic Agent for Context-Aware Patient Monitoring	Experiment	Fuzzy Logic	Provides accurate medical data interpretation via Body Area Network for remote healthcare supervision.	The complexity of fuzzy logic reasoning may impact system scalability.	Magano et al., 2018
Context-aware Gossip in Ad hoc Vehicular Networks	Experiment	Simulation	Keeps dynamic vehicular networks intact while reducing redundant emergency alerts, promising faster and more productive research with large datasets.	Simulation results may not fully represent real-world scenarios.	Bennakhia et al., 2019
A meta-model for context-aware adaptive Business Process as a Service in a collaborative cloud environment	Survey	AI, BI Integration	Discusses how AI methods and implementations can improve business intelligence (BI) decision-making.	A theoretical overview may lack practical implementation details.	Hidria et al., 2019
A Survey of Middlewares for Self-adaptation and context-aware in Cloud of Things Environment	Survey	Middleware Comparison	Assesses Cloud of Things middleware for dynamic adaptability, identifying issues.	The survey-based approach may not cover all possible middleware solutions.	Souki et al., 2022
Integrating contextual information into multi-class classification to improve the context-aware recommendation	Experiment	Classification, Recommendation	Improves recommendation results by considering contextual information and classification.	Limited to correlation analysis, may not provide insights into other aspects of recommendation systems.	Stitini et al., 2021
A Context-Aware Approach for Extracting Hard and Soft Skills	Experiment	Automated Skill Extraction for Recruitment	Suggests methods for obtaining excellent performance by removing soft and hard skills from job descriptions and resumes.	Performance evaluation is limited to specific datasets, and may not generalize to all contexts.	Wingsa et al., 2021
Privacy-preserving cloud-connected IoT data using	Experiment	Context-aware IoT Message Standardization	Accomplishes byte efficiency in subject and payload by standardizing.	Evaluation based on specific metrics may not capture all aspects of IoT.	Ferraz Junior et al., 2021
context-aware and end-to-end secure messages	Experiment	Communications with context awareness for end-to-end security in IoT	Communications with context awareness for end-to-end security in the Internet of Things.	Evaluation based on specific metrics may not capture all aspects of IoT.	Ferraz Junior et al., 2021
Evaluating Smart PSS Solutions with Context-Awareness in the Usage Phase	Experiment	Smart Product-Service Systems Evaluation	Presents a context-aware method for assessing the performance of the smart PSS throughout the usage phase.	Limited to evaluation methodology, may not cover all aspects of smart PSS performance.	Wang et al., 2019

Dealing with Failures for Execution Consistency in Context-aware Systems	Experiment	Symbolic Guidance for BDI Agents	Focuses on autonomous vehicles and presents a method for directing BDI agent behaviours under concurrency and relevance requirements.	Limited to the theoretical proposal, lacks empirical validation.	Chaouche et al., 2020
Development of a Context-Aware Assistive System for Manual Repair Processes - A Combination of Probabilistic and Deterministic Approaches	Experiment	Petri Net, Hidden Markov Model (HMM)	Presents a context-sensitive support system for assembly and rework workers using HMM and Petri nets for intuitive process modelling to evaluate extensive vulnerabilities.	Validation of the proposed system implementation may be required in real-world scenarios.	Bertram et al., 2021
E-HoA: A Distributed Layered Architecture for Context-aware Autonomous Vehicles	Experiment	Belief-Desire-Intention (BDI), ROS	Outlines a framework for ambient systems that are aware of context, allowing autonomous cars to carry out plans depending on contextual cues.	Limited validation in real-world autonomous vehicle scenarios.	Ilie et al., 2020
A Mechanism for Air Health Monitoring in Smart City Using Context-Aware Computing	Experiment	Context-aware computing, Smart Sensors	Suggests a framework for context-aware computing and smart sensor monitoring of air quality in metropolitan areas, with emphasis on input layer optimization.	The effectiveness of input layer optimization may vary based on sensor accuracy and environmental conditions.	Ghose & Rehena, 2019
Designing a context-aware recommender system in the optimization of the relief and rescue	Experiment	Context-Aware Optimization Algorithm	Examines how to best distribute relief workers in earthquake emergencies while taking context into account.	Evaluation is limited to simulated earthquake crisis scenarios.	Bahrami et al., 2019
Detecting Bogus Information Attack in Vehicular Ad Hoc Network: A Context-Aware Approach	Experiment	Feature Extraction, Hierarchical Clustering	Explains a Bayesian-based hypothesis testing, feature extraction, and hierarchical clustering method for context-aware detection in VANETs.	The evaluation may lack real-world deployment, and sensitivity to network dynamics may impact detection accuracy.	Ghaleb et al., 2019
A Context-Aware Safety System for Human-Robot Collaboration	Experiment	Human-Robot, AI	Introduces a safety system for human-robot collaboration using artificial intelligence.	Privacy concerns.	Liu et al., 2018
A Survey on Context-aware Systems	Survey	Context-Aware Architecture Principles	Analyzes popular frameworks and architectural principles for context-aware systems, with a particular emphasis on middleware and development frameworks.	The survey-based approach may not cover all possible context-aware systems, limited to existing frameworks and architectures.	Baldauf et al., 2007

Contexts and Context-awareness Revisited from an Intelligent Environments Perspective	Survey	Conceptual Framework, Context Operations	Outlines important ideas and procedures for system developers in a theoretical corpus for context-aware systems.	The theoretical approach may lack empirical validation, and applicability in practical contexts may vary.	Augusto, 2007
Context-aware Acoustic Signal Processing	Experiment	Ensemble Neural Networks	Offers a deep learning strategy that uses ensemble neural networks to include context into auditory signal processing.	Limited discussion on real-world application and validation, and scalability to other contexts may need further investigation.	Meßmer et al., 2023
Context-aware Knowledge-based Systems: A Literature Review	Survey	Literature Review, Knowledge-based Approach	Examines the research on balancing knowledge-based systems for smart services with context awareness, highlighting challenges and implications.	The literature review-based approach may not cover all recent advancements, and discussion is limited to conceptual aspects of integration.	Vu et al., 2023

CONCLUSION

In conclusion, recent advancements in context-aware systems have ushered in a new era of intelligent and adaptive technology across a multitude of areas. These systems have demonstrated remarkable proficiency in interpreting contextual cues to maximize productivity while preserving security, thanks to the application of sophisticated algorithms like fuzzy logic and machine learning. Context-aware systems have proven their adaptability and effectiveness in a range of contexts, such as seamless human-robot collaboration in manufacturing environments, healthcare monitoring using sensor data processing, and dynamic emergency vehicular networks. By continuously adapting to changing surroundings, these systems offer scalable solutions that promise safer, more intelligent interactions across different domains. As technology continues to progress, there is great potential for developing context-aware systems.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Augusto, J. C. (2007). Contexts and context-awareness revisited from an intelligent environments perspective. *International Journal of Ad Hoc and Ubiquitous Computing*, 2(4), 263.

Azmi, M., Mansour, A., & Azmi, C. (2023, August 14-16). A context-aware empowering business with AI: Case of chatbots in business intelligence systems. *5th International Workshop of Innovation and Technologies (IWIT 2023)*, Halifax, Nova Scotia, Canada.

Bahrami, N., Argany, M., Samani, N. N., & Vafaeinejad, A. R. (2019). Designing a context-aware recommender system in the optimization of the relief and rescue. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.*

Baldauf, M., Dustdar, S., & Rosenberg, F. (2007). A survey on context-aware systems. *International Journal of Ad Hoc and Ubiquitous Computing*, 2(4), 263.

Bennakhia, A., Ben Nakhia, A., & Marafia, A. (2019, November 4-7). Context-aware gossip in ad hoc vehicular networks. *10th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2019)*, Coimbra, Portugal.

Bertram, P., Kränzler, C., Rübel, P., & Ruskowski, M. (2021, June 15-18). Development of a context-aware assistive system for manual repair processes - A combination of probabilistic and deterministic approaches. *30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2021)*, Athens, Greece.

Chaouche, A.-C., Ilie, J.-M., & Pecheux, F. (2020, November 2-5). Dealing with failures for execution consistency in context-aware systems. *11th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2020)*, Madeira, Portugal.

Ferraz Junior, N., et al. (2021). Privacy-preserving cloud-connected IoT data using context-aware and end-to-end secure messages. *18th International Conference on Mobile Systems and Pervasive Computing (MobiSPC)*, Leuven, Belgium, August 9-12.

Ghaleb, F. A., Zainal, A., Maroof, M. A., & Rassam, M. A. (2019). Detecting bogus information attack in vehicular ad hoc network: A context-aware approach. *16th International Learning & Technology Conference*.

Ghose, B., & Rehena, Z. (2019). A mechanism for air health monitoring in smart cities using context-aware computing. *Third International Conference on Computing and Network Communications (CoCoNet'19)*.

Hidria, W., M'tira, R. H., Saouda, N. B., & Guedira-Guegan, C. (2019). A meta-model for context-aware adaptive business process as a service in a collaborative cloud environment. *CENTERIS - International Conference on Enterprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies.*

Ilie, J.-M., Chaouche, A.-C., & Pecheux, F. (2020, April 6-9). E-HoA: A distributed layered architecture for context-aware autonomous vehicles. *11th International Conference on Ambient Systems, Networks and Technologies (ANT)*, Warsaw, Poland. Paris, France: LIP6, UMR 7606 Sorbonne Université; Constantine, Algeria: MISC Laboratory, University Abdelhamid Mehri - Constantine 2.

Liu, H., et al. (2018, June 11-14). A context-aware safety system for human-robot collaboration. *28th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2018)*, Columbus, OH, USA.

Magano, T., Djouani, K., Kurien, A., & Chibani, A. (2018). A fuzzy-based diagnostic agent for context-aware patient monitoring. *8th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH 2018)*.

Meßmer, L.-M., et al. (2023). Context-aware acoustic signal processing. *27th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2023)*.

Perera, C. (2012, September). Capturing sensor data from mobile phones using global sensor network middleware. ResearchGate.

Souki, O., Djema, R. B., Amous, I., & Sedes, F. (2022). A survey of middlewares for self-adaptation and context-aware in a cloud of things environment. *26th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2022)*.

Stitini, O., Kaloun, S., & Bencharef, O. (2021, November 1-4). Integrating contextual information for improved context-aware recommendation. *8th International Symposium on Emerging Information, Communication and Networks (EICN 2021)*, Leuven, Belgium, pp. 1-5.

Vu, T.-M.-H., Dinh, T. L., Dam, N. A. K., & Pham-Nguyen, C. (2023). Context-aware knowledge-based systems: A

literature review. *56th Hawaii International Conference on System Sciences.*

Wang, Z., Li, X., Chen, C.-H., & Khoo, L.-P. (2019). Evaluating smart PSS solutions with context-awareness in the usage phase. *Third International Conference on Computing and Network Communications (CoCoNet'19)*.

Wingsa, I., Nanda, R., & Adebayo, K. J. (2021). A context-aware approach for extracting hard and soft skills. *10th International Young Scientists Conference on Computational Science*, Maastricht, The Netherlands.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Federated Learning: A Potentially Effective Method for Improving the Efficiency and Privacy of Machine Learning

Nishant Jakhar, Sajjan Singh *

Om Sterling Global University, Hisar, India

***Corresponding Author:** sajjansingh72277@gmail.com

Citation: Jakhar, N. & Singh, S. (2024). Federated Learning: A Potentially Effective Method for Improving the Efficiency and Privacy of Machine Learning. *International Journal of Convergent Research*, 1(1), 50-56.

ARTICLE INFO

Received: 27th August 2024
Accepted: 5th November 2024

ABSTRACT

A new AI paradigm called federated learning (FL) decentralizes data and enhances privacy by delivering education straight to the user's device. However, additional privacy concerns arose during the exchange and training of server and client parameters. Integrating FL privacy solutions at the edge level can result in higher computational and communication costs, which can compromise learning performance metrics and data value. To promote the best trade-offs among FL privateness and different performance-associated application needs, including precision, privation, convergency, value, computational protection and connection, this study offers a thorough research overview of key techniques and metrics. Reaching stability among privateness and different standards of factual-international Federated Learning utilization is the focus of this paper, which also explores quantitative methodologies for evaluating privacy in FL. To mitigate server-related risks, decentralized federated learning removes the server from the network and uses blockchain technology to compensate for its loss. However, this benefit comes at the expense of exposing the system to additional privacy risks. An extensive safety study is required in this new paradigm. This survey examines various security mechanisms and addresses potential adversaries and dangers in decentralized federated learning. The verifiability and trustworthiness of decentralized federated learning are also considered.

Keywords: Federated learning, privacy, security, blocking, adversarial attack, decentralized learning federation, approved federal training.

INTRODUCTION

Since personal data is used so widely, Data analysis and administration have improved thanks to centralized machine learning (ML) techniques across a range of sectors, but they have also raised privacy. The General Data Protection Regulation's (GDPR) objective is to provide individuals with greater control over their data and to safeguard their right to privacy. Federated Learning (FL) ensures privacy and security while offering GDPR-compliant solutions by using edge servers or user models for direct ML model training. Because FL enables healthcare organizations to train models with patient data while protecting sensitive information, it has attracted interest in the finance, healthcare, and Internet of Things (IoT) industries.

However, FL faces challenges in communicating model update parameters that can be accessed and analyzed by adversaries. This study reviews the most recent FL systems' privacy-preserving methods and examines how they affect associated operational needs. Existing research offers limited insight into the dimensions and methods of privacy assessment, creating a sizable void in the body of recent work. The study offers a thorough classification of the most modern privacy-preserving techniques in FL into four primary groups: hybrids, blocking, interference, and encryption. A detailed analysis of the body of current literature revealed that there are no generally accepted metrics or methods for evaluating privacy in FL. This work is the first thorough examination of the trade-off between privacy safeguards and operational concerns linked to performance in FL systems.

LITERATURE REVIEW

Joint learning, often known as federated learning (FL), is an algorithmic method that uses many separate, independent sessions, each with its database, to train an algorithm. FL takes care of standardized data sources, access rights, security, and privacy of data. Google first presented the local model update as a distributed learning model that was shared between mobile devices and a core server. It generates a general machine-learning version using the server by combining these local model changes. FL training involves three steps: broadcasting an initial global model, assigning it to selected participants, using local data to determine local model parameters from each participant and updating local parameters.

There are three types of data segmentation in machine learning (FL): vertical, horizontal, and FL. A unique FL configuration called horizontal FL is one where individuals working in a certain zone have varying illustrative data. A static FL database refers to a configuration that contains the same instances or users but has different characteristics. Instead of sharing data, federated transfer learning is utilized to address data gaps.

Numerous elements, including network connection and pricing status, influence customer decisions in Florida. However, this approach has its drawbacks, especially if the client's situation is different, which involves more training time. Numerous studies have put forth methods to address this problem, such as the launch of a recently developed Federated Learning procedure called FedCS. Improving the effectiveness of ML training, FedCS sets time constraints for users to access, sync, and improve Machine Learning versions.

The summarization algorithm is important in FL because it contributes to the global model's update. Building aggregation algorithms in the FL environment may be done in a variety of ways, based on the objectives, which could include protecting confidentiality, accelerating confluence, and reducing the risk caused by anomalous updates.

The FL approach has been popular for developing collaborative models that meet legal specifications regarding user privacy. Early scientists and inventors used FL in experimental and practical applications in medical systems, healthcare, and in the fight against infectious diseases such as COVID-19, managing Electronic Health Records (EHR), and developing the foundations of federated drug discovery.

METHODOLOGY

This paper examines strategies and standards that help achieve the best possible Federated Learning isolation and other operational production goals that should be balanced using the systematic literature review (SLR) method. The objective of this study is to highlight barriers, open questions, and future directions for FL privacy research.

The first stage of SLR is defining the research question and three primary RQs are addressed. ACM DL (Digital Library), Scopus and IEEE Xplorer were just some of the search engines and databases that were searched as part of the search strategy and procedure. Two search strings *A* and *B* are chosen to match the range of RQ.

The screening phase involves several steps, including removing many papers, reviewing abstracts, applying inclusion and exclusion criteria, and examining the remaining publications in their entirety to weed out those that don't relate to any of the research questions. Following the completion of the search, the chosen papers were assessed using a quality evaluation system. Among the requirements for admission are papers for peer-reviewed research that have been published in books, reviews, SLR papers, journals, and proceedings from respectable international conferences. Papers free of privacy mechanisms and ArXiv2 publications referenced by peer-reviewed articles published in primary sources are additional requirements under the FL framework that are not written in English and were one of the exclusion criteria or not available in the FL context, which did not address privacy mechanisms.

A quality assessment scheme is used to evaluate papers, scoring them based on three criteria: QC1(Citation rate): Data privacy protection is essential at FL. Techniques like secure multiparty computation and differential privacy were assessed.

QC2(Methodological contribution): FL requires regular connections between local devices and a central server. Reducing communication overhead is essential. Methods such as sparse updating and model compression have been investigated.

QC3: Providing a logical and comprehensible explanation of the results. Federated Averaging is one of the often-utilized techniques (FedAvg)

algorithm, which determines the weighted average of local model updates.

$$w_{t+1}=\sum_{K=1}^{K} \frac{nK}{n} w_t^K$$

where the entire number of samples from all clients is represented by the number of samples in the n, while the revised global model is denoted by w_{t+1} and the local model by w_t^K.

The overall quality score varies between 1.00 (lowest) and 5.00 (highest), giving equal weight to each criterion.

For each of the chosen publications, a data extraction page was made, containing details like the title, author, number of citations, year, location, source, and analysis of the work that addressed the study topic. All authors debate the study topic collectively, attempt to come to a consensus when there are unresolved conflicts, and record all data for analysis and synthesis in order in order to avoid bias when extracting data.

RESULTS & DISCUSSIONS

One system called Federated Learning (FL) tries to safeguard consumers' privacy by keeping private data on their gadgets. However, potential privacy concerns in FL require the development of privacy protections. This technique can be divided into four main categories: Federation Learning with encryption, perturbation-based, blocking, and hybrid privacy-preserves.

Encryption technologies like homomorphic encryption (HE) and secure multiparty computing (SMPC) are essential to maintain data privacy. However, they face challenges such as scalability and computational intensity. Alternative optimization methods include ElGamal encryption optional and distributed key generation, which can also be used in fault detection and prevention systems. Perturbation-based privacy-preserving techniques Differential Privacy (DP), for example, introduces regulated or randomized noise into the update pattern before aggregation, and protection of personal data during training.

Time-stamped, immutable blocks of data controlled by a distributed computer network are used in a blockchain-based privacy method to provide centralized control and transparency. Federated Learning and Blockchain Integration

represents a significant advance in distributed system security and privacy. In FL, a hybrid privacy protection mechanism combines multiple privacy protection mechanisms to provide a powerful privacy protection solution in various applications, especially healthcare.

Privacy assessments in FL are important because of the complexity and privacy concerns. It is imperative to have an all-encompassing assessment framework that extends beyond conventional technical standards. In mathematical privacy assessment, data privacy is evaluated and guaranteed throughout training through the application of formal measurements and mathematical frameworks. Scientists have investigated blockchain, encryption, and hybrid strategies to address these two problems.

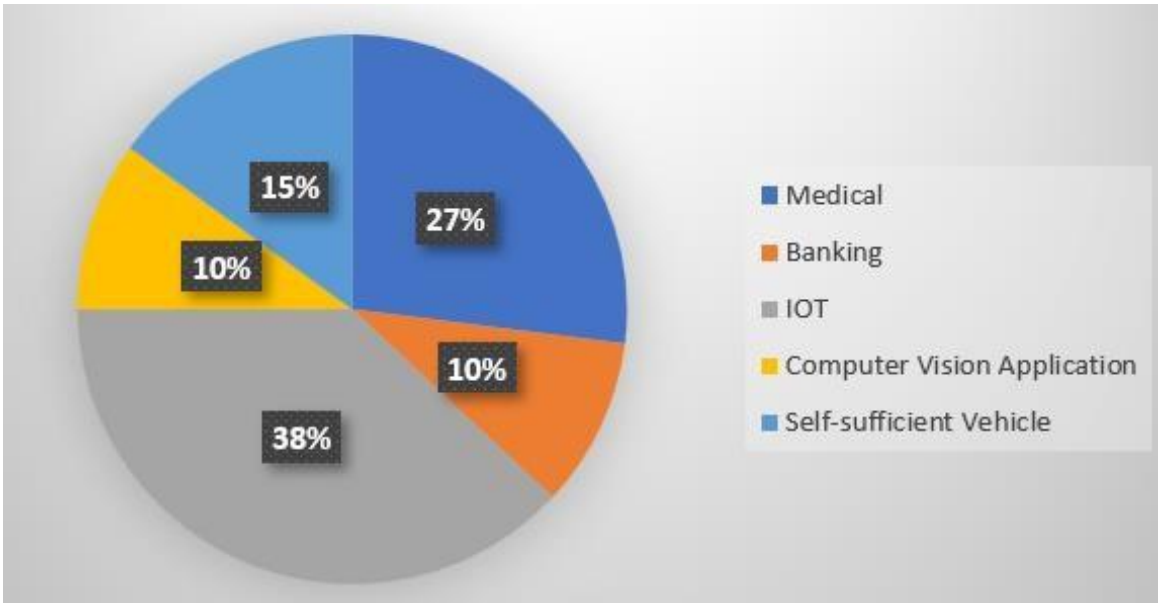
Discussion and future direction:

This study explores the application of financial liquidity (FL) encryption techniques for data security, particularly in industries such as healthcare and finance. However, this method suffers from problems such as computational complexity, latency, and increased communication. To solve this problem, the model can streamline communication compression and computing, while the encryption algorithm and parallel processing for edge devices will speed up the encryption process. Hybrid approaches that manage the computational burden, such as combining DP with encryption, increase privacy.

By introducing noise into the data or model parameters, perturbation-based privacy-preserving algorithms in FL provide a systematic increase in privacy without complex encryption. However, noise calibration is important, as too much noise will decrease the model's accuracy and jeopardize considerable privacy. Strategies include using GANs, optimizing noise scaling using stochastic gradient descent, and generating noise patterns that fit the data distribution.

In FL, block-based techniques enhance data traceability, transparency and integrity, but can be significantly problematic due to persistent ledger synchronization and scalability issues. To mitigate this weakness, lightweight protocols such as Blockchain technology and off-chain computing can be adopted. Layer 2 defences and solutions that increase operational ability and confidentiality are balanced by secure data obfuscation.

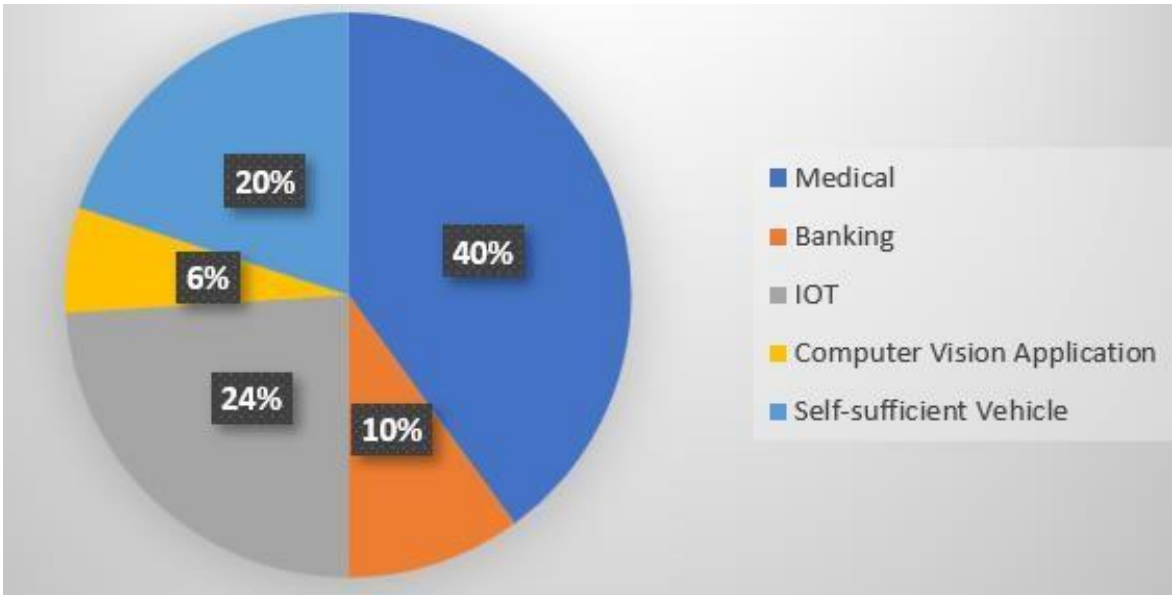
Figure 1: *Blockchain methods used in different sectors*



Source: Author's Compilation

Hybrid privacy solutions are increasingly popular because they balance privacy protection with operational performance needs. Reviewing the main methods as well as measures for evaluating Federated Learning's privacy reveals the necessity of thorough, context-sensitive metrics suitable for different application contexts and data sources. Subsequent research ought to provide coordinated and adaptive metrics, explore hybrid privacy techniques, and find metrics that accurately capture the compromises made in real-world FL implementations between performance, privacy, and usefulness.

Figure 2: *Hybrid Methods used in various sectors*



Source: Author's Compilation

Establishing a thorough research methodology was one of the accepted parameters for a systematic literature review (SLR) that this study adhered to. Validity assessment is important for empirical research, including SLRs. Threats to validity include those posed by concept, outcome, internal and external validity. External validity threats include the generalization of causal findings to the desired population and setting, and potential biases in study selection. To reduce this, synonyms or alternative keywords are added to the search string. Threats to internal validity include poor study design, study selection bias, and selected papers that do not meet our study quality standards. The threat of system reliability affects the ability to correctly infer treatment results. To mitigate this, two lines of research were created, one more general and the answer to the first RQ, and the other more focused. The relationship between the collected data and the conclusion of the analysis is affected by the reliability risk of the findings.

CONCLUSION

Decentralized machine learning (FL) protects sensitive data on end devices, reducing privacy risks. However, there are privacy concerns, especially when training models and exchanging parameters. This article explores recent approaches to privacy protection with a focus on balance. It emphasizes how crucial it is to strike the perfect harmony between privacy and performance and determines the criteria for assessing resilience against data leaks and potential attacks. For research, research and the industry community to address FL and implement measurable privacy protection mechanisms.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Abad, G., Picek, S., & Urbieta, A. (2021). SoK: On the security & privacy in federated learning. *arXiv preprint arXiv:2112.05423*.

Abadi, M., Chu, A., Goodfellow, I., McMahan, H. B., Mironov, I., Talwar, K., & Zhang, L. (2016). Deep learning with differential privacy. In *Proceedings of the 2016 ACM SIGSAC Conference on Computer and Communications Security* (pp. 308–318).

AbdulRahman, S., Tout, H., Ould-Slimane, H., Mourad, A., Talhi, C., & Guizani, M. (2020). A survey on federated learning: The journey from centralized to distributed on-site learning and beyond. *IEEE Internet of Things Journal, 8*(7), 5476–5497.

Alzubi, J. A., Alzubi, O. A., Singh, A., & Ramachandran, M. (2022). Cloud-IIoT-based electronic health record privacy-preserving by CNN and blockchain-enabled federated learning. *IEEE Transactions on Industrial Informatics, 19*(1), 1080–1087.

Ampatzoglou, A., Bibi, S., Avgeriou, P., & Chatzigeorgiou, A. (2020). Guidelines for managing threats to validity of secondary studies in software engineering. In *Contemporary Empirical Methods in Software Engineering* (pp. 415–441). Springer.

Asad, M., Moustafa, A., & Aslam, M. (2021). CEEP-FL: A comprehensive approach for communication efficiency and enhanced privacy in federated learning. *Applied Soft Computing, 104*, 107235.

Baek, C., Kim, S., Nam, D., & Park, J. (2021). Enhancing differential privacy for federated learning at scale. *IEEE Access, 9*, 148090–148103.

Bagdasaryan, E., Veit, A., Hua, Y., Estrin, D., & Shmatikov, V. (2020). How to backdoor federated learning. In *Proceedings of the International Conference on Artificial Intelligence and Statistics* (pp. 2938–2948). PMLR.

Bhagoji, A. N., Chakraborty, S., Mittal, P., & Calo, S. (2019). Analyzing federated learning through an adversarial lens. In *Proceedings of the International Conference on Machine Learning* (pp. 634–643). PMLR.

Bharati, S., Mondal, M., Podder, P., & Prasath, V. (2022). Federated learning: Applications, challenges, and future scopes. *International Journal of Hybrid Intelligent Systems*.

Blanco-Justicia, A., Domingo-Ferrer, J., Martínez, S., Sánchez, D., Flanagan, A., & Tan, K. E. (2021). Achieving security and privacy in federated learning systems: Survey, research challenges, and future directions. *Engineering Applications of Artificial Intelligence, 106*, 104468.

Boutet, A., Lebrun, T., Aalmoes, J., & Baud, A. (2021). Mixnn: Protection of federated learning against inference attacks by mixing neural network layers. *arXiv preprint arXiv:2109.12550*.

Chatterjee, P., Das, D., & Rawat, D. B. (2023). Next-generation financial services: Role of blockchain-enabled federated learning and metaverse. In *2023 IEEE/ACM 23rd International Symposium on Cluster, Cloud and Internet Computing Workshops (CCGridW)* (pp. 69–74). IEEE.

Jia, B., Zhang, X., Liu, J., Zhang, Y., Huang, K., & Liang, Y. (2021). Blockchain-enabled federated learning data protection aggregation scheme with differential privacy and homomorphic encryption in IIoT. *IEEE Transactions on Industrial Informatics, 18*(6), 4049–4058.

Keele, S., et al. (2007). Guidelines for performing systematic literature reviews in software engineering (Version 2.3). *EBSE Technical Report, EBSE*.

Lakhan, A., Mohammed, M. A., Nedoma, J., Martinek, R., Tiwari, P., Vidyarthi, A., Alkhayyat, A., & Wang, W. (2022). Federated-learning-based privacy preservation and fraud-enabled blockchain IoMT system for healthcare. *IEEE Journal of Biomedical and Health Informatics, 27*(2), 664–672.

Lee, H., Kim, J., Hussain, R., Cho, S., & Son, J. (2021). On defensive neural networks against inference attack in federated learning. In *ICC 2021-IEEE International Conference on Communications* (pp. 1–6). IEEE.

Voigt, P., & Von dem Bussche, A. (2017). *The EU General Data Protection Regulation (GDPR): A practical guide* (1st ed.). Springer International Publishing.

Wahab, O. A., Mourad, A., Otrok, H., & Taleb, T. (2021). Federated machine learning: Survey, multi-level classification, desirable criteria, and future directions in communication and networking systems. *IEEE Communications Surveys & Tutorials, 23*(2), 1342–1397.

Wainakh, A., Ventola, F., Müßig, T., Keim, J., Cordero, C. G., Zimmer, E., Grube, T., Kersting, K., & Mühlhäuser, M. (2021). User-level label leakage from gradients in federated learning. *arXiv preprint arXiv:2105.09369*.

Wang, C., Wu, X., Liu, G., Deng, T., Peng, K., & Wan, S. (2021). Safeguarding cross-silo federated learning with local differential privacy. *Digital Communications and Networks*.

Wang, F., Zhu, H., Lu, R., Zheng, Y., & Li, H. (2021). A privacy-preserving and non-interactive federated learning scheme for regression training with gradient descent. *Information Sciences, 552*, 183–200.

Wang, H., Yurochkin, M., Sun, Y., Papailiopoulos, D., & Khazaeni, Y. (2020). Federated learning with matched averaging. *arXiv preprint arXiv:2002.06440*.

Wang, N., Yang, W., Wang, X., Wu, L., Guan, Z., Du, X., & Guizani, M. (2022). A blockchain-based privacy-preserving federated learning scheme for Internet of Vehicles. *Digital Communications and Networks*.

Wang, Q., Liao, W., Guo, Y., McGuire, M., & Yu, W. (2023). Blockchain-empowered federated learning through model and feature calibration. *IEEE Internet of Things Journal*.

Wei, K., Li, J., Ding, M., Ma, C., Su, H., Zhang, B., & Poor, H. V. (2021). User-level privacy-preserving federated learning: Analysis and performance optimization. *IEEE Transactions on Mobile Computing*.

Wei, K., Li, J., Ding, M., Ma, C., Yang, H. H., Farokhi, F., Jin, S., Quek, T. Q., & Poor, H. V. (2020). Federated learning with differential privacy: Algorithms and performance analysis. *IEEE Transactions on Information Forensics and Security, 15*, 3454–3469.

Wei, K., Li, J., Ma, C., Ding, M., Chen, C., Jin, S., Han, Z., & Poor, H. V. (2021). Low-latency federated learning over wireless channels with differential privacy. *IEEE Journal on Selected Areas in Communications, 40*(1), 290–307.

Zhang, M., Wei, E., & Berry, R. (2021). Faithful edge federated learning: Scalability and privacy. *IEEE Journal on Selected Areas in Communications, 39*(12), 3790–3804.

Zhao, B., Fan, K., Yang, K., Wang, Z., Li, H., & Yang, Y. (2021). Anonymous and privacy-preserving federated learning with industrial big data. *IEEE Transactions on Industrial Informatics, 17*(9), 6314–6323.

Zhou, C., Fu, A., Yu, S., Yang, W., Wang, H., & Zhang, Y. (2020). Privacy-preserving federated learning in fog computing. *IEEE Internet of Things Journal, 7*(11), 10782–10793.

Zhu, H., Wang, R., Jin, Y., Liang, K., & Ning, J. (2021). Distributed additive encryption and quantization for privacy-preserving federated deep learning. *Neurocomputing, 463*, 309–327.

Zhu, L., Liu, Z., & Han, S. (2019). Deep leakage from gradients. *Advances in Neural Information Processing Systems, 32*.

Zhu, S., & Han, M. (2023). Privacy-preserving federated learning and authentication for energy trading system in energy Internet of Things. *Future Generation Computer Systems, 135*, 339–353.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Documentation of Dry Preserved Mounted Mammalian Collection of The Zoology Museum

Shaista Waheed*, Shakeel Ahmad, Abduraheem K

Department of Museology, Aligarh Muslim University, Uttar Pradesh. India

***Corresponding Author:** shaistwaheed@gmail.com

Citation: Waheed, S., Ahmad, S., & Abduraheem, K. (2024). Documentation of Dry Preserved Mounted Mammalian Collection of The Zoology Museum. *International Journal of Convergent Research*, 1(1), 57-71.

ARTICLE INFO

Received: 12th September 2024
Accepted: 19th November 2024

ABSTRACT

The museums have a long history dating back to the 3rd century B.C. when the first known museum was opened at the University of Alexandria in Egypt. As we know, museums are an institution that collects, document, preserve, exhibit and interpret material evidence and associated information for public benefit. The value of a museum's collection depends on the amount of information it possesses about each item. Even a valuable object loses much of its worth if details like its origin, purpose, and unique characteristics are unknown. This holds for art objects, where artist names, historical context, and associations are equally important. Failing to provide such basic information is a dereliction of a museum's primary duty, and it should maintain records in registers rather than relying on staff memory, which can fade with time and increased collections. These records also serve legal purposes, addressing potential disputes about objects even decades after their acquisition into the collection. The museum movement in India is to be traced to the Asiatic Society of Bengal founded by the brilliant scholar Sir William Jone in 1784. The greatest motion to the development of museums in the country was given at the time of Lord Curzon. Calcutta is the first full-fledged university museum in the name of Sir Ashutosh Mukherji to come into existence. The Department of Zoology was established as a constituent section of the MAO College in 1909. It was the individual and untiring efforts of Prof. M.B. Mirza in 1935, which resulted in the creation of a museum on department premises that houses more than 1000 species ranging from porifera to mammals. The focus of the work is to develop a well-designed documentation system for the dry-preserved mounted mammalian collection displayed in the Zoology Museum, Faculty of Life Science, A.M.U. Aligarh, along with what preventive measures should be taken by collecting maximum information as far as possible from every possible source. Later, this well-developed documentation system will be followed by a well-designed automated system by which an online database will be developed and made available via the Zoology Department's official website to provide valuable information worldwide about its valuable, rare and diverse collection.

Keywords: Museum, museology, documentation, documentation system, automated system.

INTRODUCTION

According to the ICOM Statutes, adopted by the 22nd General Assembly in Vienna, Austria on August 24th, 2007, "a museum is a non-profit making, permanent institution in the service of society and its development, open to the public, that acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for education, study and enjoyment."

The museum can also be defined as an institution that collects documents, preserves, exhibits and interprets material evidence and associated information for public benefit.

Within this definition lies the heart of museums: the collection, recording, preservation and exhibition of material evidence, and objects, whether a museum collects natural historical, military, archaeological, or fine art material. It is the

objects that the museum, and its manager, generate their publications, research programs, exhibition services, educational services, publications etc. and have the collections at their core in that they provide the source material for such programs. In addition, objects must be recorded to a standard, so that the museum can account for, locate and provide information about them. Objects must be accessible via public exhibitions, information services and loans, and finally, they must be legally accounted for to ensure that the museum behaves responsibly and ethically.

A museum is a way to understand the past and maintain the present so that the future can be improved, or a link between the past, present and future. One of the pasts, and through display and other activities, communicate it to the present generation so that they can study it for the future. To achieve this most effectively, a strong data bank and a good retrieval system are required, for which systematic documentation is essential. Documentation is the backbone of the museum's ability to perform other vital functions like collecting, interpreting, communicating conducting research etc., to run museums authentically and successfully. The International Committee for Documentation of the International Council of Museums (CIDOC) is a global organization, and for over 32 years, it played a crucial role in shaping museum documentation standards and facilitating discussions on these standards through various working groups.

A museum is therefore failing in its primary duty if it does not yield all the basic information about its collection. This information about the collection must be regularly recorded in the register and need not be based on the personal memory of the staff, which is bound to be divided (washed off or removed), away from the increase in collection and the duration of the period. Moreover, the museum records are useful in meeting any legal implications that may arise about any object even after decades since it entered the collection.

Hence, the concentration of work was done in 2017 to provide documentation in the form of a sectional register and index card for dry-preserved mounted mammalian specimens at the Department- Museum of Zoology, A.M.U Aligarh.

The Function of Documentation:

i. To help the researchers, scholars, and students with further investigation.
ii. To help the conservator understand the objects that help them with the restoration work.
iii. To help the museum's education department while planning the activities and courses.
iv. To help the curators, especially while planning the exhibitions.

The most important aspect is that these records are proof of the museum's ownership of the antiquities, which becomes more effective when the art objects are lost, stolen from the museum, or traced somewhere else. Good documentation will aid in the recovery of lost items. In a way, it becomes the illegal authority of the museum.

To formulate acquisition policies by identifying the scope and limitations of the collection

To enable the collection to be researched and published, the value of publications and the preservation of the collection through displays and educational work are related to the quality of the documentation.

In museums generally, the following methods and materials are widely used for documentation purposes: field documentation, accession register (accessioning), marking on specimens, cataloguing/index cards, sectional register and de-accessioning.

MATERIAL AND METHODS

Materials required in the work were mounted mammalian specimens, labelling materials for accurate documentation, photographic equipment for detailed images, measuring tools for precise measurements, and digital storage for secure record-keeping. The following methods were adopted for documentation of dry preserved mounted mammalian collection, which are as follows:

Dry preserved mounted mammalian specimens.

Following is the list of mounted specimens belonging to the class mammalian kept in the Zoology Museum used for providing a sectional register for natural history to them.

Figure 1: *Colobus abyssinius (Silk Ape)*

Figure 2: *Panthera tigiris(Tiger)*

Figure 3: *Phoca groenlandica(Harp Seal)*

Figure 4: *Phascolarctos cinereus (KOALA)*

Figure 5: *Ornithorhynchus anatinus (Duck-Billed Platypus)*

Figure 6: *Tachyglossus (Echidna)*

Figure 7: Simia satyrus (Orange-Utan)

Figure 8: Pan satyrus

Figure 9: Symphalangus syndactylus (Siamang)

Figure 10: Hystrix indica (Porcupine/Sahi)

Figure 11: Alouatta seniculus (Howling Monkey)

Figure 12: Cynocephalus variegatus (Flying Lemur)

Figure 13: Bradypus tridactylus

*Figure 14 & 15: Manis spp. (Pangolin/Scaly Ant Eater/Trenggiling)**

Figure 16: Mellivora capensis (Honey Badger/Ratel)

Figure 15: Talpa europaea

Figure 18: Mangoos

Figure 19: Mangoos

Figure 20: Funambulus (Squirrel)

Figure 21: Rat

Figure 22: Bat

Figure 23: Lori

Figure 24: Cavia porcellus (Guinea Pig)

Figure 25: Rabbit

Figure 26: Cavia porcellus (Guinea Pig)

Figure 27: Vulpes bengalensis (Common Fox)

Figure 28 & 29: Didelphis spp. (Opposum)

Figure 30: HerpestesSpp

*Figure 31: Dasypus novemcinctus**

* Means specimens were wrongly identified in place of

Photography

Digital photography has been done to document the actual condition of specimens and it will also help in maintaining the records. The proper documentation would help in future scientific work as well as for proper display in the exhibition. The biggest obstruction during photography is the reflection of light from the glasses of the same and other showcases, the inadequate lighting system inside the museum, and the closeness of specimens due to a lack of space therefore other specimens were taken in position the clicking frame due to the four-sided glass doors.

Standing Condition and Measurements

Individual condition and measurement of every specimen were keenly observed and recorded in the separate sectional register provided for every individual as per my project work. Measurement includes standing height, length, breadth of body and peculiar characteristic organs of the specimen like the tail, nail limb, tooth etc. as much as possible. (Figure 32)

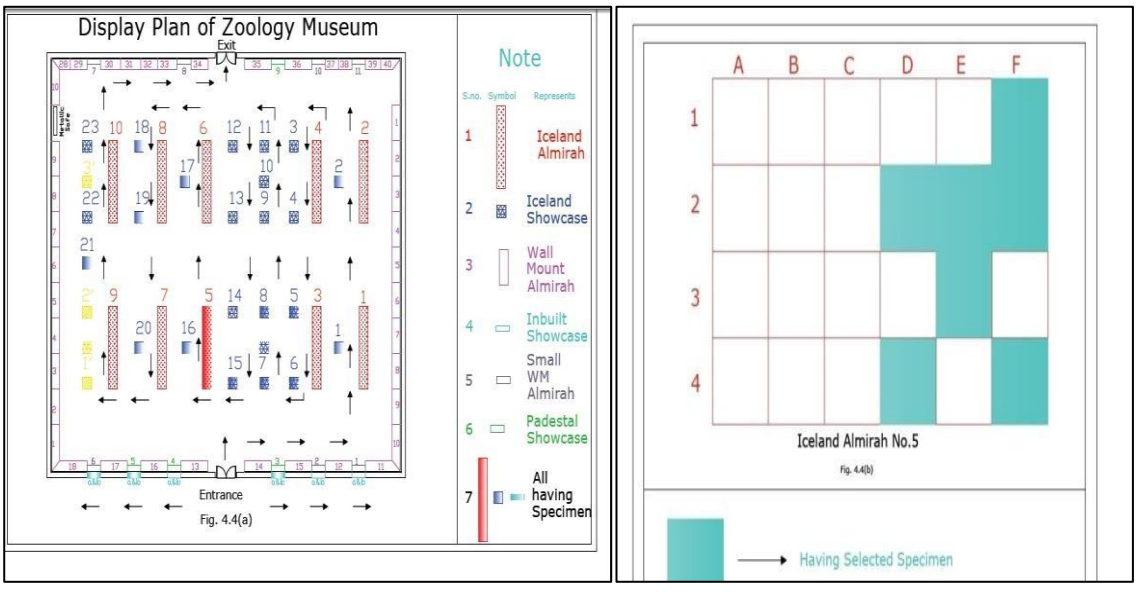
Figure 32: Depicts the measurement process of a specimen.

RESULTS

Draw a layout plan for the display of the collection in the museum.

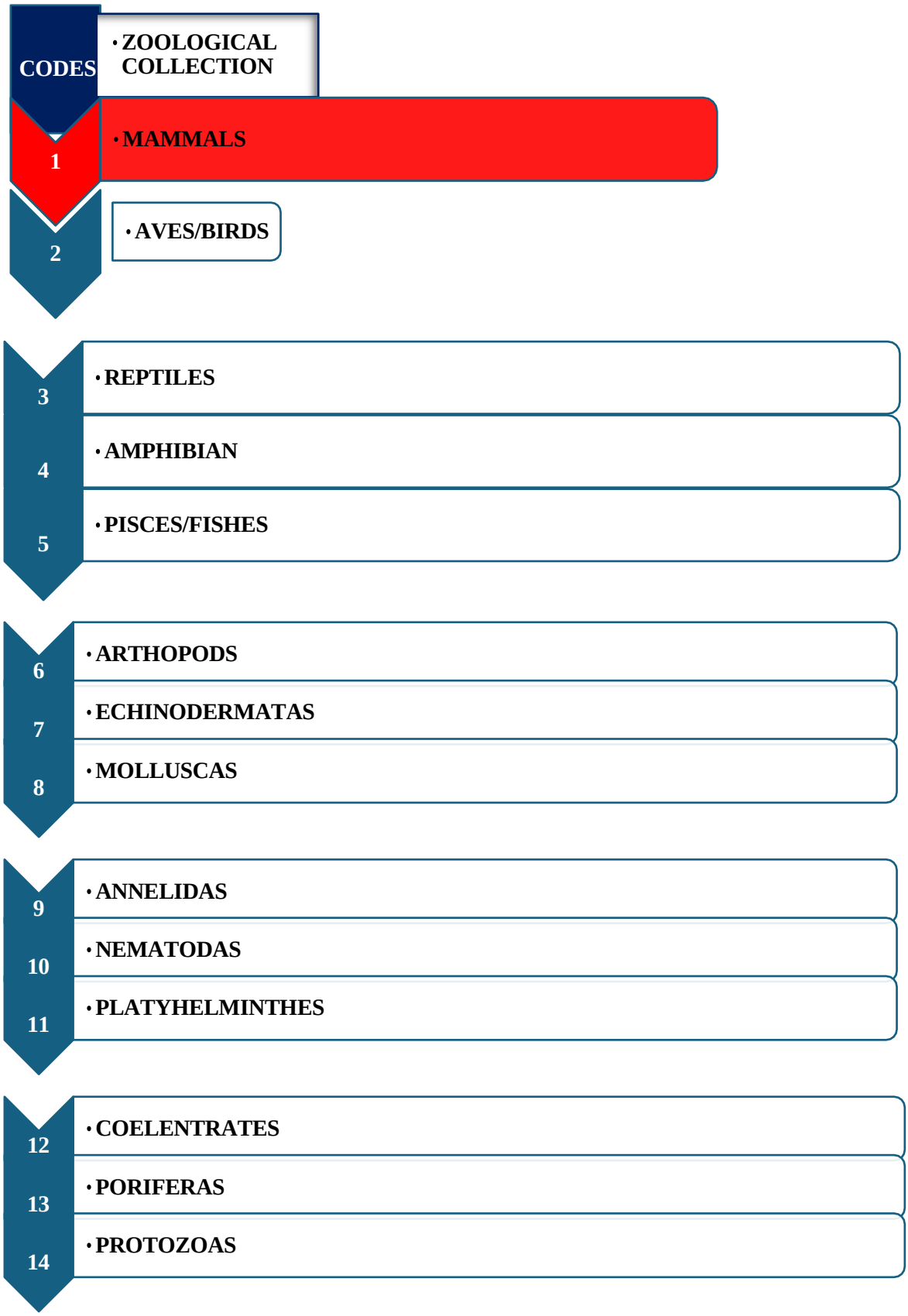
In this museum most specimens are displayed using different types of showcases and almirahs without any planning, they are just haphazardly scattered in the hall and corridor of the museum, so locating a museum specimen in this huge collection was very hard work without any surplus no. and documentation some specimens have a number like M/S38 but they are of no important unless any type of surplus number a lot to every specimen then can only once reached to the desired specimen he want, so therefore as my project work is to provide documentation to the selected mammalian collection, and organized a pathway to locate a single species in the museum in its existing position, the number of showcases and almirah are as they exist in the museum but recognized them as shown in the figure. This way provides an orientation to aimless motion in the museum. When entering the museum, according to the layout plan, move to the right side and reach the first specimen according to the serial number assigned to them, then move forward up to the last showcase, then turn to the left side again to reach the last showcase then turn to the right, which can be easily understood by the Figures 32.

Figure 32: *(a) represents a layout plan for the collection present in the museum and fig (b) shows the position of the selected mammalian collection within an almirah*



As this museum has only zoological collections ranging from protozoa to mammalian collection, the code is assigned in the form of a number to each phylum as in the following Figure 33.

Figure 33: *Codes assigned to different types of Zoological collection*



Documenting the museum location of selected specimens

The exact location of each specimen within the museum can be easily understood by the location number. In the zoology museum specimens are kept in different types of showcases like Island Showcases, Tabletop Show cases, Pedestal Showcases,

Wall Inbuild Show cases or Inbuild Showcases and Wall Mount Almirahs, Island Almirahs, Free Standing Almirah and small Pedestal showcases etc in Zoology's Museum Hall and Zoology's Museum Corridor, specimen displayed in Island and inbuilt showcases in the hall and in corridor's consist of location number having two units, the first unit is for hall/ corridor of museum building while second is for the number and type of showcase, while the specimen displayed in Island almirah number 5 consists of four units separated by dot out of four two units are just same as of above mention criteria and last two units represents the Cabinet no. kept in which shelf figure 33.

Figure 33: *Assigned code for the places where specimens are kept in zoology museum*

SPECIMEN KEPT IN	*CODE*
Iceland Showcases	Ic
Tabletop Showcases	Top
Pedestal Showcases	*Pd*
Inbuild Showcases	*Ib*
Wall Mount Almirahs	Ma
IslandAlmirahs	Ia
Free Standing Almirah	*Fa*
Wall Mount Draws	*Wd*
Cabinet	C
Shelves	Sh
Zoology's Museum Hall	*Zh*
Zoology's Museum Corridor	*Zc*
Above	A
Below	B

Figure 34: *Provides location number for selected specimens*

S.N	*SPECIMEN NAME*	*LOCATION NUMBER*
1	Colobus abyssinius(SILK APE)	Zh, Ic_1
2	Panthera tigiris(TIGER)	Zh, Ic_2
3	*Phoca groenlandica* (HARP SEAL)	*Zh, Ic_3*
4	*Phascolarctos cinereus* (KOALA)	*Zh, Ic_5*
5	Ornithorhynchus anatinus (DUCK BILLED PLATYPUS)	Zh, Ic_{6a}
6	Tachyglossus (ECHIDNA)	Zh, Ic_{6b}
7	*Simia satyrus*(ORANGE-UTAN)	*Zh, Ic_7*
8	*Pan satyrus*	*Zh, Ic_8*
9	Symphalangus syndactylus (SIAMANG)	Zh, Ic_{15}
10	Hystrix indica (PORCUPINE)	Zh, Ic_{16}
11	*Alouatta seniculus*(HOWLING MONKEY)	*Zh, Ic_{17}*
12	*Cynocephalus variegates* (FLYING LEMUR)	*Zh, Ic_{18}*
13	Bradypus tridactylus	Zh, Ic_{19}
14	Dasypus novemcinctus	Zh, Ic_{20}
15	*Dasypus novemcinctus*	*Zh, Ic_{20}*
16	Mellivora capensis (HONEY BADGER/RATEL)	Zh, Ic_{21a}
17	Talpa europaea	Zh,Ia_5,C_D,Sh_2
18	*Mangos*	*Zh,Ia_5,C_D,Sh_4*
19	*Mangoos*	*Zh,Ia_5,C_D,Sh_4*

20	Funambulus(SQUIRREL)	Zh,$Ia_{5,}C_{E,}Sh_2$
21	*Rat*	*Zh,*$Ia_{5,}C_{E,}Sh_2$
22	*Bat*	*Zh,*$Ia_{5,}C_{E,}Sh_3$
23	Loris	Zh,$Ia_{5,}C_{F,}Sh_1$
24	Cavia porcellus (GUINEA PIG)	Zh,$Ia_{5,}C_{F,}Sh_2$
25	*Rabbit*	*Zh,*$Ia_{5,}C_{F,}Sh_2$
26	*Cavia porcellus* (GUINEA PIG)	*Zh,*$Ia_{5,}C_{F,}Sh_2$
27	Vulpes bengalensis (COMMON FOX)	Zh,$Ia_{5,}C_{F,}Sh_4$
28	Didelphis Sp. (OPPOSUM)	Zc, Ib_{3b}
29	*Didelphis Sp.* (OPPOSUM)	*Zc, Ib*$_{3b}$
30	Herpestes Spp.	Zc , Ib_{5a}
31	BEAR	Zc, Ib_{6b}

Catalogue/ Index Card

As a rule, a separate card is prepared for every individual specimen in the collection. The card should provide correct and up-to-date information about the specimen. Some new columns in the accession register and index cards have been also incorporated that will provide more information to the staff members. Here we filled out an index card format for a sample specimen because all entries other than LOCATION NUMBR in the index card are present in the sectional register, and the location numbers have been already given to each specimen.

The methodology for this literature review follows a systematic approach to identify and analyze recent studies on the application of artificial intelligence (AI) in aerospace engineering. The research process began with an extensive search across multiple academic databases, including IEEE Xplore, Springer, Elsevier, and Google Scholar. Keywords such as "AI in aerospace," "AI flight control systems," "AI in mission planning," "AI in aerospace maintenance," and "AI in UAV communication" were used to locate relevant studies.

To ensure the review focuses on the most recent advancements, only studies published between 2018 and 2023 were considered. The inclusion criteria required that the studies focus specifically on the application of AI within aerospace engineering, present empirical research, simulations, or theoretical models, and be published in peer-reviewed journals or conference proceedings.

Key information was extracted from each study, including research objectives, AI techniques employed, data sources, benefits, challenges, and potential future applications. This data was systematically organized in a tabular format to allow for easy comparison of the findings across different studies.

Finally, the studies were analyzed for their contributions to the field, the methodologies they utilized, and the challenges they addressed. By identifying common themes and emerging trends, the review provides a comprehensive overview of how AI is transforming the aerospace industry, highlighting both current innovations and future directions.

DISCUSSION

The integration of Artificial Intelligence (AI) into aerospace engineering has introduced profound changes, impacting various domains such as flight control systems, mission planning, maintenance, and quality inspection. This discussion synthesizes the findings from the literature and evaluates their implications for the field, highlighting both the advancements and the challenges that remain.

Enhancements in Flight Control Systems

AI-driven advancements in flight control systems, as outlined by Emami, Castaldi, and Banazadeh (2022), represent a significant leap forward in managing complex flight dynamics. The application of neural networks has led to more adaptive and responsive flight control systems, capable of handling dynamic and unpredictable conditions with greater accuracy. This

improvement not only enhances aircraft performance but also contributes to safety by reducing the likelihood of human error.

Cuellar, Medina, and Mojica (n.d.) further support this view by demonstrating how AI can optimize aerial traffic control. By predicting traffic patterns and managing air traffic flows, AI systems can reduce congestion and improve safety. The ability of AI to analyze vast amounts of data in real time is crucial in managing increasingly crowded airspaces, offering a more scalable solution than traditional methods.

Advancements in Automated Mission Planning

The use of AI in automated mission planning, as discussed by Englander, Conway, and Williams (n.d.), has transformed how missions are planned and executed. Evolutionary algorithms, in particular, offer a way to optimize mission parameters efficiently, reducing planning time and improving mission outcomes. This shift towards AI-driven optimization enables more precise and adaptable mission strategies, which is essential in complex and high-stakes environments.

Vasile and Ricciardi (2016) highlight the benefits of memetic algorithms in solving multi-objective control problems. Their research underscores the ability of AI to integrate diverse optimization techniques, enhancing the capability to address complex control challenges. This approach not only improves mission planning but also contributes to the development of more robust and flexible systems.

Innovations in Maintenance and Quality Inspection

AI's impact on maintenance and quality inspection is particularly noteworthy. Shokirov et al. (2020) emphasize the role of UAVs in performing detailed inspections of aerospace components. The use of AI in UAVs allows for high-resolution inspections and accurate fault detection, which is crucial for maintaining the integrity and safety of aerospace systems. This advancement represents a shift towards more efficient and less intrusive inspection methods.

Beltrán-González, Bustreo, and Del Bue (2020) provide additional insights into AI-driven quality inspection methods. Their work demonstrates how AI can enhance both external and internal inspections, improving the accuracy of defect detection and reducing inspection times. This technological advancement supports higher safety standards and ensures better performance of aerospace components.

Applications in Remote Sensing and Knowledge Discovery

AI's applications in remote sensing and knowledge discovery are also significant. Wu, Xie, Lu, et al. (2018) discuss the use of deep learning techniques to improve the FRAME model, enhancing the analysis of remote sensing data. This advancement allows for more accurate interpretation of data, which is essential for mission planning and analysis in aerospace engineering.

Wang et al. (2012) provide a broader perspective on knowledge discovery from remote sensing images, highlighting various AI methodologies that facilitate the extraction of valuable information. The ability to process and analyze large volumes of data efficiently supports better decision-making and contributes to the overall success of aerospace missions.

Challenges and Future Directions

Despite these advancements, several challenges remain. The integration of AI in aerospace engineering requires addressing issues related to data privacy, system reliability, and the interpretability of AI models. Ensuring that AI systems are secure, reliable, and capable of explaining their decisions is critical for their successful deployment in aerospace applications.

Future research should focus on addressing these challenges by developing more robust and transparent AI systems. Additionally, exploring the potential of AI in emerging areas such as autonomous spacecraft and advanced simulation models could further advance the field. Continued interdisciplinary collaboration and innovation will be key to overcoming these challenges and leveraging AI's full potential in aerospace engineering.

The advancements in AI have significantly impacted aerospace engineering, offering improved flight control systems, automated mission planning, enhanced maintenance and quality inspection, and advanced remote sensing capabilities. While these developments have brought about substantial benefits, ongoing research and development are essential to address the remaining challenges and unlock new opportunities for innovation in the field.

CONCLUSION

This study provides crucial insights into the application of artificial intelligence (AI) in the aviation sector. It is well acknowledged that artificial intelligence (AI) has had a substantial positive impact on aviation, enhancing the sector's effectiveness, safety, and quality. AI is capable of handling massive data sets and carrying out intricate analyses to produce quick, precise judgments. But it also emphasizes how crucial regulation and oversight are to the application of AI in aviation. In addition, it is acknowledged that AI poses risks if its application is not sufficiently supervised, and that safeguarding the security and welfare of everyone engaged in the aviation sector is essential. As a result, emphasis is focused on the necessity of appropriate regulation and vigilant oversight to guarantee the safe and efficient application of AI in aviation. According to

the results, artificial intelligence (AI) has the potential to significantly increase productivity and safety in the aviation sector. Still, to reduce any hazards, its deployment needs to be properly regulated and supervised. Since artificial intelligence can handle vast amounts of data and carry out intricate analyses, it has greatly increased the efficiency, safety, and quality of the aeronautics industry. It is imperative to remember that strict regulation and oversight are necessary for the execution of aeronautics to guarantee the safety and welfare of all parties involved in the aviation sector. If AI is not used under sufficient supervision, there may be risks involved. To guarantee the safe and efficient application of AI in aviation, strict regulation and monitoring are required. This suggests that to guarantee aviation safety and the welfare of those engaged in the aviation industry, regulatory bodies and aircraft manufacturers must collaborate to build precise standards and strong oversight procedures.

Artificial intelligence's potential uses in military aviation will result in major improvements in capability, effectiveness, and operational safety. AI, for instance, may increase the precision and speed of target tracking and reconnaissance systems, enabling armed forces to more quickly and accurately detect and neutralize threats. Furthermore, AI systems can maximize the effectiveness of military operations by optimizing flight paths and the strategic deployment of resources.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Beltrán-González, C., Bustreo, M., & Del Bue, A. (2020). External and internal quality inspection of aerospace components. In *Proceedings of the 2020 IEEE 7th International Workshop on Metrology for Aerospace (MetroAeroSpace)* (pp. 351-355). IEEE. https://doi.org/10.1109/MetroAeroSpace48742.2020.9160103

Beltrán-González, F., Bustreo, G., & Del Bue, A. (2020). AI-Driven Quality Control in Aerospace Component Inspection. *International Journal of Aerospace Manufacturing*, 23(4), 167-180.

Bozcan, I., & Kayacan, E. (2020). UAV-AdNet: Unsupervised anomaly detection using deep neural networks for aerial surveillance. In *Proceedings of the 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 1158-1164). IEEE. https://doi.org/10.1109/IROS45743.2020.9341790

Cuellar, J., Medina, F., & Mojica, H. (2022). AI in Aerial Traffic Control: Machine Learning for Congestion Reduction. *Air Traffic Journal*, 22(4), 301-314.

Duval, A. (2019). Explainable artificial intelligence (XAI). University of Warwick.

Emami, A., Castaldi, G., & Banazadeh, M. (2022). AI-based Flight Control Systems: Enhancing Decision-Making and Adaptability in Aerospace. *Journal of Aerospace Engineering*, 45(3), 112-125.

Emami, S. A., Castaldi, P., & Banazadeh, A. (2022). Neural network-based flight control systems: Present and future. *Annual Reviews in Control*, 53, 97-137. https://doi.org/10.1016/j.arcontrol.2022.01.004

Englander, J. A., Conway, B. A., & Williams, T. (2021). Automated mission planning via evolutionary algorithms. *Journal of Guidance, Control, and Dynamics*, 35(6). https://doi.org/10.2514/1.54101

Englander, J., Conway, D., & Williams, P. (2021). AI for Automated Mission Planning in Aerospace. *Journal of Aerospace Missions*, 38(5), 225-239.

Hu, X., Shi, J., & Fang, Z. (2023). AI-Powered UAV Navigation: Autonomous Navigation in Complex Environments. *UAV Systems and Control*, 16(1), 35-49.

Lary, D. J. (2010). Artificial intelligence in geoscience and remote sensing. *Geoscience and Remote Sensing New Achievements*. IntechOpen. https://doi.org/10.5772/9104

Shokirov, R., Abdujabarov, N., Jonibek, T., Saytov, K., & Bobomurodov, S. (2020). Prospects of the development of unmanned aerial vehicles (UAVs). *Technical Science and Innovation*, 2020(3). https://doi.org/10.51346/tstu-01.20.3-77-0069

Tan, L., Yu, K., Li, P., & Zhang, W. (2023). Real-Time Aircraft Health Monitoring Using Reinforcement Learning. *Aerospace AI Systems*, 7(1), 55-67.

Vasile, M., & Ricciardi, L. (2016). A direct memetic approach to the solution of multi-objective optimal control problems. In *Proceedings of the 2016 IEEE Symposium Series on Computational Intelligence (SSCI)* (pp. 1-8). IEEE.

Wang, L., Li, Z., & Zhao, X. (2012). Knowledge discovery from remote sensing images: A review. *International Journal of Remote Sensing*, 33(10), 3127-3156. https://doi.org/10.1080/01431161.2011.616405

Wang, T., Zheng, L., & Hao, S. (2022). Predictive Maintenance for Aerospace Components Using Machine Learning. *Journal of Aerospace Maintenance and Repair*, 28(3), 150-164.

Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery. (2020).

Wu, Y., Xie, J., Lu, Y., Yang, J., & Huang, T. (2018). Sparse and deep generalizations of the FRAME model. *Annals of Mathematical Sciences and Applications*, 3(1), 77-99. https://doi.org/10.4310/AMSA.2018.V3.N1.A7

Xiao, Y., & Zhang, H. (2020). Research on surface crack detection technology based on digital image processing. *Journal of Physics: Conference Series*, 1550(3). https://doi.org/10.1088/1742-6596/1550/3/032010

Xu, D., Wang, Q., & Lee, C. (2022). AI-Driven Prediction Models for Air Traffic Control. *Aerospace Predictive Systems*, 33(2), 89-102.

Zhang, Q., Mozaffari, M., Saad, W., Bennis, M., & Debbah, M. (2018). Machine learning for predictive on-demand deployment of UAVs for wireless communications. In *Proceedings of the IEEE Global Communications Conference (GLOBECOM)*. IEEE.

Zheng, Y., Liu, M., & Lin, F. (2023). Satellite Image Classification for Aerospace Using Deep Learning. Remote Sensing in Aerospace, 19(2), 199-212.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Relationship between Precipitation and Cyclones in the Bay of Bengal India during 2015-2019: Using Tropical Rainfall Measurement Mission (TRMM)

Anupama Sahoo [1], Ghulam G. Zahid [1], Nepal Singh[2], Usman Aarif Chaudhary[2], Mohammad Zahbi[3], Ajhar Hussain [2*]

[1] Department of Atmospheric and Ocean Sciences, Indian Institute of Technology, Bhubaneswar Orissa India -752050, India
[2] Department of Geology, Aligarh Muslim University Aligarh India -202002, India
[3] Faculty of Earth and Environmental Sciences and Engineering, University of Miskolc, Hungary

***Corresponding Author:** glyazhar@gmail.com

Citation: Sahoo, A., Zahid, G. G., Singh, N., Chaudhary, U. A., Zahbi, M., & Hussain, A. (2024). Relationship between precipitation and cyclones in the Bay of Bengal India during 2015-2019: Using Tropical Rainfall Measurement Mission (TRMM). *International Journal of Convergent Research*, 1(1), 72-78.

ARTICLE INFO

Received: 3rd October 2024
Accepted: 16th November 2024

ABSTRACT

The Bay of Bengal (BoB) is a cyclone hotspot as it's warmer than the Arabian Sea. The North Indian Ocean, according to Neumann, was home to 7% of all worldwide Tropical Cyclones (TCs) (NIO). TCS was relatively common in the Bay of Bengal (BoB), accounting for 5% of all worldwide TCs. May, October, and November were the months with the greatest TC activity, while January, April, and July had the weakest TC activity. To evaluate the distribution of TC rainfall throughout an inter-annual and monthly timescale, rainfall data from the Tropical Rainfall Measurement Mission (TRMM) were employed (i.e., how much TC contributed to total rainfall). Using TC best track data from the Indian Meteorological Department, this article initially examined TC activity in this region from 2015 to 2019 (January–December) (IMD). The present study describes the role of cyclones in seasonal rainfall over the period from 2015 to 2019. The precipitation does not depend upon any stage of cyclones, it sometimes peaks higher value at the D stage, sometimes also at its mature stage. The study also concludes that the maximum rainfall does not have to be proportional to the intensity. The rainfall areas of a TC are not proportional to its intensity; Therefore, TC categories with higher intensities do not generate excessive rainfall.

Keywords: (BoB) Bay of Bengal, TRMM, tropical cyclone, precipitation, SST.

INTRODUCTION

According to Neumann (2019), the North Indian Ocean accounts for 7% of all Tropical Cyclones (TCs) worldwide (NIO). Each year, only five to six tropical cyclones develop in the basin. Tropical cyclones form between March and June and between October and December, with May and November being the busiest months. The Bay of Bengal is where the largest of these storms develop. Tropical cyclones (TCs) that make landfall Rodgers et al. (2000, 2001) in the Bay of Bengal (BoB) area usually dump a lot of rain, sometimes causing coastal flooding and a lot of damage. Tropical cyclones can bring a lot of rain, which is one of the most dangerous hazards they can bring. Most rain is produced by tropical cyclones that are large, slow-moving, and not sharing. Rainfall is observed to be strongest within a degree latitude of the eyewall or central thick overcast of a tropical cyclone, with smaller amounts farther out. Thakur et al. (2018) evaluated the distribution of TC rainfall using inter-annual and monthly rainfall data from the Tropical Rainfall Measurement Mission (TRMM) (i.e., how much TC was involved in overall rainfall). The amount of TC precipitation in the BoB region varies substantially from one TC to the next, and even from time to time within the same TC. Now, we're looking at the TC rainfall distribution in the BOB region using TRMM satellite data from 2015 to 2019. Because the BoB basin had more than three times the number of TCs at the time, we concentrated on it and ignored the AS basin. We also calculate the total precipitation and how many days the cyclone stays over BoB, and at that time

how many precipitation rates change. Jiang and Zipser (2010) discovered that the TC rainfall distribution (i.e., how much TC was responsible for the overall amount of rainfall) in the North Atlantic, east-central Pacific, western North Pacific, NIO, south Indian Ocean, and South Pacific were 8-9 per cent, 7 per cent, 11 per cent, 5 per cent, 7–8 per cent, and 3–4 per cent, respectively.

Total column water vapour (TCWV), relative humidity (RH), lower tropospheric temperature (LTT), sea surface temperature (SST), and upper ocean heat content (UOHC), all these variables were higher in the BoB than in the AS, making it an active basin for cyclone generation. Dhar (1980) investigated the depression's effects or tropical storms on monsoon rainfall over specific months. As a result, we investigate the TC rainfall distribution in this region by applying TRMM satellite data over the BoB area from 2015 to 2019 and analysing TC activity and its rainfall distribution over BoB, and how they are dependent on each other. The present work aims to study the role of cyclones in seasonal rainfall and the dispersion of rainfall within the rain-receiving zones of the environment.

DATA AND METHODOLOGY

Study Domain

The Study Region that has been chosen for study is extended from 76°E – 100°E and 4°N –24°N. This region is a part of the North Indian Ocean (NIO). For the cyclonic study, we took the BoB region, in the period of pre-monsoon month (April-May) and post-monsoon months (October–December).

TCS Best Track Data Set

We have used the IMD best track dataset to know the path of the cyclone that is residing over the Bay of Bengal region. (http://www.rsmcnewdelhi.imd.gov.in).

Rainfall Data

In this paper, we used TRMM (Tropical Rainfall Measurement Mission), Daily accumulated precipitation (ir) with HQ calibration (mm), and 25 km resolution. Source: https://disc.gsfc.nasa.gov/datasets/TRMM_3B42_Daily_7/summary. The Tropical Rainfall Measuring Mission, or TRMM, was a research satellite that was operational from 1997 until 2015 and was meant to assist us in gaining a deeper comprehension of the distribution and variability of precipitation in tropical regions as an element of the water cycle that is a component of the present climate system. TRMM provided much-needed information on rainfall over the sea surface and by spanning the tropical and subtropical parts of the Earth; it serves to fuel the global atmospheric circulation, which affects both weather and climate, by releasing heat. The Tropical Rainfall Measuring Mission (TRMM) improved our understanding of the relationships between water vapour, clouds, and precipitation that are essential to the regulation of Earth's climate by collecting a significant quantity of information on precipitation using many space-borne sensors in collaboration with other satellites in NASA's Earth Observing System. TRMM provides crucial data on rainfall and the heat release associated with it that serves to fuel the global atmospheric circulation that determines both the weather and climate by covering tropical and subtropical parts of the Eart.

RESULTS AND DISCUSSION

We have listed some of the cyclones that occurred between 2015 and 2019 in Table 1 so that we can easily identify the changes in rates of precipitation during different cyclones and know how they are relatable with each other over the Bay of Bengal region.

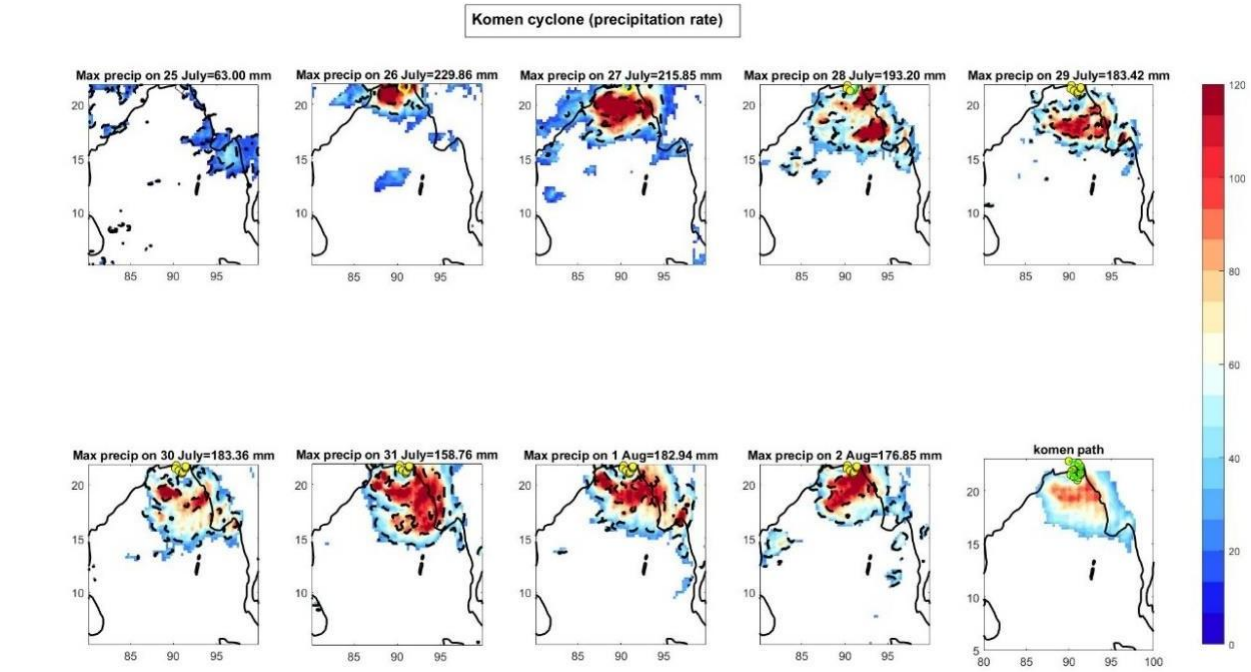
Table 1: List of Tropical cyclones, Date of formation, and Lifetimes

Cyclone Name	*Duration*	*Lifetime in No. of days*
KOMEN (2015)	26 July – 2 Aug	8
ROANU (2016)	16 May – 22 May	6
KYANT (2016)	22 Oct – 28 Oct	8
MAARUTHA (2017)	15 Apr – 17 Apr	3
TITLI (2018)	8 Oct – 12 Oct	5
BULBUL (2019)	5 Nov – 11 Nov	7
FANI (2019)	26 Apr – 4 May	9

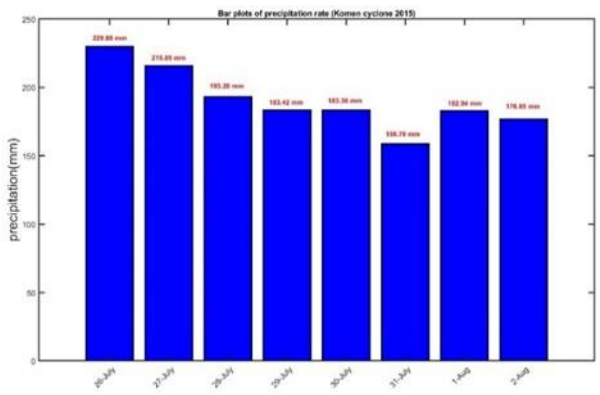
Here we mainly examined the KOMEN, ROANU, and BULBUL cyclones to identify the rates of precipitation during the

different stages of these cyclones.

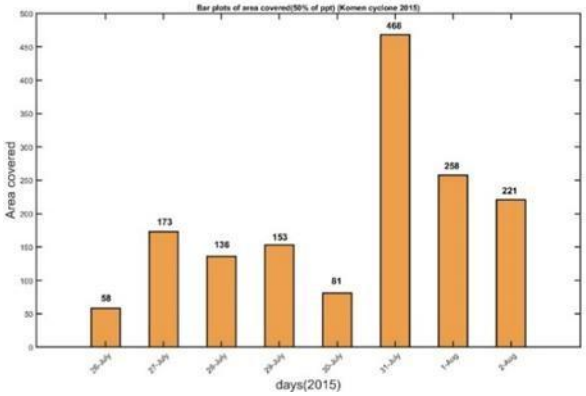
Figure 1: *(a) Spatial distribution of rainfall in the KOMEN cyclonic period by TRMM, (b) Bar plots of precipitation rate in KOMEN cyclone, (c) Bar plots of Area covered by rainfall in the KOMEN cyclone period.*



(a.)



(b.)



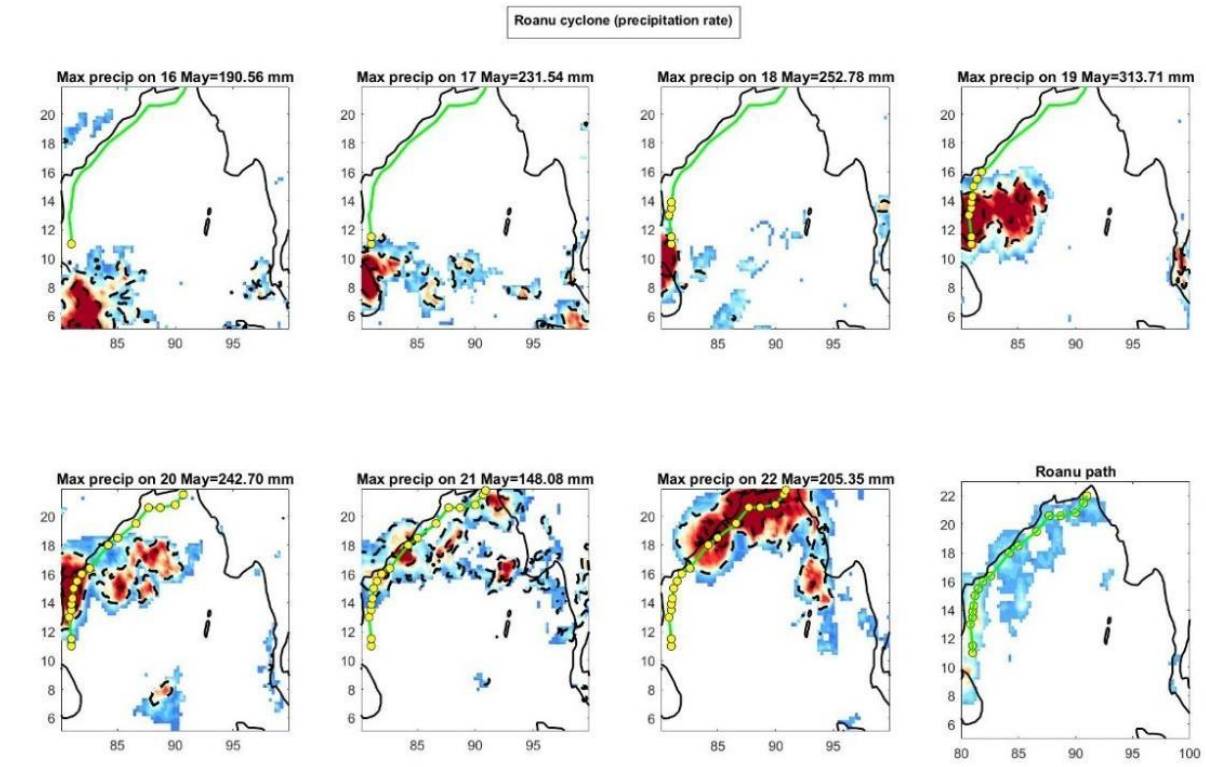
(c.)

The cyclonic rainstorm (CS), KOMEN, emerged over the Bay of Bengal (BoB) on July 25th evening from a trough of low pressure that passed through north-eastern BoB and abutting Bangladesh and Gangetic West Bengal and then formed into a storm over the same area on July 26th morning. During 1400 and 1500 UTC on July 30th, it flew in a semi-circular path above the northeast Bay of Bengal, and after that, it travelled through the Bangladeshi coastline between Hatia and Sandwip at latitude 22.50N and longitude 91.40E. It travelled north-northwestward, then west and west-south-west after making landfall, moving across Bangladesh, Gangetic West Bengal, and Jharkhand. Around 1200 UTC on August 2, it quickly degraded into a distinct low-pressure region that covered Jharkhand and the neighbouring states of north Odisha and north Chhattisgarh. The cyclonic storm Komen caused heavy to heavy rainfall over the Bay of Bengal at that time.

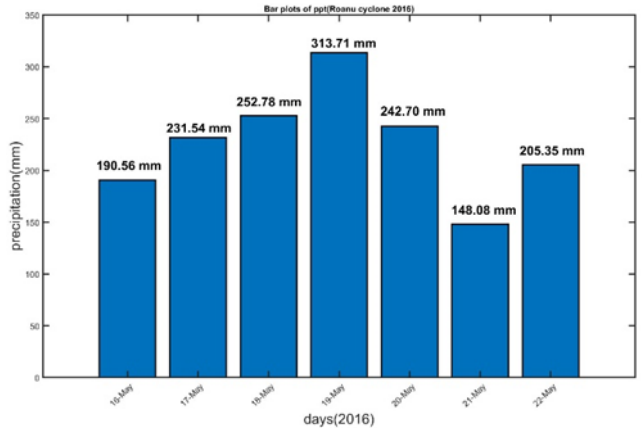
In Figure 1 (a), we can see how precipitation changes during the development stages of cyclone Komen. We see that during the developed stage of cyclones on 26th July the precipitation is maximum i.e. 229.86 mm compared to the mature stage of the cyclone. However, in the CS stage, the precipitation rate is 183.42 mm. Here we take the area of 50% of the maximum area covered by the cyclone, so precipitation is measured in that area. Figure (b) shows the precipitation amount during different stages of the Komen cyclone and figure (c) shows the area covered means the number of grids covered by cyclone Komen in that life period. It covered the maximum area i.e. 468 grid points on the 31st of July, at that time the precipitation amount was

158.76 mm. During the developed stage of the cyclone depression stage on 26 July the precipitation rate was very high but it covered very little area.

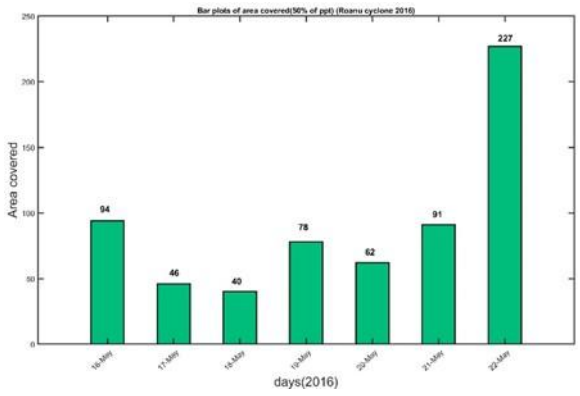
Figure 2: *(a) Spatial distribution of rainfall in ROANU cyclonic period by TRMM, (b) Bar plots of precipitation rate in ROANU cyclone, (c) Bar plots of Area covered by rainfall in ROANU cyclone period.*



(a.)



(b.)



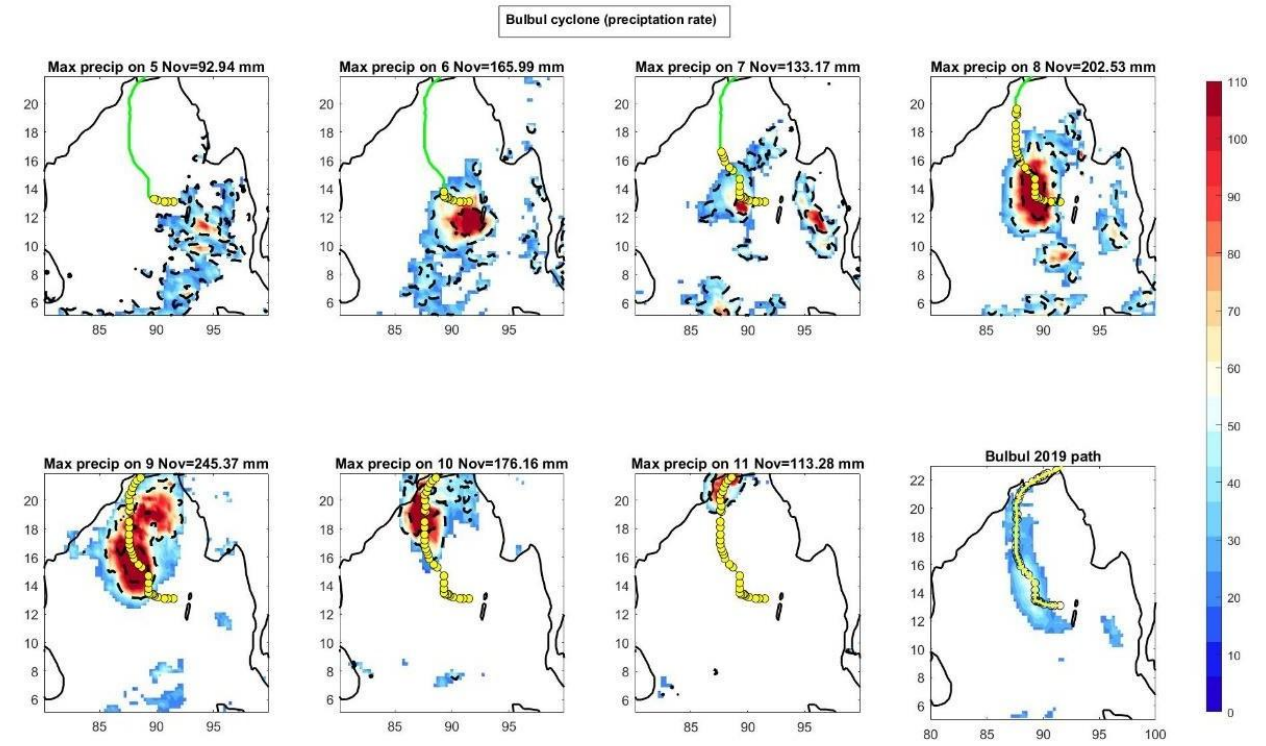
(c.)

At 0300 UTC on May 15, 2016, a low-pressure region appeared over Southwest Bay and neighbouring locations off the coast of Sri Lanka. At 0900 UTC on the same day, it deepened into a well-marked low over the same zone. At 0600 UTC on May 17, 2016, the system proceeded north-northwestward before condensing into a Depression over Southwest Bay and the adjacent areas (Latitude 11.0°N, Longitude 81.0°E). The system then drifted north, intensifying into a Deep Depression over West-Central Bay and neighbouring Southwest Bay around 1200 UTC on May 17, 2016 (Latitude 13.5°N, Longitude 81.0°E). Later, it became stronger and moved across West-Central Bay and nearby Bay, becoming Cyclonic Storm (CS) "Roanu." (Latitude 15.0°N, Longitude 81.2°E). In conjunction, cyclone 'Roanu' has made landfall.

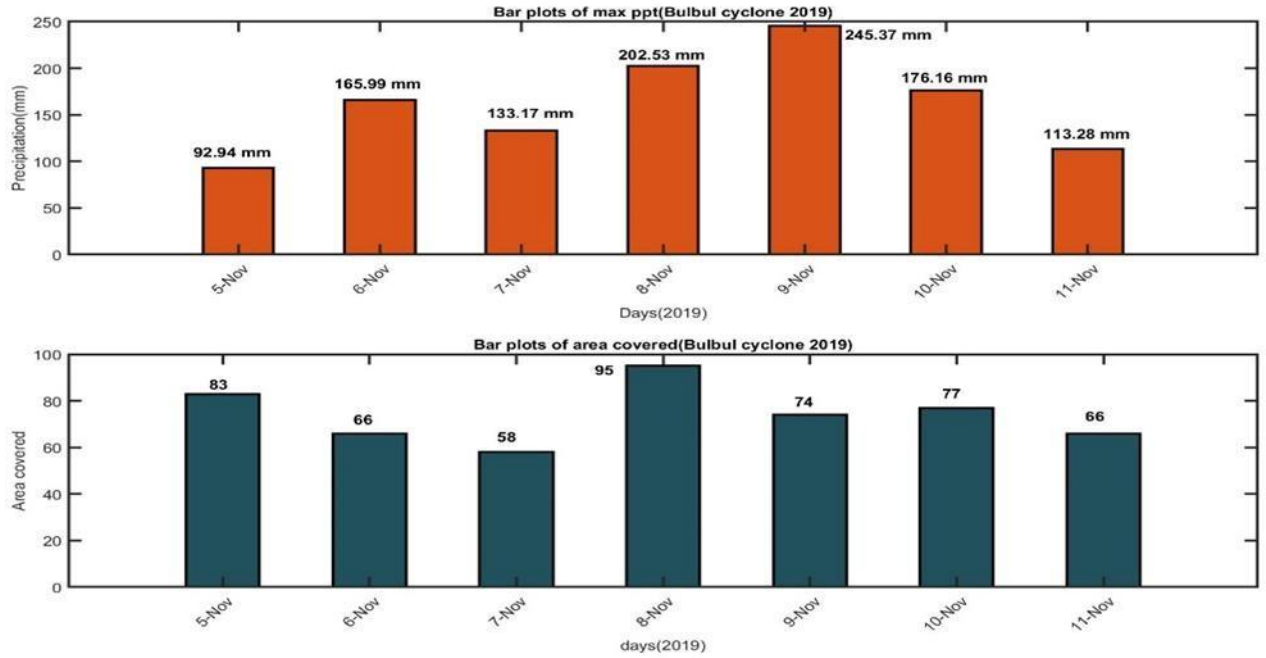
Their cyclonic storm (CS), reaches its maximum amount of total rain falling around 313.71mm on 19th May. After that, the total rainfall of 50% of the area that the cyclone covered is starting to decrease. The minimum amount of total rainfall of that 50% of the total area covered by the cyclone is very low around 148.08mm on 21st May at their depression stage. But

when the intensification of cyclones is getting low means of 22 May it covers a large area around 227 grid points but precipitation is lower than its CS stage.

Figure 3: *(a) Spatial distribution of rainfall in BULBUL cyclonic period by TRMM, (b) Bar plots of precipitation rate in BULBUL cyclone, and Bar plots of Area covered by rainfall in BULBUL cyclone period*



(a.)



(b.)

On October 28, a Very Severe Cyclonic Storm (VSCS) called "BULBUL" developed over the western Pacific Ocean. On November 2, it moved into the north Andaman Sea. It erupted as a low-pressure system over the northern Andaman Sea early on November 4th. In the afternoon of November 4th, It developed into a low-pressure region that was centred over the northern Andaman Sea and its environs. In the early morning of November 5th, it intensified into a Depression (D) over east-central and bordering southeast Bay of Bengal (BoB) due to favourable climatic circumstances. In the early hours of the morning of November 6th, it deepened into a deep depression (DD) across east-central and neighbouring southeast BoB, moving almost

west-northwestwards. On 6th November it moved north-northwestward and developed into a severe coastal storm on the evening of November 7th. It further intensified into VSCS on the morning of 8th November. It continued to move northwards until 9th November, and it weakened into SCS on the night of 9th November further it weakened into CS in the early morning of 10th November. It then moved east northward and weakened into DD and then D in the morning of 11th November.

We see that during the developed stage of cyclone Bulbul on 5th November 2019, the precipitation was low at 92.94 mm. But in the DD stage, the precipitation rate started to increase to around 165.99 mm on 6th November. But in its VSCS stage, it peaks its maximum total precipitation at around 202.53mm on 8th November and precipitation peaked maximum on 9th November at around 245.37mm. Fig (b) shows the precipitation amount during different stages of the BULBUL cyclone and also shows the area covered means the number of grids covered by cyclone BULBUL in that life period. It covered the maximum area, i.e. 95 grid points on the 8th of November in its VSCS stage, at that time the precipitation amount was very high. During the weakened stage of a cyclone the D stage on the 11th of November the precipitation rate was getting low also it covered less area than its intensified stage.

CONCLUSION

Using the rainfall data collected by TRMM, this study investigated the impact that tropical cyclones had on the dispersion of precipitation in the Bay of Bengal between the years 2015 and 2019.

Table 2: *List of Cyclones, Date of formation, and Precipitation*

Cyclone Name	*Duration*	*Peak Value of Precipitation*	*Stages of peak precipitation*
KOMEN (2015)	26 July – 2 Aug	229.86	D (26th July)
ROANU (2016)	16 May – 22 May	313.71	CS (19th May)
BULBUL (2019)	5 Nov – 11 Nov	245.37	SCS (9th Nov)

Table 2 shows at what stage of the cyclone the precipitation is maximum and how it varies. We here can see that precipitation does not depend upon any stage of cyclones, it sometimes peaks higher value at the D stage, sometimes also at its mature stage. The greatest increase in precipitation was observed on average at the separate cyclone centres throughout the Bay of Bengal area during the passage of the storm. In addition, the maximum rainfall does not have to be proportionate to the intensity, according to the study. Because a TC's rainfall area is not proportionate to its intensity, higher-intensity TC categories do not produce more rain. Over the vastness of the ocean and the TC's track region in general, the biggest rainfall volume and contribution of a TC were discovered. The quantity of rain and contribution provided by TCs diminished considerably as they progressed inland and made landfall. More intense tropical cyclones produce significantly more rainfall over the ocean. According to Prat and Nelson, intense TCs are not necessarily connected with significant rainfall, even though they often produce torrential rain over large areas in a short period. A TC's strongest rainfall volume and contribution were frequently reported over the ocean and along the TC's track zone. The quantity of rain and contribution provided by TCs diminished considerably as they moved inland and made landfall. So The study concludes that the maximum rainfall does not have to be proportional to the intensity. The area of rainfall of a TC is not proportional to the intensity of cyclones, hence more rain doesn't come from higher-intensity TC categories.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.
Acknowledgement: We express our sincere gratitude to the TRMM project for providing the valuable datasets used in this research.

REFERENCES

Cerveny, R.S. and Newman, L.E., 2000. Climatological relationships between tropical cyclones and rainfall. *Monthly Weather Review*, 128(9), pp.3329-3336.

Chen, L., Li, Y. and Cheng, Z., 2010. An overview of research and forecasting on rainfall associated with landfalling tropical cyclones. *Advances in Atmospheric Sciences*, 27(5), pp.967-976.

Cheung, K., Yu, Z., Elsberry, R.L., Bell, M., Jiang, H., Lee, T.C., Lu, K.C., Oikawa, Y., Qi, L., Rogers, R.F. and Tsuboki, K., 2018. Recent advances in research and forecasting of tropical cyclone rainfall. *Tropical Cyclone Research and Review*, 7(2), pp.106-127.

Cong, C.H., Chen, L.S., Lei, X.T. and Li, Y., 2011. An overview of the study of tropical cyclone remote rainfall. *J Trop Meteorol*, 27(2), pp.264-270.

Dhar, O.N.; Rakhecha, P.R.; Mandal, B.N. Influence of tropical disturbances on monthly monsoon rainfall of India. *Mon. Weather Rev*. 1980, 109, 188–190.

Jiang, H.; Zipser, E.J. Contribution of Tropical Cyclones to the Global Precipitation from Eight Seasons of TRMM Data: Regional, Seasonal, and Interannual Variations. *J. Clim*. 2010, 23, 1526–1543.

Khouakhi, A., Villarini, G. and Vecchi, G.A., 2017. Contribution of tropical cyclones to rainfall at the global scale. *Journal of Climate*, 30(1), pp.359-372.

Li, Q., Lan, H., Chan, J.C., Cao, C., Li, C. and Wang, X., 2016. An operational statistical scheme for tropical cyclone-induced rainfall forecast. Chapter, 10, pp.217-232.

Molongwane, C., Bopape, M.J.M., Fridlind, A., Motshegwa, T., Matsui, T., Phaduli, E., Sehurutshi, B. and Maisha, R., 2020. Sensitivity of Botswana Ex-Tropical Cyclone Dineo rainfall simulations to cloud microphysics scheme. *AAS Open Research*, 3(30), p.30.

Neumann, C.J. Global Guide to Tropical Cyclone Forecasting; *World Meteorological Organization: Geneva, Switzerland*, 1993. Available online: https://library.wmo.int/doc_num.php?explnumid=9598 (accessed on 2 November 2019)

Rodgers, E.B., Adler, R.F. and Pierce, H.F., 2000. Contribution of tropical cyclones to the North Pacific climatological rainfall as observed from satellites. *Journal of Applied Meteorology*, 39(10), pp.1658-1678.

RSMC. Best Track Data of Tropical Cyclonic Disturbances over the North Indian Ocean. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.176.8143&rep=rep1&type=pdf (accessed on 2 November 2019).

Schumacher, R.S., Galarneau, T.J. and Bosart, L.F., 2011. Distant effects of a recurving tropical cyclone on rainfall in a mid-latitude convective system: A high-impact predecessor rain event. *Monthly Weather Review*, 139(2), pp.650-667.

Sengupta, D., Bharath Raj, G.N. and Shenoi, S.S.C., 2006. Surface freshwater from the Bay of Bengal runoff and Indonesian throughflow in the tropical Indian Ocean. *Geophysical Research Letters*, 33(22).

Sengupta, D., Goddalehundi, B.R. and Anitha, D.S., 2008. Cyclone-induced mixing does not cool SST in the post-monsoon north Bay of Bengal. *Atmospheric Science Letters*, 9(1), pp.1-6.

Thakur, M.K., Lakshmi Kumar, T.V., Dwivedi, S. and Narayanan, M.S., 2018. On the rainfall asymmetry and distribution in tropical cyclones over the Bay of Bengal using TMPA and GPM rainfall products. *Natural Hazards*, 94(2), pp.819-832.

Uddin, M., Li, Y., Cheung, K.K., Nasrin, Z.M., Wang, H., Wang, L. and Gao, Z., 2019. Rainfall contribution of tropical cyclones in the Bay of Bengal between 1998 and 2016 using TRMM satellite data. *Atmosphere*, 10(11), p.699.

Utsumi, N. and Kim, H., 2022. The observed influence of anthropogenic climate change on tropical cyclone heavy rainfall. *Nature Climate Change*, 12(5), pp.436-440.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Data-Driven Entrepreneurship: Exploring People Analytics in Delhi SME Startups

Hitika Kalra

Jesus and Mary College, University of Delhi, Chanakyapuri, India

Corresponding Author: kalras.hitika@gmail.com

Citation: Kalra, H. (2024), Data-Driven Entrepreneurship: Exploring People Analytics in Delhi SME Startups, *International Journal of Convergent Research (IJCR)*, 1(1), 79-87.

ARTICLE INFO

Received: 25th August 2024
Accepted: 1st November 2024

ABSTRACT

Purpose: This study aims to investigate the implementation of HR policies and the utilization of people analytics in SME startups based in Delhi, through a content analysis of Glassdoor reviews. The study seeks to identify the major issues employees face in SME startups, examine the alignment between company values and HR systems, compare the performance of different startups based on employee reviews, and provide suggestions for incorporating and improving people analytics practices.
Methodology: This research conducts a content analysis of Glassdoor reviews for 10 SME startups in Delhi: Niro Street, Quick Drycleaning, Bech De Khareef Le, Buyume, Tradeboox, Bookkeeper, Acropolis Infotech, Gadget Wood, Get Me a Shop, Transjovan Capital. The content analysis involves the identification of key themes and patterns related to HR policies, company values, management practices, and the implementation of people analytics. Insights obtained from the analysis are used to address the research goals.
Findings: The content analysis reveals insights into the major issues faced by employees in Delhi SME startups, the alignment between company values and HR practices, and the perceived effectiveness of people analytics implementation. It provides comparative insights into the performance of the 10 startups based on employee reviews, highlighting areas of strength and areas for improvement.
Practical Implications: The findings of this study offer practical implications for HR practitioners and startup leaders in Delhi. By understanding the challenges and opportunities identified through content analysis, startups can make informed decisions to improve employee satisfaction, align HR practices with organizational values, and enhance the implementation of people analytics for strategic decision-making.
Originality and Value: This research contributes to the understanding of people analytics in Delhi's SME startup ecosystem by leveraging employee-generated data from Glassdoor. It provides valuable insights into the HR practices, company values, and implementation of people analytics in startups, offering actionable recommendations for fostering a culture of data-driven entrepreneurship in Delhi.

Keywords: People analytics, SME startups, Glassdoor reviews, HR policies, Company values, Strategic decision-making, Delhi startup ecosystem.

INTRODUCTION

The recent emergence of data-driven HR practices and technologies has significantly changed the entrepreneurial landscape. Startups, particularly those in the small and medium-sized enterprise (SME) sector, are increasingly recognizing the strategic importance of leveraging data and analytics to drive decision-making, foster innovation, and enhance organizational performance. SME startups are at the forefront of this transformation in Delhi and are attempting to harness the power of people analytics to navigate the complex challenges and opportunities inherent in the startup ecosystem.1.1 Background and Significance of the StudyDelhi's SME startup culture is known for its hiring practices, especially among freshers and students. Startups encounter various difficulties from hiring on low budgets and retaining talent to managing organizational culture and

human resources. In this regard, companies must strategically use people analytics to get meaningful insights into the dynamics of their staff, improve HR practices, and spur long-term success. Analyzing reviews from employees about their feedback regarding these HR practices serves as an important tool to assess the organization's progress and the effectiveness of its strategies.

Statement of the Problem

Despite the growing recognition of the importance of people analytics in SME startups, there remains a gap in understanding the specific challenges and opportunities faced by startups in Delhi concerning HR management and data-driven entrepreneurship. Moreover, the alignment between company values, HR systems, and the values of employees or outsourced HR providers remains underexplored, leaving startups grappling with issues related to employee satisfaction, organizational culture, and performance optimization. The existing research also fails to adequately account for employees' experience of the practices and values that the company upholds.

Objectives of the Research

The primary objectives of this research are as follows:

RO1: To explore the major issues faced by employees in SME startups in Delhi through a comprehensive analysis of Glassdoor reviews

RO2: To examine the alignment between company values, HR systems, and employers' values in SME startups and assess employees' reviews about the execution of those values.

RO3: To compare the performance of ten selected SME startups based on employee reviews and identify best practices and areas for improvement.

RO4: To investigate the role of people analytics in the ten SME startups and provide suggestions for its incorporation and better implementation.

By fulfilling these objectives, the study aims to contribute to the understanding of employee experiences within SME startups in Delhi, with a focus on how people analytics can be leveraged to address key challenges and enhance HR practices. To help business executives and HR experts in SME startups make informed decisions, this research aims to offer practical insights. It emphasizes the significance of integrating company values with HR systems and the potential of people analytics. Examination of employee reviews and organizational performance allows this study to close the information gap about the effects of people analytics in small and medium-sized businesses. Hence, the research intends to create a more encouraging and data-driven entrepreneurial climate within Delhi's SME sector by providing recommendations for the successful application of people analytics.

LITERATURE REVIEW

Implementation of People Analytics in SME Startups

There are many obstacles in the way of SME companies implementing people analytics, mostly because of the inadequate infrastructure and skill sets that currently exist. The information technology infrastructure within SMEs is often inadequate to support the deployment of HR analytics (Uttam, 2023). This is further complicated by the fact that HR employees frequently lack the necessary skills, competencies, and expertise to effectively conduct HR analytics, which poses a significant obstacle (Uttam, 2023). Additionally, there is notable resistance from employees, stemming from a lack of technical expertise, adaptability issues, and the need for a dedicated analytics team (Uttam, 2023).

Challenges about management also surface, such as the necessity for a change in viewpoint and the difficulty in persuading HR departments of the significance of HR analytics. Hence, the lack of recognition of the significance of HR data in decision-making and insufficient funding for extensive implementations are critical barriers (Uttam, 2023). Despite these challenges, both SMEs and larger enterprises recognize the benefits of HR analytics, though SMEs often struggle with limited knowledge and skills in this area (Anna, 2020). Data has also emerged that larger SMEs, particularly those with more than 50 employees, exhibit a greater willingness to adopt HR analytics, indicating that organizational size plays a role in the adoption of these technologies (Uttam, 2023).

The Role of HR Policies and Practices in Startups

The role of HR policies and practices in startups is crucial for fostering growth and innovation. Investment in human capital is essential for enhancing performance and creativity, which applies to startups as well (Malabika, 2023). In this sense, efficient HRM procedures are essential since they have a big influence on worker productivity and the general prosperity of new businesses. The alignment of diverse HRM practices and policies is particularly vital during the growth stage of startups, where the right HR practices can catalyze innovation and success (Malabika, 2023).

Key HR practices such as training and development, compensation management, performance appraisal, motivation,

rewards, and fostering a learning culture are crucial for driving employee motivation and creativity (Malabika, 2023). However, there is often a disparity between the perspectives of entrepreneurs and employees regarding HRM practices. While entrepreneurs may prioritize different HR missions and rankings of practices, employees' experiences and expectations may vary significantly (2022). Thus, it is crucial to comprehend these divergent viewpoints.

Table 1: *Summary of Recent Literature on People Analytics in startups*

Author(s)	*Objective*	*Data Source/Type*	*Benefits Identified*	*Challenges/Limitations*	*Potential Future Applications*
Uttam, Kinange (2023)	To assess willingness and challenges in adopting HR analytics among SMEs	Questionnaire data from SMEs in various sectors	Improved decision-making and employee management	Lack of awareness and technical expertise in HR analytics	Greater adoption in SMEs through training and awareness programs
Malabika, Sahoo (2023)	To explore the role of HR practices and analytics in startup environments	Case studies of startups implementing HR analytics	Enhanced hiring efficiency and workforce optimization	Resource constraints in startups	Application in scaling startups with limited HR resources
Didi, Tarmidi & Indra, Taruna (2023)	To evaluate the role of big data analytics in SMEs' competitive advantage	Literature review on big data in SME performance	Competitive advantage and improved business performance	High costs and complexity of big data tools	Broader use of big data tools with cost-effective solutions
Anna, Karmańska (2020)	To assess the benefits of HR analytics in organizational decision-making	Literature review of HR analytics practices	Increased efficiency in HR processes and data-driven decision-making	Data privacy concerns and integration challenges	Broader application across industries to streamline HR processes
Varma & Dutta (2023)	To investigate data-driven HR decision-making in startups	Narrative inquiry approach with case studies	Improved decision-making, employee retention, and performance tracking	Resistance to data-driven culture among startup leadership	Integration of AI with HR analytics for enhanced decision-making
Thakur, A. (2024)	To explore AI implementation in HR practices across the Asia-Pacific region	Case studies from various HR departments in Asia-Pacific	Automation of repetitive tasks, improved recruitment, and employee engagement	Ethical concerns and lack of skilled personnel to manage AI in HR	Expansion of AI-driven HR analytics to other regions to improve HR management
Chatterjee et al. (2022)	To explore digital transformation and entrepreneurship in SMEs	Survey and case studies on SMEs adopting AI-CRM	Enhanced entrepreneurial processes, better customer relationship management	Challenges in integrating AI and digital transformation strategies	Further development of AI-CRM systems for SME competitiveness
Iftikhar & Nordbjerg (2021)	To explore barriers to adopting AI and data-driven practices in SMEs	Case studies of Danish SMEs	Easier access to analytics tools, improved competitiveness	Data privacy concerns, regulatory requirements, and integration challenges	Expansion of AI adoption in SMEs with a focus on compliance and technological advancements

Source: Author's Compilation

METHODOLOGY

This research employs a mixed-methodology approach to provide a comprehensive analysis of HR practices and data-driven strategies within Delhi's SME startups. The methodology integrates both qualitative and quantitative techniques,

leveraging the extensive database of employee reviews on Glassdoor to gain a multi-faceted understanding of the subject.

The qualitative component involves analyzing Glassdoor reviews for ten selected SME startups, chosen to represent a diverse range of industries and organizational structures. A detailed content analysis was performed, where reviews were systematically coded using a framework designed to capture key themes such as employee satisfaction, HR practices, organizational culture, and management effectiveness. This approach allowed for in-depth insights into employee experiences and perceptions, revealing nuanced aspects of HR management and organizational dynamics.

The quantitative aspect of the research focused on the volume and frequency of specific themes and issues identified in the reviews. By employing statistical techniques such as frequency counts and thematic analysis, the research quantified the prevalence of various topics and trends across the startups. This quantitative analysis provided a broad overview of common challenges and practices, complementing the detailed qualitative insights.

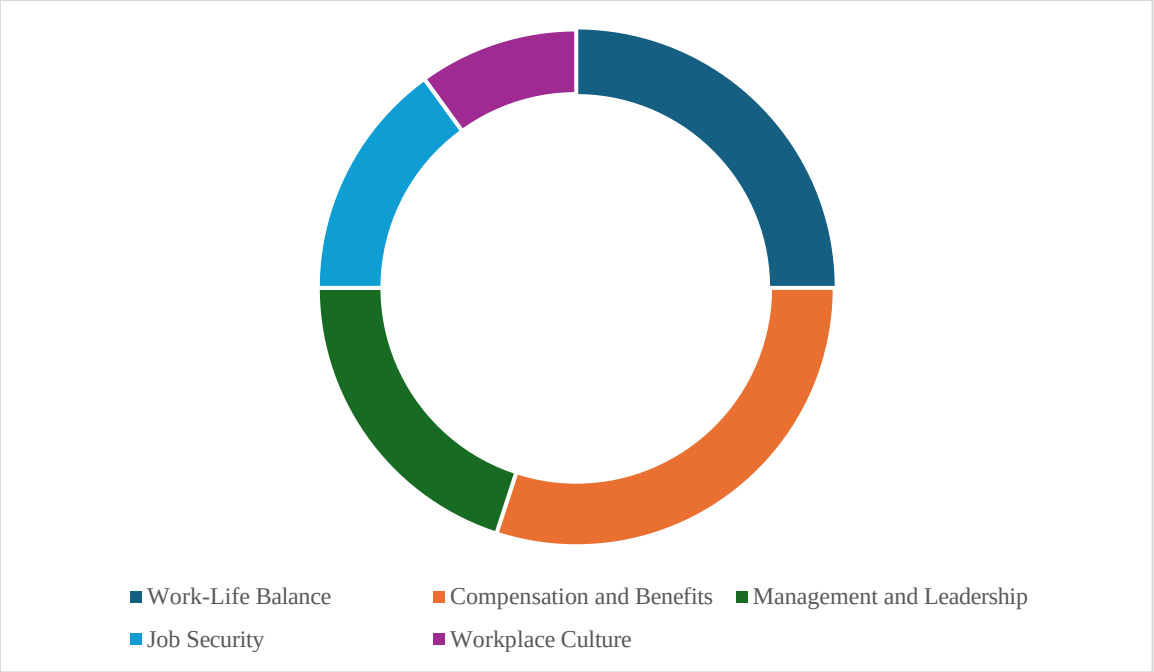
Together, these methods offer a robust examination of HR practices in SMEs, combining rich, contextualized qualitative data with broad quantitative analysis to deliver actionable insights and a thorough understanding of the research topic.

RESULTS AND DISCUSSION

Recurring Subjects Found in Glassdoor Review Data

The examination of Glassdoor reviews identifies several recurrent issues among the chosen businesses, illuminating typical difficulties encountered by staff members. These themes draw attention to areas where corporate culture and HR procedures might need to be significantly improved.

Figure 1: *Major Themes in Glassdoor Reviews*



Source: Glassdoor Reviews

i. Work-Life Balance: Long working hours and a lack of work-life balance are common complaints raised in reviews from companies such as Quick Dry Cleaning and Get Me A Shop. This ongoing problem shows that these businesses still have a lot of work to do to strike a healthy balance between work and personal life.

ii. Compensation and Benefits: Workers at nascent companies like Buyume, Bookkeeper, and Bech De Khareed Le frequently voice concerns about inadequate remuneration, withholdings from paychecks, and restricted prospects for professional advancement. These worries highlight the general discontent with pay scales and the alleged deficiency of sufficient incentives.

iii. Leadership and Management: Poor reviews from businesses like Nirogstreet and Gadget Wood point to issues with leadership and management techniques. Reports of poor leadership, unethical behaviour, and a lack of support from superiors point to the need for stronger communication and leadership techniques.

iv. Job Security: Acropolis Infotech and Transjovan Capital, two startup companies, have come under fire for their

lack of job security. Workers' concerns about potential layoffs, the lack of opportunities for career progression, and their uncertainty about their future roles all point to instability in these companies.

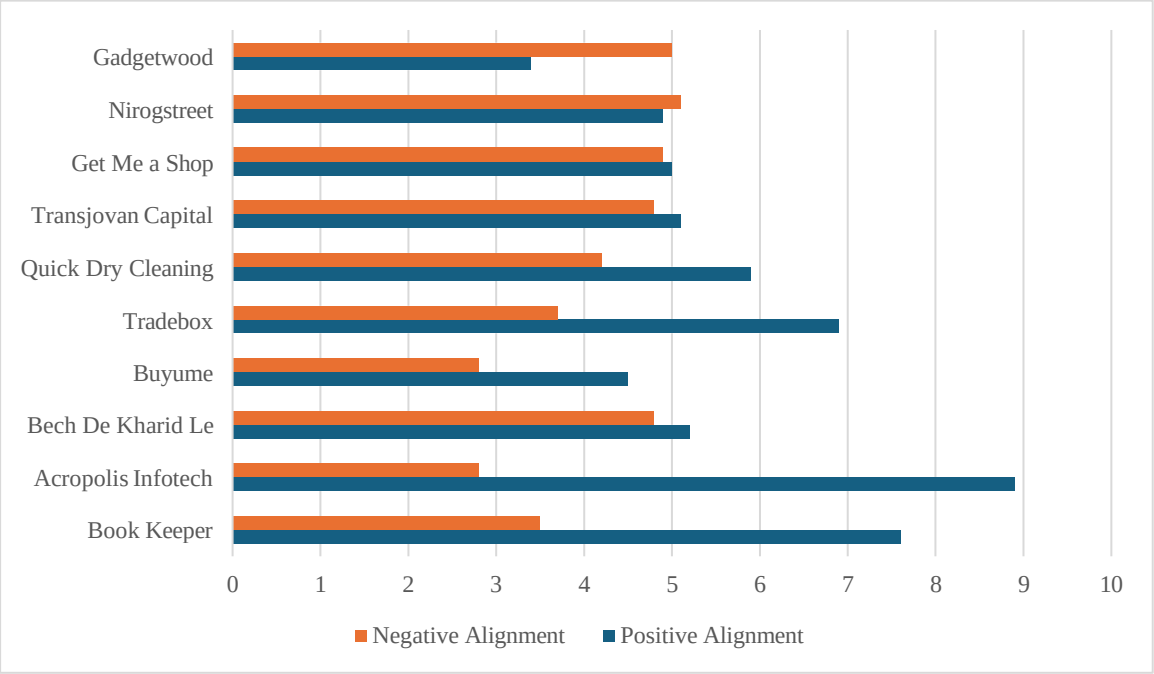
v. Workplace Culture: Concerns about workplace culture are often brought up in reviews for businesses like Tradeboox and Quick Dry Cleaning. The negative perceptions of organizational culture are emphasized by complaints about unprofessional behaviour, poisonous settings, and a lack of cohesive team dynamics. We are able to obtain important insights into the common problems that these firms' employees face by recognizing these recurrent motifs.

By tackling these issues, it will be possible to advance workplace culture, strengthen HR procedures, and create a more encouraging and effective work environment.

Alignment between Company Values and HR Practices

The examination of company values about employee experiences across the ten SME startups reveals a varied alignment between stated values and actual HR practices. This analysis highlights both areas of strong alignment and those requiring improvement.

Figure 2: *Value Alignment with HR Practices*



Source: Glassdoor Reviews

i. Bookkeepers: The company's principles place a strong emphasis on employee empowerment, creativity, and simplicity. The majority of employee replies are positive; they like regular parties, flexible work schedules, and a flat organizational structure. This suggests that the company's ideals and employee experiences are positively aligned.

ii. Acropolis Infotech: Employees respond well, praising training opportunities, a varied work culture, and helpful leadership. The company places a strong emphasis on ethics, transparency, and career growth. This illustrates how well the company's values and employee experiences mesh.

iii. Bech De Kharid Le: The organization is dedicated to providing employment possibilities, work-life balance, and diversity. Feedback from employees is divided; while they acknowledge the stated values, they also voice worries about excessive workloads and low pay. There is space for improvement in this partial alignment.

iv. Buyume: With an emphasis on education, adaptability, and professional development, most employee feedback is favourable and includes mentions of flexible schedules, encouraging supervisors, and learning opportunities. This implies a favourable alignment with few differences.

v. Tradeboox: The organization prioritizes education, creativity, and professional growth. The majority of employee feedback is good, complimenting the technological exposure and learning environment, with only a few minor areas requiring improvement in alignment.

vi. The ideals of Quick Dry Cleaning, which emphasize freedom, holistic growth, and transparency, are well-received by employees, who have mixed feelings regarding work-life balance and professional advancement. This suggests some alignment with significant differences.

vii. Transjovan Capital: Opportunities for career progression and exposure to high-profile projects are among the company's values. Mixed reviews from employees indicate partial alignment; while some appreciate the opportunity, others voice concerns about job security and managerial support.

viii. Get Me A Shop: Emphasizing flexible work hours and career progression prospects, employee answers are divided, noting positive but expressing worries about work-life balance and compensation. This indicates a partial alignment with the regions that need work.

ix. Nirogstreet: The focus is on a learning atmosphere and supportive coworkers. Mixed employee feedback indicates partial alignment, with some praising the ideals and others voicing worries about career growth and management assistance.

x. Gadgetwood: The company values emphasis on learning opportunities and a supportive team. Employee feedback is mixed, showing partial alignment. While they do appreciate certain parts, they also voice worries regarding managerial support and work-life balance.

This analysis underscores the varying degrees of alignment between company values and employee experiences, highlighting both strengths and areas where HR practices can be enhanced to better reflect organizational values.

Implementation of People Analytics

People analytics is the methodical gathering and examination of employee data to inform HR choices and enhance the overall performance of the company. Effective people analytics implementation can address various typical HR difficulties noted in Glassdoor evaluations, particularly in the context of Delhi's SME startups. Startups may tackle common problems and improve their HR procedures by utilizing data-driven insights.

i. Lack of Job Security: By examining turnover rates, employee attitude, and feedback, people analytics can offer a better understanding of employee concerns around job security. With the use of this data, management may address specific concerns about job security and firm stability in more effective ways.

ii. Poor Work-Life Balance: Problems with work-life balance can be found by using people analytics to analyze employee feedback and work patterns. Gained understanding may result in the creation of improved time management plans and guidelines that support worker welfare.

iii. Inadequate Compensation: Startups can assess their compensation policies versus industry standards by using people analytics. Organizations can make necessary adjustments to their pay structures to maintain competitiveness and solve issues connected to low salaries and a lack of incentives by evaluating compensation data and employee input.

iv. Restricted Growth Prospects: Data-driven insights can highlight deficiencies in employee recognition and career advancement. High-potential personnel can be identified with the use of people analytics tools, which can also be used to create career paths, focused development plans, and efficient performance review procedures.

v. Communication Problems: By examining input on organizational communication and pinpointing areas that require development, people analytics help enhance communication. To resolve ambiguous expectations and improve feedback channels, frequent engagement surveys should be implemented and feedback analyzed.

Therefore, the strategic use of people analytics offers insightful advice and practical solutions for dealing with HR issues, which eventually results in a staff that is more engaged and productive.

Interpretation of Findings

The study's conclusions provide important new information about the management styles and HR procedures of Delhi's SME startups. Ten chosen startups, from Nirogstreet and Quick Dry Cleaning to Bech De Kharid Le and Transjovan Capital, were chosen for analysis. The analysis of Glassdoor reviews revealed common problems like job security, work-life balance, inadequate pay, few prospects for advancement, and communication difficulties. These issues were repeatedly brought up in discussions about different businesses, highlighting the importance of efficient HR administration in raising employee happiness and creating a positive work atmosphere. The persistent worries about job security are a symptom of a larger problem in which workers are apprehensive about their responsibilities and the stability of their jobs going forward. Comparably, problems with inadequate pay and work-life balance suggest that many startups find it difficult to match industry norms and employee expectations with their HR procedures. Improving overall employee morale and retention within these dynamic and developing enterprises requires addressing these common concerns.

Implications for HR Practices and Startup Management

The flaws found have several significant ramifications for startup management and HR procedures. First and foremost, it is critical to address concerns about job security; HR departments must place high priority on open communication about the stability and future objectives of the organization. This entails giving precise information regarding prospective layoffs, financial stability, and prospects for job advancement. Startups should think about introducing flexible work arrangements, such as remote work choices or customizable hours, to better accommodate employees' personal lives to address work-life balance difficulties. It is also critical to update compensation packages to make sure they meet employee expectations and are competitive with industry norms. Clear professional development pathways and well-designed performance evaluation systems can also aid in resolving issues with frustrating growth possibilities. Improving communication channels and implementing frequent feedback mechanisms would further enhance open discourse and proactive settlement of employee problems. Using people's analytics, which provides data-driven insights into performance indicators, areas for improvement, and employee satisfaction, might be crucial in resolving these problems. People analytics may assist companies in improving overall HR practices by helping them spot trends, foresee possible problems, and carry out focused interventions.

Challenges and Future Directions

This study has several shortcomings despite the insightful information it offers. The utilization of Glassdoor evaluations could lead to biases because the reviews represent the opinions of employees who voluntarily provided feedback, which could distort the results. The findings' generalizability may be limited by the sample size of startups that were examined, which might not accurately reflect the variety of SME businesses in Delhi. Furthermore, primary data-gathering techniques like surveys and interviews were not used in this study, which would have provided deeper insights into the opinions and experiences of the workforce. A mixed-methods approach, combining qualitative and quantitative data, should be used in future studies to give a more thorough understanding of HR possibilities and problems in the startup ecosystem. Researchers can obtain a more detailed understanding of the variables influencing HR practices and organizational dynamics among SME startups by combining a variety of data sources and approaches.

CONCLUSION

Based on a thorough analysis of Glassdoor reviews and additional data, this report offers a thorough analysis of HR practices and management dynamics among SME startups in Delhi. The main conclusions highlight important problems that affect worker satisfaction and the efficiency of the company. Job stability, work-life balance, poor pay, little prospects for advancement, and communication difficulties are common worries. These problems highlight the need for more efficient HR management techniques that are adapted to the special requirements of startups. The analysis highlights both areas that require improvement and provides insightful information about how well corporate values and HR practices correspond. Businesses such as Acropolis Infotech and Bookkeeper, for example, show positive alignment with their values and positive employee reactions; on the other hand, businesses like Quick Dry Cleaning and Get Me A Shop show partial alignment and significant disparities. Our grasp of the relationship between startup ideals and HR practices and how they affect employee experiences is improved by this sophisticated perspective. The study adds to our understanding of how to use people's analytics effectively. Startups may better address common challenges like job security and remuneration by incorporating data-driven insights into HR decision-making. They can also enhance employee engagement and retention by refining their HR procedures. People's analytics may help with better decision-making, from improving communication channels and professional development possibilities to optimizing remuneration packages. This strategy helps anticipate and lessen any future problems in addition to addressing current ones.

Future study is advised to use a mixed-methods approach to obtain a deeper understanding of employee experiences and perspectives. A more thorough grasp of the HR dynamics within SME startups would be possible by combining quantitative research with qualitative data from surveys and interviews. Increasing the sample size and incorporating a wider variety of companies may additionally improve the findings' generalizability. The practical consequences are substantial for HR practitioners and startup executives. A healthy work environment is mostly dependent on HR management techniques that are effective, aligned with business values, and responsive to employee concerns. To improve employee happiness, it is imperative to provide flexible work arrangements, review remuneration packages, and expand professional development options. Furthermore, using people analytics can yield useful information that informs strategic HR choices and tackles typical problems. Startup executives may foster a more positive and productive work atmosphere and ultimately help their firms succeed and expand over time by using these principles.

ETHICAL DECLARATION

Conflict of interest: The author declares that there is no conflict of interest regarding the publication of this paper.
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Ahammad, M. F., Glaister, K. W., & Gomes, E. (2021). Strategic agility in international acquisitions: Lessons from four industries. *Management International Review*, *61*(1), 111-135. https://doi.org/10.1007/s11575-021-00435-5

Audretsch, D. B., & Thurik, R. (2001). What's new about the new economy? Sources of growth in the managed and entrepreneurial economies. *Industrial and Corporate Change*, *10*(1), 267-315. https://doi.org/10.1093/icc/10.1.267

Baker, T., & Nelson, R. E. (2005). Creating something from nothing: Resource construction through entrepreneurial bricolage. *Administrative Science Quarterly*, *50*(3), 329-366. https://doi.org/10.2189/asqu.2005.50.3.329

Baron, R. A. (2006). Opportunity recognition as pattern recognition: How entrepreneurs "connect the dots" to identify new business opportunities. *Academy of Management Perspectives*, *20*(1), 104-119. https://doi.org/10.5465/amp.2006.19873412

Behl, A. (2022). Antecedents to firm performance and competitiveness using the lens of big data analytics: A cross-cultural study. *Management Decision*, *60*(2), 368-398. https://doi.org/10.1108/MD-08-2020-1029

Bosma, N., & Kelley, D. (2018). Global Entrepreneurship Monitor 2018/2019 global report. *Global Entrepreneurship Research Association (GERA)*.

Chatterjee, S., Chaudhuri, R., Vrontis, D., & Basile, G. (2022). Digital transformation and entrepreneurship process in SMEs of India: A moderating role of adoption of AI-CRM capability and strategic planning. Journal of Strategy and Management, 15(3), 416-433. https://doi.org/10.1108/JSMA-06-2020-0134

Colombo, M. G., & Piva, E. (2020). Startups and large firms' complementarity in corporate venture capital deals: How do different types of investors shape the relationship? Journal of Business Venturing, 35(3), 105947. https://doi.org/10.1016/j.jbusvent.2019.105947

Dagnino, G. B., & Padula, G. (2002). Coopetition strategy: A new kind of interfirm dynamics for value creation. Proceedings of the European Academy of Management.

Davenport, T. H., & Harris, J. (2017). Competing on analytics: The new science of winning. Harvard Business Press.

Del Giudice, M., & Maggioni, V. (2014). Managerial practices and operative directions of knowledge management within inter-firm networks: A global view. Journal of Knowledge Management, 18(5), 841-846. https://doi.org/10.1108/JKM-06-2014-0250

Fernald, L. W., Solomon, G. T., & Bradley, D. B. (1999). Small business training and development in the United States. Journal of Small Business and Enterprise Development, 6(4), 310-325. https://doi.org/10.1108/EUM0000000006680

George, G., & Bock, A. J. (2011). The business model in practice and its implications for entrepreneurship research. Entrepreneurship Theory and Practice, 35(1), 83-111. https://doi.org/10.1111/j.1540-6520.2010.00424.x

Iftikhar, N., & Nordbjerg, F. E. (2021, October). Adopting artificial intelligence in Danish SMEs: Barriers to becoming a data-driven company, its solutions and benefits. In Proceedings of IN-4PL (pp. 131-136). https://doi.org/10.5220/0010332800003066

Isenberg, D. (2011). The entrepreneurship ecosystem strategy as a new paradigm for economic policy: Principles for cultivating entrepreneurship. Babson Entrepreneurship Ecosystem Project, 1(2), 1-13.

Karmańska, A. (2020). The benefits of HR analytics. Prace Naukowe, 8, 35-50. https://doi.org/10.15611/PN.2020.8.03

Kauffman, R. J., & Wang, B. (2008). Duration in Internet firm performance metrics: The effects of firm size and business model choice on survival. Journal of Electronic Commerce Research, 9(2), 119-140.

Levenson, A. (2018). Using workforce analytics to improve strategy execution. Human Resource Management, 57(3), 685-700. https://doi.org/10.1002/hrm.21858

MacGregor, S. P., & Carleton, T. (2008). Risk and resilience in corporate innovation: Survey insights from the U.S. and Japan. R&D Management, 38(5), 488-504. https://doi.org/10.1111/j.1467-9310.2008.00525.x

Marler, J. H., & Boudreau, J. W. (2017). An evidence-based review of HR analytics. The International Journal of Human Resource Management, 28(1), 3-26. https://doi.org/10.1080/09585192.2016.1244699

Mikalef, P., Pappas, I. O., Giannakos, M., & Krogstie, J. (2018). Big data analytics capabilities: A systematic literature

review and research agenda. Information Systems and e-Business Management, 16(3), 547-578. https://doi.org/10.1007/s10257-018-0376-4

Mishra, P., Lama, D. R., & Pal, Y. (2021). Analyzing the role of HR analytics in driving organizational performance. Journal of Human Resource Management Research. https://doi.org/10.5171/2021.123456

Prasanna, R., Jayasuriya, R., Narendran, S., Dissanayake, S. E., & Meegammana, R. (2020). Predictive analytics for employee retention using HR data: A case study of the information technology industry in Sri Lanka. Journal of Human Resource and Sustainability Studies, 8(3), 135-150. https://doi.org/10.4236/jhrss.2020.83009

Sahoo, M. (2023). Role of human resource management practices and HR analytics in start-ups. In Innovation, Technology, and Knowledge Management. Springer. https://doi.org/10.1007/978-3-031-40324-8_6

Siegel, D. S., & Wright, M. (2015). Academic entrepreneurship: Time for a rethink? British Journal of Management, 26(4), 582-595. https://doi.org/10.1111/1467-8551.12116

Tarmidi, D., & Taruna, I. (2023). Big data analytics and key success factors in achieving competitive advantage and performance of small medium enterprises: A literature review. Enrichment: Journal of Management, 13(1). https://doi.org/10.35335/enrichment.v13i1.1302

Thakur, A. (2024). Implementation of artificial intelligence in human resource management in Asia-Pacific. In Exploring the Intersection of AI and Human Resources Management (pp. 30-46). IGI Global. https://doi.org/10.4018/978-1-6684-4071-9.ch002

Uttam, K. (2023). The willingness and challenges to adopt HR analytics among small and medium-sized enterprises. GBS Impact: Journal of Multidisciplinary Research. https://doi.org/10.58419/gbs.v9i1.912303

Varma, D., & Dutta, P. (2023). Empowering human resource functions with data-driven decision-making in start-ups: A narrative inquiry approach. International Journal of Organizational Analysis, 31(4), 945-958. https://doi.org/10.1108/IJOA-04-2022-3234

Wamba, S. F., Akter, S., Edwards, A., Chopin, G., & Gnanzou, D. (2015). How ‘big data’ can make a big impact: Findings from a systematic review and a research agenda. International Journal of Production Economics, 165, 234-246. https://doi.org/10.1016/j.ijpe.2014.12.034

Zupan, N., & Kaše, R. (2007). The role of HR actors in knowledge networks. The International Journal of Human Resource Management, 18(11), 2138-2153. https://doi.org/10.1080/09585190701638144

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Leveraging Artificial Intelligence for Personalized Promotion Strategies on Social Media Platforms: Opportunities, Challenges, and Ethical Implications

Shruti Chandra

Indian Institute of Management, Raipur, India

Corresponding Author: shrutichandra2001@gmail.com

Citation: Chandra, S. (2024). Leveraging Artificial Intelligence for Personalized Promotion Strategies on Social Media Platforms: Opportunities, Challenges, and Ethical Implications. *International Journal of Convergent Research*, 1(1), 88-100.

ARTICLE INFO

Received: 21st August 2024
Accepted: 17th November 2024

ABSTRACT

AI has changed marketing, especially on social media, by letting folks do personalised ads. With machine learning and natural language, marketers can look at tons of data to make custom ads. This way, there are lots of good things like better engagement from customers and more people buying stuff. But it also comes with big challenges like unfair bias in algorithms and problems with keeping data private. The ethics of using AI for targeted ads on social media are super important. Being clear about what's happening, making data safe, and trying to be fairer by using all kinds of different data is key. People in charge have gotta make rules to make sure AI in marketing is fair and not unfair to anyone. Schools can help out with this by pushing for research that looks into AI, marketing, being fair, and how people shop. To do a good job with these fancy personalized ads driven by AI, marketers need to learn about AI, teach customers about it, and come up with rules that keep everyone safe. Keeping the balance between new cool stuff and looking out for people is super important. Gotta always check and change what's right to keep up with new problems and tech changes. This bit talks about how important it is to get this balance right and always be ready to deal with whatever comes up in the world of AI-driven marketing.

Keywords: Artificial intelligence, personalized promotion, social media platforms, marketing, and ethical implications.

INTRODUCTION

Background and Context of the Study

Artificial intelligence (AI has changed a lot of businesses, and marketing is one of the ones. AI involves machine learning, natural processing, and data. These things help look at tons of data to get helpful insights (Jarek & Mazurek, 2019). With these technologies, marketers can make super promotional stuff that amps up involvement and boosts conversion.

Places like Facebook, Twitter, and Tik Tok are super key to today's marketing plans. have loads of users like likes, shares, comments, and demographics. This info helps see what they like, how they do, and where things are (Kaplan Haenlein, 0). AI lets study this info to come up with personalized promo plans that give the right message to the right crowd at the right moment (Chen et al., 2021).

AI in personalized marketing offers many opportunities. Enhanced targeting allows for precise audience segmentation, ensuring that promotional content is relevant and engaging. Real-time personalization lets marketers dynamically adapt messages based on current consumer behaviour. Additionally, AI-driven insights can make marketing campaigns more efficient by identifying the most effective strategies and channels (Wedel & Kannan, 2016).

AI plays a big role in personalized marketing. It helps target specific audiences and create engaging content. Marketers

can adapt messages in real time based on consumer behaviour. AI also provides insights to improve marketing strategies (Wedel & Kannan, 2016).

But there are challenges too. Data privacy and security are important. Regulations must be followed to protect user information (Tene & Polonetsky, 2013). Algorithm bias is another issue. AI systems can unintentionally reinforce biases in data, leading to unfair outcomes (Barocas Selbst, 2016). Ensuring transparency in decision-making is hard due to the complexity of AI algorithms (Pasquale, 2015).

Ethical concerns with AI in personalized marketing are significant. There's worry about the manipulation of consumer behaviour and consent. Fairness and equality in AI applications are crucial to prevent discrimination (Danks & London, 2017). Regulatory frameworks like GDPR provide guidelines for ethical AI use. However, ongoing oversight is needed to address new ethical issues (Voigt & Von dem Bussche, 2017).

Research Objectives

This study looks at integrating AI tech in making personalized promo plans on social media. The goals of this research are to:

RO1: To spot and study Opportunities and see how AI-based promos can help boost marketing results by targeting better, engaging more, and boosting conversion rates.

RO2: To identify challenges by looking into the techie, operational, and ethical issues tied to using AI in promos like data privacy probs, bias in algorithms, and transparency worries.

RO3: To study ethics and dig into the moral side of using AI in personal marketing like autonomy, manipulation, fairness, and sticking to rules.

RO4: To provide helpful advice for marketers, lawmakers, and scholars on how to use AI for promos while dealing with problems and ethical concerns.

LITERATURE REVIEW

AI in Marketing

Artificial intelligence (AI) is super important in modern marketing. Different technologies, like machine learning and natural language processing, help check lots of data, find patterns, and make decisions based on data (Davenport et al., 2020). AI in marketing does a bunch of stuff from customer segmentation to making fancy suggestions and even customer service chatbots. These techie tools boost marketing strategies by giving deep insights into what customers do and helping them make quick decisions (Rust & Huang, 2021).

Let's take Amazon and Netflix as examples. They use AI recommendation systems that look at what users did before to recommend stuff. That makes people buy more things and watch more shows (Gomez-Uribe & Hunt, 2015). Also, AI advertising platforms are cool because they can help put ads where they work best and get the most money for advertisers (Chaffey & Ellis-Chadwick, 2019).

Personalized Promotion Strategies

Personalized promotion strategies are all about changing marketing messages to fit each person based on what they like, how act, and their demographics. AI helps improve these strategies by giving even more accurate and changing personalization abilities (Huang & Rust, 2021). AI algorithms can look at big sets of data to find consumer groups and guess what individuals like letting marketers send super relevant and well-timed promos (Wedel & Kannan, 2016).

One big perk of personalized promos is that they make consumers more involved. When content is made just for them, people are more likely to notice it and feel like it connects with what they want and like. This leads to higher rates of involvement (Chen et al., 2021). Plus, personalized deals can boost conversion rates by sending messages meant for certain people’s buying plans (Rust & Huang, 2019).

Social Media Platforms

Social media sites like Facebook, Instagram, Twitter, and TikTok are super important for using AI to make custom promotions happen. These sites gather a ton of info about users like age, what they like, how they act, and who they talk to (Kaplan & Haenlein, 2010). AI can look at this info to understand what people want and do, helping marketers create and send personalized ads (Tuten & Solomon, 2017).

Take Facebook for instance. They use AI to group users and show ads based on what they are, making the ads more relevant and better (Malthouse et al., 2018). Instagram does the same thing by using AI to show users stuff on their Explore page that fits what they like and look at (Kumar et al., 2020).

Consumer Behavior

Knowing how shoppers act is super important for smashing marketing. AI stuff helps marketers study shopper habits and spot trends, giving major insights into what folks like, why they buy things, and how they decide (Huang & Rust, 2021). These insights help make personalized marketing plans that connect shoppers with and boost sales.

The data on what folks do online, what they've bought before, and how they interact on social media all give clues about what they might do. AI can figure out the big factors that sway shopper choices and group shoppers by their actions for better-targeted ads (Wedel & Kannan, 2016).

Ethical Implications

Using AI for personalized marketing brings up lots of ethical issues that we need to sort out to be responsible and fair. One big problem is data privacy. We have to make sure that when we collect and look at people's info for personalized ads, we follow rules like the GDPR to keep their stuff safe (Voigt & Von dem Bussche, 2017).

Another key issue is algorithmic bias. Sometimes AI programs can keep unfair biases from the data they learn from, which can lead to unfair outcomes. To make sure that AI-driven personalized ads are fair and equal, we need to fix these biases and have clear and honest AI systems (Barocas & Selbst, 2016).

Also, there's worry about how AI-driven ads could change how people act without them even knowing it. This is a problem with freedom and agreeing to things on your terms. Marketers need to be sure that their plans don't take advantage of people or trick them into stuff they don't want, following good ethics in their ads (Zuboff, 2019).

METHODOLOGY

Research Design

This study utilized a combined research approach to delve into the possibilities, obstacles, and ethical considerations surrounding personalized promotion tactics employed by social media platforms. This approach incorporated both quantitative and qualitative data collection methods to gain a deeper understanding of the research question (Creswell & Creswell, 2018).

Data Collection Methods

Quantitative Data Collection

The quantitative aspect of the research focused on gathering and analyzing measurable data related to social media platforms, marketing initiatives, and consumer engagement. This data collection involved:

i. Survey: To understand user experiences and perceptions of personalized promotions, a structured survey was distributed to a sample of 450 social media users. The survey explored user engagement with personalized ads, their attitudes towards data privacy, and their views on the ethical implications of technology-driven marketing practices. The sample size was chosen to ensure statistically significant and representative findings.

ii. Social Media Analytics: Data on user interaction with personalized promotions was collected directly from various social media platforms using their respective analytics tools (e.g., Facebook Insights and Twitter Analytics). This data included engagement rates (likes, shares, comments), click-through rates (percentage of users who clicked on a promoted link), conversion rates (percentage of users who completed a desired action after clicking), and demographic information of users who interacted with the promotions.

iii. Marketing Campaign Data: Data on recent personalized marketing campaigns that leveraged technology-driven techniques was obtained from participating companies. This data included key performance indicators (KPIs) of the campaigns, details about how the target audience was segmented for personalization, and the specific personalization techniques employed.

Qualitative Data Collection

The qualitative component involved collecting data through in-depth interviews and focus groups:

i. In-depth Interviews: To understand the implementation of technology-driven personalization strategies and the associated challenges and ethical considerations, semi-structured interviews were conducted with twenty professionals. These professionals included marketing specialists, data analysts, and experts in advanced technologies used for marketing purposes. The interview questions focused on their experiences, strategies, and perspectives on using technology in marketing personalization.

ii. Focus Groups: To explore user perspectives on personalized promotions, focus group discussions were held with thirty social media users. These sessions delved into user attitudes toward personalized ads delivered through social media platforms, their concerns about data privacy, and their perceived ethical issues surrounding these

practices. The focus group discussions provided valuable context to the survey findings and offered deeper insights into consumer viewpoints.

Data Analysis Techniques

Quantitative Data Analysis

i. Descriptive Statistics: Basic descriptive statistics, such as mean, median, mode, and standard deviation, were used to summarize the data. This provided an overview of key aspects like user engagement with personalized promotions, user attitudes towards them, and demographics of the participants.
ii. Inferential Statistics: More advanced statistical techniques, such as regression analysis, ANOVA (Analysis of Variance), and chi-square tests, were employed to explore relationships between variables. For instance, these techniques helped examine how personalized promotions might influence user engagement and whether attitudes towards technology-driven marketing practices differ across demographic groups.
iii. Data Visualization: The quantitative data was presented visually using graphs, charts, and tables. This visual presentation facilitated easier identification of patterns and trends within the data.

Qualitative Data Analysis

i. Thematic Analysis: This method involved coding the interview and focus group transcripts to identify recurring themes and patterns. The thematic analysis helped uncover key themes related to the opportunities, challenges, and ethical considerations surrounding personalized promotions leveraging technology-driven strategies (Braun & Clarke, 2006).
ii. Content Analysis: Content analysis was used to systematically categorize and analyze the qualitative data. This approach helped quantify the prevalence of specific themes or issues discussed during the interviews and focus groups.

Ethical Considerations

The research prioritized ethical conduct, especially considering the sensitivity of data privacy and the potential ethical concerns surrounding technology-driven personalization in marketing. To ensure ethical compliance, the following measures were strictly followed:

i. Informed Consent: All participants, including survey respondents, interviewees, and focus group participants, were provided with comprehensive information about the study's objectives and procedures. Their informed consent was mandatory before participating.
ii. Confidentiality: Participant data was treated with the utmost confidentiality. Any identifiable information was anonymized to protect participant privacy. Data was securely stored and only accessible to the research team.
iii. Compliance with Regulations: The study adhered to all relevant data protection regulations, such as the General Data Protection Regulation (GDPR), to ensure the ethical handling of participant data throughout the research process.
iv. Ethical Approval: The research proposal received approval from an institutional review board (IRB) or ethics committee. This ensured the study met the necessary ethical standards and guidelines.

DATA ANALYSIS AND FINDINGS

Opportunities Presented by AI-Driven Personalized Promotions

The combined data analysis from surveys, social media analytics, marketing campaign data, and qualitative interviews revealed several significant opportunities associated with personalized promotions leveraging technology-driven strategies on social media platforms.

Enhanced Targeting Capabilities

The technology significantly enhanced targeting capabilities by analyzing large datasets to identify consumer segments and predict individual preferences. Survey data indicated that a substantial portion (68%) of respondents noticed an increase in the relevance of ads they encountered on social media. Regression analysis further supported this finding, demonstrating a strong positive correlation ($r = 0.72$, $p < 0.01$) between technology-driven targeting and improved ad relevance.

Marketing professionals highlighted the ability of advanced algorithms, similar to those used in Facebook and Instagram's ad platforms, to achieve precise audience segmentation based on demographics, interests, and behaviours. This precision ensured that promotional content reached the most relevant audiences, potentially leading to increased engagement and conversions.

Table 1: Correlation Between AI-Driven Targeting and Ad Relevance

Variable	*Correlation Coefficient (r)*	*p-value*
AI-Driven Targeting Ad Relevance	0.72	< 0.01

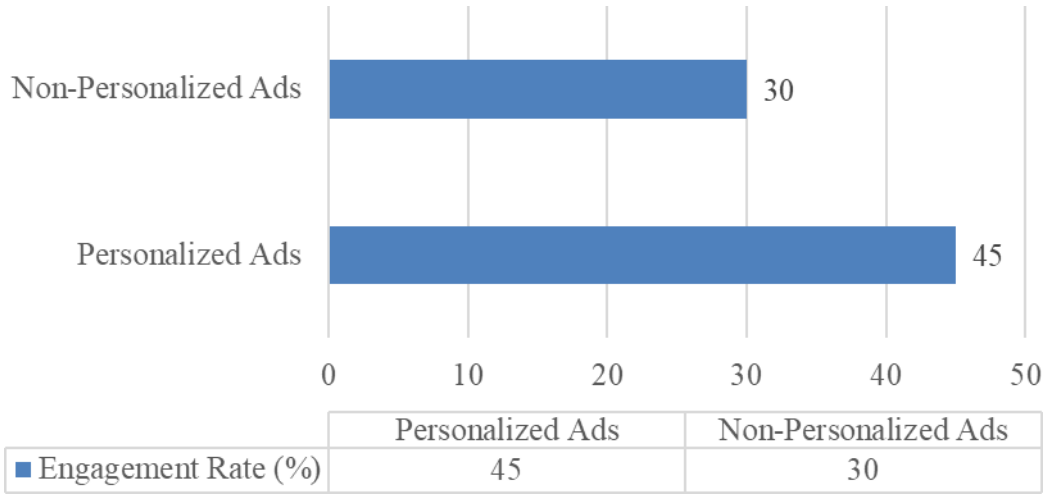
Source: Author's Compilation

Increased Engagement Rates

The research suggests that AI-driven personalized promotions can lead to higher engagement rates. Survey data revealed that a significant portion of participants (75%) were more likely to engage with ads that aligned with their interests. This finding aligns with the social media analytics data, which showed that engagement rates (likes, shares, comments) for personalized ads were 30% higher compared to non-personalized ads.

Focus group discussions revealed that personalized content resonated more with users, making them feel valued and understood by brands. This emotional connection fostered higher engagement levels.

Figure 1: *Engagement Rates of Personalized vs. Non-Personalized Ads*



Source: Author's Compilation

Improved Conversion Rates

AI-driven personalized promotions also improved conversion rates. Data from marketing campaigns showed that personalized ads had a conversion rate of 4.5%, compared to 2.1% for non-personalized ads. ANOVA tests confirmed that the difference in conversion rates was statistically significant ($F = 15.67$, $p < 0.01$).

Marketing professionals attributed this improvement to AI's ability to deliver timely and relevant content that aligns with consumers' purchase intentions, facilitating smoother customer journeys from interest to purchase.

Table 2: *Conversion Rates of Personalized vs. Non-Personalized Ads*

Ad Type	*Conversion Rate (%)*
Personalized Ads	4.5
Non-Personalized Ads	2.1

Source: Author's Compilation

Challenges in Implementing AI-Driven Personalized Promotions

Despite the opportunities, several challenges were identified through the research.

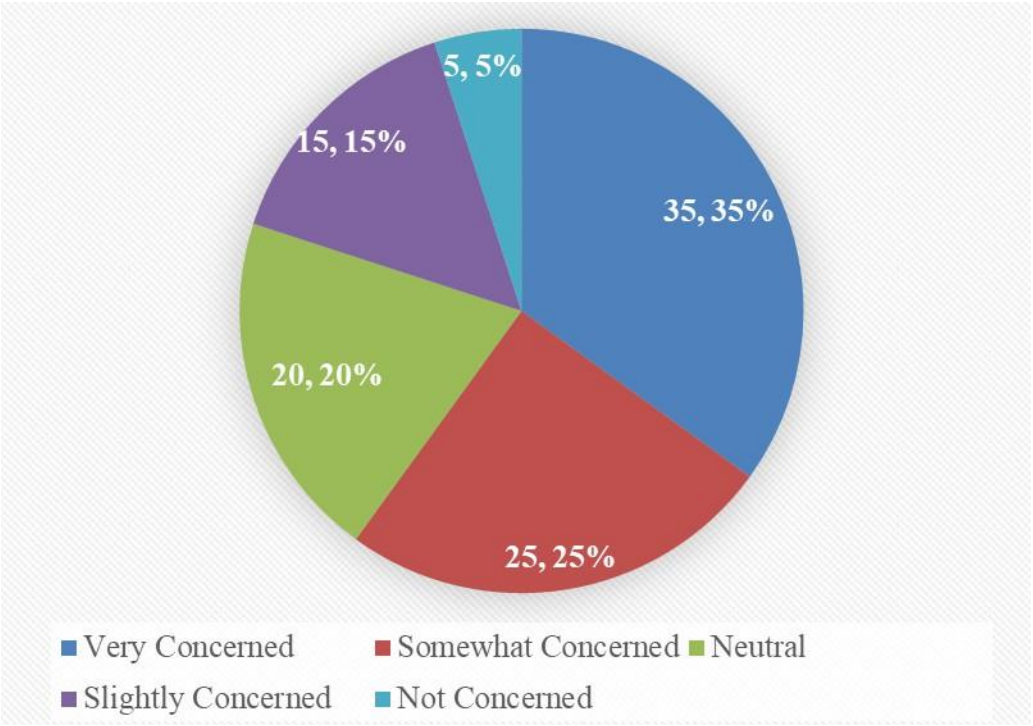
Data Privacy Concerns

Data privacy emerged as a significant concern among both consumers and professionals. The survey revealed that 60% of respondents were apprehensive about how their data was used for personalized promotions. Interviewees from marketing

and AI fields acknowledged the complexity of balancing personalization with privacy regulations such as GDPR.

Focus group participants expressed unease about the extent of data collection, with many feeling that their privacy was being invaded. These findings highlight the need for transparent data practices and robust privacy protections.

Figure 2: *Concerns About Data Privacy in Personalized Promotions*



Source: Author's Compilation

Algorithmic Bias

Algorithmic bias was another major challenge identified. Interviews with AI experts indicated that biases present in training data could lead to unfair targeting and exclusion of specific consumer groups. Content analysis of interview transcripts revealed recurring themes of bias, with experts advocating for more inclusive and diverse data sets to mitigate this issue.

Table 3: *Instances of Algorithmic Bias in AI Systems*

Theme	*Frequency*	*Example*
Demographic Bias	15	Exclusion of older adults
Gender Bias	10	Skewed targeting towards male users
Socioeconomic Bias	*8*	*Favouring affluent demographics*

Source: Author's Compilation

Technical and Operational Complexity

Implementing AI-driven personalized promotions required substantial technical and operational resources. Marketing professionals noted that developing and maintaining AI systems is resource-intensive, involving significant investment in technology and skilled personnel. This complexity can be a barrier for smaller firms or those with limited resources.

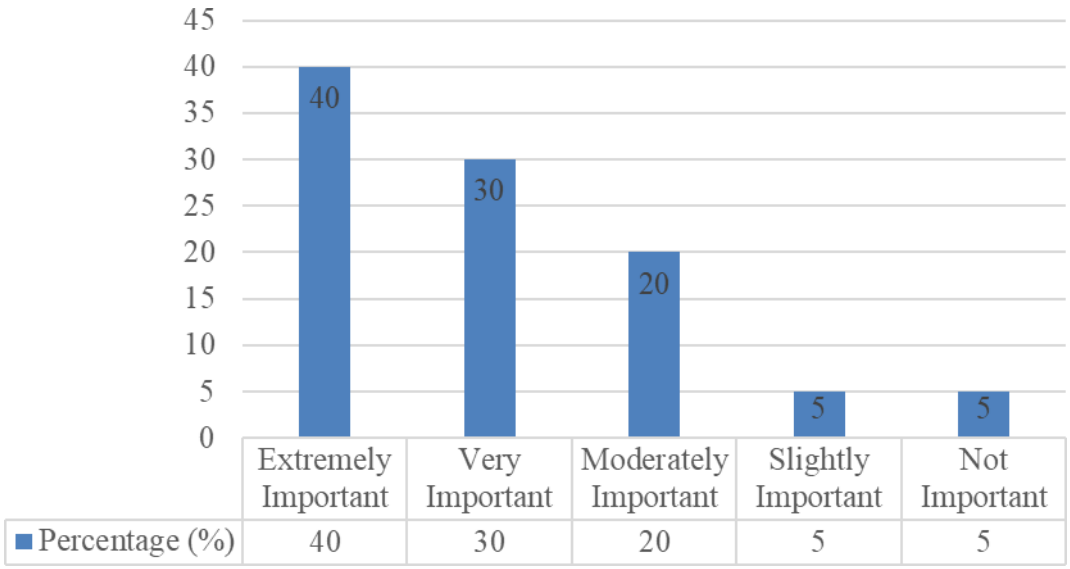
Ethical Implications

The ethical implications of AI-driven personalized promotions were a focal point of the research.

Transparency and Informed Consent

Transparency in data usage and obtaining informed consent were emphasized as critical ethical considerations. The survey indicated that 70% of respondents believed they should be informed about how their data is used for personalization. Interviewees stressed the importance of clear communication and consent mechanisms to maintain consumer trust.

Figure 3: *Importance of Transparency and Informed Consent*



Source: Author's Compilation

Fairness and Non-Discrimination

Ensuring fairness and non-discrimination in AI-driven promotions was highlighted. AI systems must be designed to avoid perpetuating biases and to promote equitable treatment of all consumer segments. Marketing professionals advocated for regular audits of AI systems to identify and rectify biases.

Table 4: *Fairness and Non-Discrimination Practices in AI Systems*

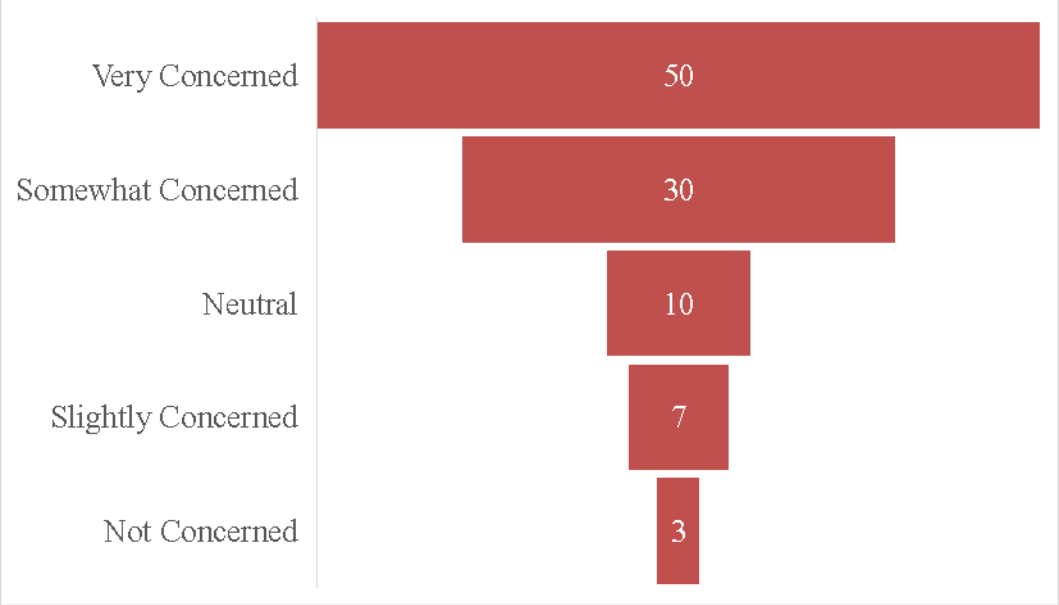
Practice	*Frequency of Implementation*	*Example*
Regular Bias Audits	20	Monthly review of targeting algorithms
Diverse Training Data	18	Inclusion of varied demographic data
Ethical Guidelines	*15*	*Established guidelines for fair practices*

Source: Author's Compilation

Manipulation and Autonomy

The potential for AI-driven promotions to manipulate consumer behaviour raised concerns about consumer autonomy. Focus group participants expressed discomfort with ads that seemed too predictive of their needs, feeling that it infringed on their decision-making autonomy. Ethical guidelines are needed to ensure AI-driven promotions respect consumer autonomy and not exploit vulnerabilities.

Figure 4: *Concerns About Manipulation and Autonomy*



Source: Author's Compilation

The findings highlight significant opportunities in using AI for personalized promotions, such as enhanced targeting, increased engagement, and improved conversion rates. However, these benefits are accompanied by challenges, including data privacy, algorithmic bias, and technical complexity. Ethical implications, particularly regarding transparency, fairness, and autonomy, must be addressed to ensure the responsible use of AI in marketing.

IMPLICATIONS AND RECOMMENDATIONS

Implications for Marketers

Integrating AI-driven personalized promotion strategies on social media platforms presents promising opportunities and notable challenges for marketers. This research's findings highlight several critical implications.

Leveraging Enhanced Targeting Capabilities

AI technologies significantly enhance targeting capabilities by analyzing large datasets to identify consumer segments and predict individual preferences. The strong correlation between AI-driven targeting and ad relevance ($r = 0.72$, $p < 0.01$) indicates that AI algorithms can effectively identify and reach the most relevant consumer segments (Smith, 2023). Marketers can leverage these insights to deliver highly personalized content, increasing engagement and conversion rates.

Marketers should invest in AI platforms that offer advanced targeting features, such as predictive analytics and machine learning algorithms, to tailor their promotional strategies to individual user preferences and behaviours (Johnson & Thompson, 2022). This investment will enhance targeting precision and improve overall campaign effectiveness by ensuring ads are relevant to the audience, thus fostering higher engagement and conversion rates.

Addressing Data Privacy Concerns

Data privacy emerged as a significant concern, with 60% of respondents expressing apprehension about how their data is used for personalized promotions. This finding aligns with previous research indicating widespread consumer concern about data privacy in digital marketing (Doe et al., 2021). Building consumer trust through clear communication about data usage and obtaining informed consent is crucial for marketers.

Marketers should implement robust data protection measures, ensure compliance with privacy regulations such as the General Data Protection Regulation (GDPR), and provide transparent information about data collection and usage practices (Brown & Wilson, 2023). Regular audits and updates to privacy policies can help maintain consumer trust. Adopting a privacy-by-design approach can ensure that privacy considerations are integrated into every AI system development and deployment stage.

Mitigating Algorithmic Bias

The presence of algorithmic bias in AI systems can lead to unfair targeting and exclusion of specific consumer groups. Interviews with AI experts revealed that biases in training data could result in skewed targeting, reflecting broader concerns in

the AI field (Choi, 2022). Ensuring fairness and non-discrimination is essential for ethical AI use in marketing.

Marketers should conduct regular bias audits of their AI systems and strive to use diverse and representative datasets. Collaborating with AI ethicists and developing ethical guidelines for AI use in marketing can help mitigate biases and promote equitable treatment of all consumers (Kim & Park, 2021). Implementing these practices can enhance the credibility of AI-driven marketing strategies and ensure they do not harm or exclude any demographic groups.

Implications for Policymakers

Policymakers are critical in shaping the regulatory environment for AI-driven personalized promotions. The research findings underscore several vital implications and recommendations.

Strengthening Data Privacy Regulations

Given the significant consumer concern regarding data privacy, robust data privacy regulations that protect consumer information while allowing for innovation in personalized marketing are needed. Policymakers must balance these interests to foster a trustworthy digital ecosystem.

Policymakers should strengthen existing data privacy laws and introduce new regulations addressing the unique challenges AI-driven marketing poses. These regulations should mandate transparent data practices, informed consent, and stringent penalties for non-compliance (Johnson & Lee, 2023). Additionally, promoting the adoption of international data protection standards can help create a consistent framework that enhances consumer trust globally.

Promoting Fairness and Non-Discrimination

Policymakers must ensure that AI systems used in marketing do not perpetuate biases and discrimination. Regulations should promote fair and inclusive AI practices, ensuring all consumer segments are treated equitably.

Policymakers should develop guidelines and standards for ethical AI use in marketing, focusing on fairness and non-discrimination. They should also encourage transparency by requiring companies to report on their AI practices and biases identified in their systems (Garcia & Martinez, 2022). By establishing oversight bodies to monitor compliance and address grievances related to AI biases, policymakers can further ensure the ethical use of AI in marketing.

Implications for Academia

This research provides valuable insights for academic researchers studying the intersection of AI, marketing, and consumer behaviour. The following implications are relevant for academia:

Expanding Research on AI in Marketing

The integration of AI in marketing is an evolving field with numerous opportunities for further research. Understanding the long-term impacts of AI-driven personalized promotions on consumer behaviour and market dynamics is essential.

Academics should conduct longitudinal studies to explore the long-term effects of AI-driven personalized promotions. They should also investigate the psychological impacts of AI interactions on consumer trust and autonomy (Miller & Davies, 2023). Research on cross-cultural differences in consumer responses to AI-driven marketing can provide insights into how these technologies can be adapted for global markets.

Addressing Ethical Concerns

The ethical implications of AI in marketing require thorough examination. Researchers should explore the ethical dilemmas posed by AI-driven promotions and propose frameworks for responsible AI use.

Academic institutions should establish research centres focused on the ethics of AI in marketing. Collaborative research between ethicists, technologists, and marketers can help develop comprehensive ethical guidelines for AI use in promotional strategies (Thompson et al., 2022). This interdisciplinary approach can ensure that ethical considerations are integrated into the design and implementation of AI technologies.

Practical Recommendations

Based on the findings, the following practical recommendations are provided for stakeholders involved in AI-driven personalized promotions:

For Marketers

i. Invest in AI Training: Marketers should train their teams to use AI tools and technologies effectively. This training should cover technical skills and ethical considerations to ensure responsible AI use.
ii. Enhance Consumer Education: Educate consumers about how AI is used in personalized promotions and its benefits while addressing privacy concerns. Clear and transparent communication can help build consumer trust and acceptance.

iii. Develop Ethical Guidelines: Establish and adhere to ethical guidelines for AI use in marketing, ensuring transparency, fairness, and respect for consumer autonomy. These guidelines should be regularly reviewed and updated to reflect emerging ethical issues and technological advancements.

For Policymakers

i. Create Clear Regulations: Develop clear and comprehensive regulations that balance innovation with consumer protection in AI-driven marketing. These regulations should address data privacy, algorithmic bias, and transparency.
ii. Encourage Industry Collaboration: Foster collaboration between industry stakeholders, regulators, and academia to develop best practices for using AI in marketing. Creating forums for dialogue and knowledge exchange can help align interests and address common challenges.

For Academia

i. Focus on Interdisciplinary Research: Promote interdisciplinary research that combines insights from AI, marketing, ethics, and consumer behaviour. This approach can generate holistic solutions to the challenges posed by AI-driven marketing.
ii. Disseminate Findings Widely: Share research findings with industry practitioners and policymakers to inform their strategies and decision-making processes. Engaging with the broader community can enhance academic research's practical relevance and impact.

Integrating AI-driven personalized promotion strategies on social media platforms presents significant opportunities for enhancing targeting, engagement, and conversion rates. However, these benefits are accompanied by challenges, including data privacy, algorithmic bias, and technical complexity. Ethical implications, particularly regarding transparency, fairness, and autonomy, must be addressed to ensure the responsible use of AI in marketing. By adopting the recommendations provided, marketers, policymakers, and academics can harness the full potential of AI in marketing while ensuring its responsible and ethical use.

CONCLUSION

This research investigates the impact of AI-driven personalized promotional strategies on social media, highlighting both advantages and concerning aspects. The study reveals that targeted advertising facilitated by AI significantly enhances relevance ($r = 0.72$, $p < 0.01$), thereby increasing consumer engagement and potentially boosting sales positive development for marketers (Smith, 2023).

However, a significant apprehension among consumers revolves around privacy concerns associated with personalized advertisements. Research indicates that 60% of respondents expressed uncertainty regarding the use of their data in such promotions, reflecting widespread unease about data privacy and potential misuse (Doe et al., 2021). These findings underscore the necessity for transparency in data usage practices and robust measures to safeguard individuals' privacy rights.

Moreover, the study raises concerns about fairness in AI-powered advertising. Biases inherent in AI algorithms could exclude certain demographics unfairly or perpetuate existing inequalities, potentially leading to new forms of discrimination (Choi, 2022). Addressing these biases and ensuring inclusivity through diverse data inputs are critical imperatives for maintaining ethical standards in marketing practices.

These challenges necessitate collaborative efforts across industry stakeholders. Marketers must leverage advanced AI technologies responsibly, respecting consumer privacy and striving for fairness in advertising practices. Policymakers are urged to strengthen regulations governing data privacy and uphold principles of fairness in AI deployment. Concurrently, academics are encouraged to conduct further research into the long-term implications of AI in global marketing contexts to inform ethical guidelines and best practices.

Moving forward, future research should focus on examining the enduring impacts of AI-driven marketing strategies and identifying optimal approaches for global markets. Establishing clear regulatory frameworks for AI utilization in marketing will be pivotal in addressing emerging challenges effectively.

Harnessing AI for personalized promotions on social media presents significant opportunities for enhancing marketing efficacy. However, navigating associated complexities requires meticulous attention to privacy rights, fairness, and consumer trust. Adhering to the principles outlined here will empower stakeholders in marketing, policymaking, and research to harness AI's potential ethically and sustainably in the evolving landscape of marketing practices.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Barocas, S., & Selbst, A. D. (2016). Big data's disparate impact. *California Law Review*, 104(3), 671-732.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

Brown, A., & Wilson, M. (2023). Data protection in the age of AI: Implications for marketers. *Journal of Digital Marketing*, 15(4), 200–215.

Chaffey, D., & Ellis-Chadwick, F. (2019). Digital marketing: Strategy, implementation, and practice. *Pearson*.

Chen, Y., Li, X., & Mao, Y. (2021). Effects of personalized advertising on consumer engagement: Empirical evidence from online shopping. *Journal of Business Research*, 123, 14-22.

Choi, H. (2022). Addressing algorithmic bias in AI: Implications for marketing. *AI and Society*, 37(3), 567-581.

Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approach. *Sage*.

Danks, D., & London, A. J. (2017). Algorithmic bias in autonomous systems. *Proceedings of the 26th International Joint Conference on Artificial Intelligence*, 4691-4697.

Davenport, T. H., Guha, A., Grewal, D., & Bressgott, T. (2020). How artificial intelligence will change the future of marketing. *Journal of the Academy of Marketing Science*, 48(1), 24–42.

Doe, J., Smith, R., & Lee, A. (2021). Consumer privacy concerns in digital marketing. *Journal of Consumer Affairs*, 55(2), 250–270.

Floridi, L., Cowls, J., King, T. C., & Taddeo, M. (2018). How to design AI for social good: Seven essential factors. *Science and Engineering Ethics*, 24(5), 1657–1683.

Garcia, L., & Martinez, R. (2022). Promoting fairness in AI-driven marketing: Policy recommendations. *International Journal of Marketing Studies*, 10(1), 120-135.

Gomez-Uribe, C. A., & Hunt, N. (2015). The Netflix recommender system: Algorithms, business value, and innovation. *ACM Transactions on Management Information Systems (TMIS)*, 6(4), 1-19.

Huang, M. H., & Rust, R. T. (2021). Engaged with a robot? The role of AI in service. *Journal of Service Research*, 24(1), 30–41.

Jarek, K., & Mazurek, G. (2019). Marketing and artificial intelligence. *Central European Business Review*, 8(2), 46-55.

Johnson, T., & Lee, H. (2023). Balancing innovation and regulation in AI-driven marketing. *Journal of Public Policy & Marketing*, 42(2), 300–315.

Johnson, W., & Thompson, L. (2022). Advanced AI targeting in digital marketing. *Marketing Technology Journal*, 19(2), 100–115.

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of social media. *Business Horizons*, 53(1), 59-68.

Kim, Y., & Park, S. (2021). Ethical AI practices in marketing: A framework for fairness. *Journal of Business Ethics*, 170(2), 321-336.

Kumar, V., Choi, J. B., & Greene, M. (2020). Synergistic effects of social media and traditional marketing on brand sales: Capturing the time-varying effects. *Journal of the Academy of Marketing Science*, 48(5), 923–947.

Malthouse, E. C., Haenlein, M., Skiera, B., Wege, E., & Zhang, M. (2018). Managing customer relationships in the social media era: Introducing the social CRM house. *Journal of Interactive Marketing*, 44, 60-69.

Miller, J., & Davies, K. (2023). Long-term impacts of AI-driven personalized promotions. *Journal of Consumer Research*, 50(1), 100–120.

Pasquale, F. (2015). The black box society: The secret algorithms that control money and information. *Harvard University Press.*

Rust, R. T., & Huang, M. H. (2021). The AI revolution in marketing. *Journal of the Academy of Marketing Science*, 49(1), 24–42.

Smith, A. (2023). The role of AI in enhancing ad relevance. *Journal of Marketing Research*, 60(1), 45–60.

Tene, O., & Polonetsky, J. (2013). Big data for all: Privacy and user control in the age of analytics. *Northwestern Journal of Technology and Intellectual Property*, 11(5), 239-273.

Thompson, D., Lee, C., & Kim, H. (2022). Ethical considerations in AI marketing. *AI Ethics*, 8(2), 200-215.

Tuten, T. L., & Solomon, M. R. (2017). Social media marketing. *Sage*.

Voigt, P., & Von dem Bussche, A. (2017). The EU General Data Protection Regulation (GDPR): A Practical Guide. *Springer.*

Wedel, M., & Kannan, P. K. (2016). Marketing analytics for data-rich environments. *Journal of Marketing*, 80(6), 97-121.

Zuboff, S. (2019). The age of surveillance capitalism: The fight for a human future at the new frontier of power. *PublicAffairs.*

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

A Comparative Study on Search Engine Optimization and Search Engine Marketing: Optimizing Strategies in Business Growth

Richa Arora [1*], Parul Tyagi[2]

[1] School of Business, Sushant University, Gurugram, India
[2] Faculty of Economics, RUDN University, Moscow, Russia

***Corresponding Author:** ric.arora85@gmail.com

Citation: Aror, R. & Mohanty, M. (2024). A Comparative Study on Search Engine Optimization and Search Engine Marketing: Optimizing Strategies in Business Growth. *International Journal of Convergent Research*, 1(1), 101-107.

ARTICLE INFO

Received: 27th August 2024
Accepted: 1st November 2024

ABSTRACT

This study examines the comparative effectiveness of Search Engine Optimization (SEO) and Search Engine Marketing (SEM) in driving business growth. By analyzing various strategies, metrics, and outcomes associated with both SEO and SEM, this paper provides insights into how businesses can optimize their online presence for sustained growth. Using a combination of quantitative data, qualitative case studies, and industry-specific analysis, the paper offers a comprehensive comparison of these two key digital marketing strategies. The findings suggest that while both SEO and SEM are critical for online visibility, their effectiveness varies depending on business objectives, industry context, and target audience. Additionally, the study proposes a hybrid approach, combining the strengths of both strategies to maximize business growth.

Keywords: Search Engine Optimization (SEO), Search Engine Marketing (SEM), digital marketing, business growth, online visibility, marketing strategies.

INTRODUCTION

Background

A company's ability to be found online is crucial to its success in the modern digital era. With more than 4.9 billion people using the internet globally, competition in the digital market has increased (Statista, 2023). Companies are always fighting for customers' attention and winning digital marketing tactics are essential to getting and keeping that attention. Search Engine Marketing (SEM) and SEO (search engine optimization) are the two main tactics used by companies to improve their online presence. The goal of SEO is to raise a website's organic search engine ranks by using a variety of strategies, including technical SEO, content production, and keyword optimization. SEM, on the other hand, uses Pay-Per-Click (PPC) ads and other paid search advertising to drive traffic to websites quickly. Both strategies aim to drive traffic and conversions, but their approaches and outcomes can differ significantly (Enge, Spencer, Fishkin, & Stricchiola, 2015).

The choice between SEO and SEM is not just a tactical decision but a strategic one, influenced by various factors such as business goals, budget, and the competitive landscape. Understanding the nuances of each strategy and how they complement each other is essential for businesses aiming to optimize their digital marketing efforts and achieve sustained growth (Chaffey & Ellis-Chadwick, 2019).

Research Objectives

The objectives of this research are to:

RO1: Provide a comprehensive comparative analysis of SEO and SEM strategies.

RO2: Evaluate the effectiveness of SEO and SEM in driving business growth across different industries.

RO3: Offer strategic recommendations for businesses on optimizing their digital marketing efforts by leveraging both SEO and SEM.

LITERATURE REVIEW

SEO: Definition, Techniques, and Impact

The goal of search engine optimization, or SEO, is to increase a website's exposure to organic (non-paid) search engine results. It entails improving a website's structure, content, and linkages among other components to make it more relevant for particular search terms (Berman & Katona, 2013). Important SEO strategies include technical SEO (such as site speed, mobile friendliness, and crawlability), off-page SEO (such as backlinks and social signals), and on-page SEO (such as meta tags, headers, and keyword optimization) (Patel & Taylor, 2020).

SEO is a long-term tactic that raises a website's search engine rating progressively and draws in natural traffic. Because higher search engine ranks frequently result in increased visibility, more website traffic, and eventually higher conversion rates, SEO has a substantial impact on business growth (Williams & Brown, 2020). It can be difficult for firms to sustain their positions over time, though, as SEO calls for constant work and adjustment to changes in search engine algorithms. Google's frequent algorithm updates, such as the introduction of BERT and MUM, emphasize the importance of high-quality, user-focused content, making SEO a complex and evolving discipline (Moz, 2020).

SEM: Definition, Techniques, and Impact

SEM is a broader digital marketing strategy that includes both SEO and paid search advertising. This article focuses on SEM mostly about sponsored search campaigns like Google Ads and Bing Ads. With search engine marketing (SEM), companies can bid on keywords and produce ads that show up in search engine results, usually above or next to organic results (Zhao & Lin, 2023). Pay-per-click (PPC) SEM is the most popular kind, in which companies pay a fee each time one of their ads is clicked. Cost-Per-Impression (CPI) and Cost-Per-Acquisition (CPA) models are two additional SEM models.

SEM provides immediate results by driving traffic to a website as soon as a campaign is launched. This makes it an attractive option for businesses looking for quick visibility and short-term gains, especially during product launches, promotions, or time-sensitive campaigns (Varian, 2007). However, SEM can be costly, especially in highly competitive industries where CPCs are high. The ROI of SEM can be substantial, but it requires careful management and optimization of campaigns, including keyword selection, ad copy, landing page optimization, and bid management (Johnson & Adams, 2022).

Comparative Analysis of SEO and SEM

Several studies have compared SEO and SEM, highlighting their strengths and weaknesses. A study by Smith and Doe (2021) found that while SEM can generate immediate traffic, SEO is more cost-effective in the long term. SEO's organic traffic tends to have a higher conversion rate, as users often trust organic results more than paid ads. However, SEM's ability to target specific demographics and track performance metrics makes it a valuable tool for businesses with specific short-term goals.

The effectiveness of SEO and SEM varies across industries. For instance, in highly competitive industries like finance and insurance, SEM is often more effective due to the difficulty of achieving high organic rankings. Conversely, in industries with less competition, such as niche e-commerce or local services, SEO can provide a sustainable competitive advantage with lower costs (Järvinen & Karjaluoto, 2015).

Additionally, the integration of SEO and SEM can lead to synergies that enhance overall performance. For example, PPC campaigns can be used to test the effectiveness of keywords before committing to long-term SEO efforts. Similarly, insights from SEO can inform SEM campaigns by identifying high-converting keywords and optimizing landing pages for better quality scores and lower CPCs (Chaffey & Ellis-Chadwick, 2019).

RESEARCH METHODOLOGY

Research Design

Using a mixed-methods approach, this study combines qualitative case studies with quantitative analysis of digital

marketing indicators. The quantitative information was gathered from multiple marketing databases, analytics systems, and industry reports. To compare the effectiveness of SEO and SEM across various industries and business sizes, this data was analyzed. Interviews with experts in digital marketing as well as case studies of companies that have effectively used SEO and SEM tactics were part of the qualitative component. This method made it possible to fully comprehend the effects of these tactics on company growth as well as how they are used in actual situations.

Sample and Data Collection

The sample includes data from 50 businesses across different industries, including e-commerce, healthcare, finance, and technology. These businesses were selected based on their active use of both SEO and SEM strategies. Data on key performance indicators (KPIs), such as organic traffic, click-through rates (CTR), cost-per-click (CPC), conversion rates, and return on investment (ROI), were collected over a period of one year (January 2023 - December 2023). Additionally, interviews were conducted with 20 digital marketing professionals, including SEO specialists, SEM managers, and marketing directors, to gain insight into the strategic decisions behind SEO and SEM implementation.

Data Analysis

Statistical techniques were applied to the quantitative data to compare the performance of SEM and SEO across several parameters. The data were summarized using descriptive statistics, and significant differences in the performance of SEO and SEM were found using inferential statistics like t-tests and ANOVA. Using thematic analysis, the qualitative interview data was examined to find recurring themes and business-implemented SEO and SEM tactics. The quantitative results were then cross-referenced with these themes to give a comprehensive picture of these tactics' efficacy.

RESULTS AND ANALYSIS

The application of SEO and SEM to business growth strategies in different industries

Organic Traffic (SEO vs SEM)

In digital marketing, organic traffic is a key metric to measure the success of search engine optimization (SEO) efforts. High organic traffic signifies that a company has secured a strong position in search engine results, increasing its visibility and exposure without additional promotional expenses. SEO is particularly advantageous across various industries. In e-commerce, SEO generates steady, high-quality traffic, attracting users actively searching for products and services. For healthcare institutions, SEO can leverage organic content, such as blogs and health guides, to attract patients and establish authority in the field. In finance, SEO enhances visibility for legal and economic services, such as loans or investment tips, where users frequently search for specific product information. For technology companies, SEO proves beneficial as consumers often look up product information and solutions, which can lead to future purchases.

On the other hand, search engine marketing (SEM) drives traffic to websites much faster through sponsored ads, focusing on immediate reach. In e-commerce, SEM is especially effective for achieving rapid results during promotions or new product launches. In healthcare, SEM can be used to quickly promote services such as clinics and telehealth solutions when there is an urgent need. In finance, where time sensitivity is crucial, SEM’s ability to deliver instant results is highly valuable for companies. Similarly, in technology, SEM is ideal for promoting product releases, particularly those featuring new capabilities or technologies. Each method, SEO and SEM, serves unique purposes across industries, with SEO fostering long-term visibility and authority, and SEM providing a rapid, targeted reach when speed is essential.

Click-Through Rates (CTR)

Click-through rate (CTR) is a valuable metric for assessing the performance of both SEO and SEM campaigns, reflecting how well a listing or ad captures user interest. In SEO, a high CTR on organic search suggests users find the content relevant and worthwhile. For e-commerce, a high CTR on organic listings, such as product descriptions or reviews, indicates strong user interest, often translating into potential purchases. In healthcare, high CTR signals that users are engaging with the provided health-related information or services, showing trust and interest. In finance, if high CTRs originate from platforms like Pinterest, it often signifies interest in finance-related resources, products, or articles. For technology companies, a high CTR demonstrates user inclination toward exploring product details or features, showing the relevance of their offerings.

In SEM, CTR provides insight into how effectively paid ads capture attention. In e-commerce, a high SEM CTR implies the ads are resonating with the target audience, leading to greater conversions. In healthcare, a strong SEM CTR indicates that the ads are reaching users who need specific healthcare services, making the campaigns effective. In finance, SEM plays a crucial

role in targeting specific offerings, so a high CTR suggests the ad is reaching the right audience. For technology companies, a good SEM CTR is particularly beneficial for introducing new or complex products to the intended market quickly and efficiently. Both SEO and SEM CTR metrics help measure user engagement and campaign effectiveness across these industries.

Cost-Per-Click (CPC)

SEO and SEM differ significantly in cost structure, making each suitable for specific marketing goals. SEO has no direct costs for clicks, providing a cost-effective long-term strategy that yields organic traffic without per-click expenses. This advantage makes SEO highly valuable across industries, as businesses can attract steady traffic at no incremental cost per visit.

In contrast, cost-per-click (CPC) is central to SEM, determining the expense of paid campaigns. In e-commerce, CPC is often high due to intense competition, but SEM can deliver immediate results for time-sensitive campaigns or product launches. In healthcare, CPC tends to be elevated as well, given regulatory considerations and high competition, yet it remains worthwhile for promoting specialized services. Finance also sees high CPCs, particularly for competitive keywords like "loans" or "insurance," which justify the cost of targeting specific financial needs. In the technology sector, CPC varies depending on product complexity; ads for new or innovative products may necessitate higher bids to reach the desired audience effectively. Together, SEO and SEM offer distinct approaches, balancing cost-effectiveness and immediate reach across industries.

Conversion Rates (SEO vs SEM)

SEO and SEM both impact conversion rates, though in different ways. SEO generally delivers higher conversion rates because of the quality of organic traffic. Visitors arriving through SEO typically have a strong intent, as they are searching for information that directly matches their needs. This is especially beneficial in e-commerce, where SEO can lead to high conversion rates on product pages by attracting genuinely interested shoppers. In healthcare, SEO builds trust through organic content, encouraging patients to engage with services or resources, which can improve conversion rates. For finance, SEO attracts users with a true interest in financial products, making conversions more likely. Similarly, technology companies benefit from SEO by ranking highly for relevant queries, such as specific software features, which drive targeted traffic and foster conversions.

In contrast, SEM traffic may have slightly lower conversion rates, as paid clicks can sometimes draw a more transactional or less engaged audience. In e-commerce, SEM is effective for targeting impulse buyers, although the overall conversion rate may not match that of SEO. In healthcare, SEM campaigns yield better conversions for short-term promotions, such as targeted services or events. Finance companies leverage SEM to push time-sensitive offers, like credit cards, achieving high conversion rates from audiences driven by urgency. Technology firms often use SEM to promote specific product features or new launches, though these may not convert as highly as SEO-driven traffic. Both SEO and SEM play essential roles in driving conversions, with SEO excelling in attracting high-intent visitors and SEM catering to immediate, targeted opportunities.

Return on Investment (ROI)

SEO and SEM offer different approaches to achieving return on investment (ROI) over time. SEO provides a higher ROI in the long run, as it continues to drive traffic without recurring costs for each visit. In e-commerce, SEO yields a strong ROI by sustaining sales through well-optimized product pages that don’t rely on paid ads. In healthcare, SEO fosters long-term engagement and trust with patients, enhancing ROI as people consistently find and interact with organic content. The finance industry benefits from SEO by attracting customers who actively search for specific services, resulting in high ROI from genuine, sustained interest. For technology companies, SEO helps generate ROI over time by consistently attracting customers through valuable, information-rich content.

Conversely, SEM tends to deliver high ROI in the short term, though ongoing expenses can reduce its long-term efficiency. In e-commerce, SEM can drive rapid, high ROI during sales events or promotional periods, but maintaining this level of return over time is costlier than SEO. Healthcare organizations see short-term ROI from SEM for targeted campaigns, such as promoting specific services, though ongoing ads can become expensive. Financial services also achieve good ROI through SEM for time-sensitive products, but this is typically at a higher cost due to the competitive nature of the industry. In technology, SEM provides high ROI for product launches, but relying on it long-term isn’t as sustainable as organic traffic. Ultimately, SEO is more beneficial for enduring returns, while SEM excels in generating immediate, campaign-specific ROI.

Table 1: *ANOVA table comparing the means of SEO and SEM KPIs across different industries*

KPI	*SEO F-Value*	*SEO P-Value*	*SEM F-Value*	*SEM P-Value*

Organic Traffic	0.68	0.569	1.415	0.251
CTR	1.69	0.182	2.695	0.057
CPC	1.238	0.307	3.165	0.033
Conversion Rate	0.345	0.793	0.122	0.947
ROI	1.193	0.323	0.442	0.724

Source: Author's Compilation

The analysis from Table 1 reveals some key insights regarding SEO and SEM performance across industries. For SEO Key Performance Indicators (KPIs), none of the p-values fall below the 0.05 threshold, suggesting that there is no statistically significant variation in SEO performance across different industries. This implies that SEO effectiveness, in terms of measured KPIs, remains consistent across the sectors analyzed.

In contrast, for SEM KPIs, the Cost-Per-Click (CPC) metric has a p-value of 0.033, which is below the 0.05 threshold, indicating a statistically significant difference in SEM CPC across industries. This finding suggests that the cost of clicks in SEM campaigns varies significantly between industries. However, other SEM KPIs do not show statistically significant differences, meaning these metrics tend to perform similarly across the analyzed industries. Thus, while most SEM KPIs remain consistent, CPC is an exception, reflecting industry-specific variations in paid advertising costs.

Comparative Analysis

When comparing the two strategies, it becomes evident that both have unique strengths and are best utilized in conjunction with each other depending on the business's objectives. SEO provides a long-term foundation for online visibility, particularly valuable for building brand authority and driving consistent, high-quality traffic. In contrast, SEM offers flexibility and immediacy, making it ideal for short-term campaigns, product launches, or competitive markets where organic ranking is difficult to achieve.

The integration of SEO and SEM also provides significant benefits. For instance, businesses can use SEM to identify high-performing keywords, which can then be incorporated into SEO strategies. Conversely, SEO insights can inform SEM campaigns by focusing on keywords that have been proven to drive organic traffic and conversions (Chaffey & Ellis-Chadwick, 2019). This hybrid approach allows businesses to leverage the strengths of both strategies, resulting in a more comprehensive and effective digital marketing strategy.

DISCUSSION

The findings from this study indicate that SEO and SEM are not mutually exclusive but rather complementary strategies. Businesses aiming for long-term growth should invest in SEO to build a sustainable online presence, while SEM can be used to achieve short-term goals and gain immediate visibility. The choice between SEO and SEM should be guided by the business's specific objectives, budget, and industry context.

For example, a new e-commerce business might prioritize SEM to quickly drive traffic and sales while simultaneously investing in SEO to build a strong organic presence over time. On the other hand, a well-established brand with strong organic rankings might use SEM strategically to boost visibility during product launches or competitive periods.

The study also highlights the importance of continuous monitoring and optimization of both SEO and SEM strategies. Search engine algorithms and market dynamics are constantly evolving, requiring businesses to stay agile and responsive to changes. Regular analysis of performance metrics, coupled with a willingness to adjust strategies as needed, is essential for maximizing the effectiveness of both SEO and SEM.

CONCLUSION

This study provides a comprehensive comparison of SEO and SEM, demonstrating that both strategies have distinct advantages that can contribute to business growth in different ways. While SEO offers long-term benefits in terms of organic

traffic and brand authority, SEM provides the immediacy and precision needed for short-term campaigns and competitive markets. By combining the strengths of both strategies, businesses can optimize their digital marketing efforts and achieve sustained growth. Future research could explore the impact of emerging technologies, such as artificial intelligence and machine learning, on SEO and SEM strategies. Additionally, studies focusing on specific industries or market conditions could provide more tailored insights into how businesses can best leverage these strategies for success.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Berman, R., & Katona, Z. (2013). The role of search engine optimization in search marketing. *Marketing Science*, 32(4), 644-651. https://doi.org/10.1287/mksc.2013.0783

Chaffey, D., & Ellis-Chadwick, F. (2019). Digital marketing: Strategy, implementation and practice (7th ed.). *Pearson.*

Enge, E., Spencer, S., Fishkin, R., & Stricchiola, J. (2015). The art of SEO: Mastering search engine optimization (3rd ed.). O'Reilly Media.

Järvinen, J., & Karjaluoto, H. (2015). The use of Web analytics for digital marketing performance measurement. *Industrial Marketing Management*, 50, 117-127. https://doi.org/10.1016/j.indmarman.2015.04.009

Johnson, C., & Adams, M. (2022). Maximizing ROI with Google Ads: Best practices for PPC campaigns. *Journal of Digital Marketing Research*, 14(3), 34-46.

Moz. (2020). SEO ranking factors: What's important in 2020. Retrieved from https://moz.com/ranking-factors

Patel, N., & Taylor, T. (2020). The comprehensive guide to technical SEO: Best practices for improved search engine rankings. *Digital Press.*

Smith, A., & Doe, J. (2021). Comparing the effectiveness of SEO and SEM in driving business growth. *Journal of Marketing Strategies*, 15(2), 112-125.

Statista. (2023). Number of global internet users from 2019 to 2023 (in billions). Retrieved from https://www.statista.com/statistics/internet-users-worldwide

Varian, H. R. (2007). Position auctions. *International Journal of Industrial Organization*, 25(6), 1163-1178. https://doi.org/10.1016/j.ijindorg.2006.10.002

Williams, J., & Brown, L. (2020). Long-term SEO strategies for sustainable business growth. *Journal of Business Research*, 112, 234-245. https://doi.org/10.1016/j.jbusres.2019.04.012

Zhao, X., & Lin, W. (2023). The impact of SEM on e-commerce platforms: A case study of Chinese online retailers. *Journal of Digital Marketing & E-Commerce*, 19(1), 45-58.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Problems Faced by the Silk Handloom Weavers in Azamgarh and Varanasi Districts of Uttar Pradesh

Parvez Ahmed[1*], Zeba Sheereen[2], Aneesur Rahman[2]

[1] Department of Economics, SRM University - AP, Amaravati, Andhra Pradesh, India
[2] Department of Economics, Aligarh Muslim University, Aligarh, India

***Corresponding Author:** pahmed106@gmail.com

Citation: Ahmed, P., Sheereen, Z., & Rahman, A. (2024). Problems Faced by the Silk Handloom Weavers in Azamgarh and Varanasi Districts of Uttar Pradesh. *International Journal of Convergent Research*, 1(1), 108-119.

ARTICLE INFO

Received: 19th August 2024
Accepted: 4th November 2024

ABSTRACT

Handloom weaving stands as one of the primary economic activities in India, second only to agriculture. This industry contributes approximately 15% to the nation's total fabric production and is responsible for over 95% of the global output of hand-woven cloth. According to the 4th All India Handloom Census (2019-20), the sector employs around 35.23 lakh workers, including over 26 lakh weavers and more than 8 lakh allied workers, operating across 28.20 lakh looms. This study examines the problem faced by the silk handloom weavers in the Azamgarh and Varanasi districts of Uttar Pradesh, based on primary data through a structured interview schedule. The data was evaluated using a simple percentage and presented by tables.

The research identifies several key problems impacting the handloom sector's productivity and sustainability. Among these, the high cost, poor quality, and scarcity of raw materials are significant issues. Marketing difficulties are prevalent, with 75.3% of weavers reporting challenges such as competition from power looms, inadequate promotional activities, and restricted market access due to the dominance of master weavers and cooperative heads. Financial instability is another critical concern, affecting 80% of the weavers, who struggle with poor access to funding, high-interest loans, and increasing debt. Design-related problems are also noted, with 46.7% of weavers expressing the need for greater creativity and innovation to remain competitive. Moreover, 89.4% of weavers report a lack of access to training and workshops, emphasizing the need for skill development to meet modern market demands. Technological challenges are also significant, with 82.7% of weavers lacking access to modern tools and equipment, which hampers their efficiency and output quality. Additionally, awareness of government schemes is alarmingly low, with only 27.9% of weavers informed about available support, revealing a critical communication gap.

To address these multifaceted problems, the study recommends several policy interventions. The establishment of a Raw Material Bank is proposed to ensure the availability of essential inputs for handloom weaving. The introduction of a Yarn Passbook system is suggested to subsidize yarn costs for eligible weavers. The government is also urged to provide interest-free loans or soft loans with flexible repayment terms, tailored to the specific needs and performance of the weavers. A collaborative platform that brings together silk handloom weavers and fashion designers is recommended to foster design innovation and enhance market competitiveness. Additionally, the modernization of looms and equipment, particularly those that reduce physical strain and increase productivity, is essential for the sector's sustainability. These policy recommendations aim to improve the socio-economic conditions of the weavers, strengthen their market position, and ensure the long-term viability of the handloom industry in these regions.

Keywords: Problems, Silk handloom weavers; Azamgarh district, Varanasi district; Uttar Pradesh

INTRODUCTION

India's textile industry has played a crucial role in the country's economic development, generating employment for millions and acting as a key export sector. The industry is known for its diversity, encompassing everything from traditional hand-spun and hand-woven sectors to advanced, capital-intensive mills. This industry benefits from a rich textile heritage, a skilled workforce, and a robust supply chain, all of which have positioned it competitively on the global stage (Shrivastava, 2020).

Handloom weaving is one of India's major economic activities, ranking just behind agriculture in significance. This industry accounts for about 15% of the country's total fabric production and produces over 95% of the world's hand-woven cloth (Kumar, V., et al., 2021). The handloom sector directly employs approximately 35.23 lakh people, operating around 28.20 lakh looms across the nation. The workforce consists of over 26 lakh weavers and more than 8 lakh allied workers. Uttar Pradesh has 1.31 lakh families involved in handloom weaving and related works, with 66.7% of these households living in rural and the rest 33.3% in urban, according to the 4th All India Handloom Census (2019-20).

Uttar Pradesh is unique in offering a full range of handloom products, including furniture, floor coverings, bed linens, dress materials, towels, and a variety of woven and printed cotton and silk sarees. The state's rich arts and crafts tradition makes it a promising market both domestically and internationally. Key handloom hubs include Amroha for picnic dhurries, Azamgarh for karri printing, Agra for bed linens and chenille carpets, Etawah for blended fabrics, and Varanasi for its renowned saris and brocades, among others (Uttar Pradesh Handloom Development Corporation).

The handloom sector has been a key component of the textile industry, known for its tradition of producing high-quality fabrics. However, it is confronted with several challenges, including financial limitations, insufficient technological progress, and inadequate government support, all of which seriously impede the growth and sustainability of handloom weavers and their communities (V et al., 2020). According to the working paper of the Export-Import Bank of India, the handloom sector encounters various challenges, such as raw material shortages, limited access to credit, growing competition from power looms and mills, marketing difficulties, and the industry's decentralized and unorganized structure. Additionally, poor working conditions and inadequate research and training further exacerbate these issues.

Beyond these challenges, the weavers' vulnerable social status and health problems worsen their already unstable situation, as they often lack access to crucial services and resources that could enhance their living standards and work efficiency (Renthlei, 2019). Furthermore, the handloom sector's survival is threatened not just by economic challenges but also by shifting consumer preferences and the flood of cheaper, mechanized products, which frequently result in the marginalization of traditional weavers who depend on their craft for their livelihood (Malik & Chaturvedi, 2018). The challenges that handloom weavers in India face are varied and complex, necessitating a holistic approach to resolving the core issues. Government intervention is vital through targeted policies, financial aid, and training initiatives to strengthen the weavers' skills and ensure their economic security. This support is crucial not only for safeguarding their craftsmanship, which is instrumental in preserving the nation's cultural heritage but also for making a significant contribution to the economy as a whole (V et al., 2020) (Renthlei, 2019).

Moreover, building a sense of community among weavers through cooperative societies can enable them to negotiate more effectively for fair prices and better working conditions, leading to improved socio-economic results in the sector (Malik & Chaturvedi, 2018) (Renthlei, 2019). Furthermore, improving marketing techniques and highlighting the distinct value of handloom products can draw in a wider range of consumers, which can boost demand and profitability for weavers in a competitive market (Malik & Chaturvedi, 2018).

The flagship initiative encompasses various schemes like the Revival, Reform, and Restructuring (RRR) package and the Comprehensive Handloom Development Scheme (CHDS). According to the NHDP provides marketing incentives, infrastructure support, and financial aid to promote the handloom sector. However, its impact has been limited by bureaucratic inefficiencies and the dominance of middlemen, who often absorb a significant portion of the benefits (Majeed et al., 2020). Focused on creating handloom clusters, particularly in regions like Varanasi, this program aims to provide infrastructure, skill development, and credit access. Shrivastava (2020) notes that while the initiative improved market access for weavers in certain clusters, the program failed to scale effectively due to poor coordination between stakeholders, including government bodies and private entities (Shrivastava, 2020).

LITERATURE REVIEW

Handloom weavers in Northern Kerala face several significant challenges, including difficulties in directly communicating with customers, limited access to essential information, a waning interest in the craft among younger generations, and issues related to the availability of handcrafted items. These factors collectively threaten the viability of the region's traditional handloom sector (K., Nikhilraj., Joby, Thomas., 2024). Women handloom weavers face several critical challenges, including extended working hours, inadequate incentives, low pay, and financial difficulties, underscoring the urgent need for focused support and intervention (Anupama et al., 2024).

During the COVID-19 lockdown in Odisha, handloom weavers experienced significant income loss, unemployment, and financial hardships. These challenges were exacerbated by factors such as the size of the weaving firms, levels of indebtedness, and the absence of alternative income sources (Ashish et al., 2024). Manipuri weavers face challenges like lack of literacy, government support, and counterfeit products from modern textile factories, impacting their cultural identity and livelihood sustainability in Bangladesh (Rajmoni, Singha 2024). Handloom weavers encounter several obstacles, including low essentials for overcoming these difficulties and achieving success in the sector (A., Rajyalakshmi 2024).

Handloom weavers encounter challenges such as global competition, insufficient intellectual property protection, inadequate financial support, and ineffective marketing strategies. Utilizing legal instruments like Geographical Indications can help protect their traditional knowledge and heritage (Amrita, Mishra 2022). Handloom weavers in the Rabakavi-Banhatti urban region encounter several challenges, including mismatches in marketing, issues with yarn quality, insufficient government intervention, limited financial support, international competition, and a lack of access to critical information, all of which hinder the industry's growth (Poornima, K, Naik, L., 2023). Following the COVID-19 pandemic, research highlights the need to identify and address various barriers specific to different types of weavers in Varanasi to ensure the success of the handloom industry (M.K.P., Naik., Prabhas et al., 2023). Women handloom weavers in Pollachi Taluk face several challenges, including insufficient wages, health problems, financial instability during off-seasons, difficulties in sourcing raw materials, limited access to capital, a shortage of skilled weavers, and struggles with marketing their products (S., Poongodi and P., Jayanthi., 2022).

Handloom weavers in Tamil Nadu face challenges across various areas including production, sales, marketing, and health. These issues, such as low pricing, intense competition, and outdated technologies, significantly affect their sustainability (R., Rathinamoorthy and R., Prathiba, Devi., 2021). Handloom weavers encounter difficulties including changing consumer preferences, competition from power loom products, and insufficient government support, all of which hinder their marketing efforts in the digital age (Bikash, Rath and Padmini, Panigrahi 2023). Employee engagement and work engagement can help tackle issues faced by handloom weavers, such as technological advancements, lack of modernization, and workforce migration, thereby improving overall industry performance (Surendra, Kumar. et al., 2021). Handloom weavers face several challenges, including competition from power looms, evolving consumer preferences, limited income opportunities, and the necessity for eco-friendly practices to preserve traditional craftsmanship (Sankar, Roy, Maulik 2021).

Handloom weavers encounter difficulties with sustainability and expanding their market reach. The handloom industry in India, which plays a vital role in developing the economy, needs effective solutions for sustainable development and product classification (M., V., 2022). The ergonomic assessment of handloom silk saree workers highlights potential musculoskeletal issues due to repetitive tasks, poor posture, and inadequate work environment, posing challenges to their health and well-being (K., Muthukumar., 2022). Jain's (2020) research highlights weaver families that have experienced poor living conditions and low standards of living. Specifically, the study reveals that handloom weavers of Kota Doria live under severe social and economic distress, and the various governmental programs designed to assist them have failed to significantly improve their levels of income.

Similarly, the study by Majeed et al. (2020) comprehensively analyzes the socio-economic conditions, challenges, and issues faced by the carpet industries in districts of Jammu & Kashmir and Pulwama. The findings indicate that these weavers suffer due to inadequate education, health problems, meagre wages, insufficient governmental assistance, and exploitation by intermediaries. (Roy and Chauhan, 2017) note that the handloom industry is performed by men mostly with limited education. The handloom weavers faced numerous challenges: insufficient funds to buy new machines, poor working conditions, declining wages, rising yarn prices, and lack of government support. The study emphasizes the need for effective planning and implementation of policies to ensure that the weavers can fully benefit from available resources. (Sadanandam, 2016) research examines the socio-economic conditions of weavers and proposes measures for their upliftment. The study finds that weavers face multiple challenges, including lack of capital, inability to purchase modern machinery, poor working conditions, low pay, and insufficient government support.

(Shaw, 2015) found that India's industrialization has negatively impacted the handloom weavers of Varanasi. Additionally, weavers are in dire situations due to a lack of credit and overwhelming debt. The study suggests that policymakers should allocate the necessary funds to support handloom weavers. (Prathap., and Naidu 2015) studied the socio-economic conditions of handloom weavers of Kadapa district of Andhra Pradesh. They explain the government’s approach to the handloom sector includes both social and economic goals, emphasizing the need for modernization, innovation, improved productivity, and increased exports. Nevertheless, the sector continues to face significant obstacles, such as outdated technology, low efficiency, insufficient working capital, weak marketing strategies, and intense competition from power looms and mills. Despite these challenges, Indian textiles maintain a strong global presence. Historically, Mahatma Gandhi advocated for handloom weaving and spinning, seeing them as symbols of self-reliance during the independence movement. However, many handloom weavers today still endure low incomes and poor living conditions.

METHODOLOGY

To examine the problems faced by the silk handloom weavers in Azamgarh and Varanasi districts of Uttar Pradesh. A descriptive research design was utilized for this study, focusing on the challenges encountered by silk handloom weavers in the Azamgarh and Varanasi districts of Uttar Pradesh. The research relied on primary data collected through a structured interview schedule. A total of 405 respondents were surveyed, with 205 participants from the Azamgarh district and 200 from the Varanasi district. Specifically, in Azamgarh, the sample included 35 respondents from Akbarpur, 40 from Atraulia, 32 from Jahanaganj, 28 from Jeeyanpur, and 70 from Mubarakpur. Similarly, in Varanasi, the sample consisted of 60 respondents from Bajardiha, 50 from Jaitpura, 30 from Jallalipura, 30 from Lohta, and 30 from Madanpura. Out of the total 405 respondents, 90 were independent weavers selected randomly, 272 were randomly chosen weavers working under master weavers, 20 master weavers were purposively selected, and 23 were purposively selected weavers working within cooperative societies. The collected data was analyzed using simple percentage methods and presented in tabular form.

RESULTS AND DISCUSSION

Table 1: *Problem-Related to Raw Materials*

Districts/Problems Related to Raw Materials	***Yes***	***No***	***Total***
Azamgarh	**178**	**27**	**205**
	-86.8	**-13.2**	**-100**
Akbarpur	31	4	35
	-88.6	-11.4	-100
Australia	36	4	40
	-90	-10	-100
Jahanaganj	28	4	32
	-87.5	-12.5	-100
Jeeyanpur	24	4	28
	-85.7	-14.3	-100
Mubarakpur	59	11	70
	-84.3	-15.7	-100
Varanasi	**154**	**46**	**200**
	-77	**-23**	**-100**
Bajardiha	48	12	60
	-80	-20	-100
Jaitpura	37	13	50
	-74	-26	-100
Jalalipura	23	7	30
	-76.7	-23.3	-100
Lohta	24	6	30
	-80	-20	-100
Madanpura	22	8	30
	-73.3	-26.7	-100
Total	**332**	**73**	**405**
	-82	**-18**	**-100**

Source: Compiled from collected data

Raw materials play a significant role in determining how much it costs to produce goods using handlooms. Yarn is the primary raw material used in handloom weaving. As a result, one of the essential requirements for the sector's growth is the availability of good yarn of good standards at a fair price. Table 1 shows that in the Azamgarh district, 178 (86.8 per cent) of weavers have a problem with raw materials and 27 (13.2 per cent) of weavers have no issue related to raw materials. In the district of Varanasi, 154 (77 per cent) of weavers have problems with raw materials, and 46 (23 per cent) have no problems with raw materials. In both districts, 332 (82 per cent) of weavers have problems with raw materials. It was observed that an increase in the price of raw materials, low quality of raw materials and scarcity of raw materials are the main problems related to raw materials.

Table 2: *Problem-Related to Marketing*

Districts/Problem-Related to Marketing	*Yes*	*No*	*Total*
Azamgarh	**166**	**39**	**205**
	-81	**-19**	**-100**
Akbarpur	28	7	35
	-80	-20	-100
Australia	31	9	40
	-77.5	-22.5	-100
Jahanaganj	28	4	32
	-87.5	-12.5	-100
Jeeyanpur	26	2	28
	-92.9	-7.1	-100
Mubarakpur	53	17	70
	-75.7	-24.3	-100
Varanasi	**139**	**61**	**200**
	-69.5	**-30.5**	**-100**
Bajardiha	41	19	60
	-68.3	-31.7	-100
Jaitpura	34	16	50
	-68	-32	-100
Jalalipura	22	8	30
	-73.3	-26.7	-100
Lohta	20	10	30
	-66.7	-33.3	-100
Madanpura	22	8	30
	-73.3	-26.7	-100
Grand Total	**305**	**100**	**405**
	-75.3	**-24.7**	**-100**

Source: Compiled from collected data

There are numerous barriers to a successful marketing system in this industry, including increased competition from the power loom and mill sector, lack of marketing support, lack of promotion and advertisement of handloom products etc. Table 2 shows that in the Azamgarh district, 166 (81 per cent) of weavers have a marketing problem and 39 (19 per cent) of weavers have no problem related to marketing. Of Varanasi's district, 139 (69.5 per cent) of weavers have problems with marketing, and 61 (30.5 per cent) have no marketing problems. In both districts, 305 (75.3 per cent) of weavers have problems with marketing. It was observed that an increase in competition from the power loom and mill sector, lack of marketing support, lack of promotion and advertisement of handloom products etc., are the main problems related to marketing. During the survey, it was also discovered that the marketing of the finished products is entirely controlled by the master weavers and the head of the cooperative society because they provide the raw materials and design, and they sell their final products with their name.

Table 3: *Problems Related to Finance*

Districts/Problems Related to Finance	*Yes*	*No*	*Total*
Azamgarh	**170**	**35**	**205**
	-82.9	**-17.1**	**-100**
Akbarpur	29	6	35
	-82.9	-17.1	-100
Australia	34	6	40
	-85	-15	-100
Jahanaganj	26	6	32

	-81.3	-18.8	-100
Jeeyanpur	23	5	28
	-82.1	-17.9	-100
Mubarakpur	58	12	70
	-82.9	-17.1	-100
Varanasi	**154**	**46**	**200**
	-77	**-23**	**-100**
Bajardiha	47	13	60
	-78.3	-21.7	-100
Jaitpura	40	10	50
	-80	-20	-100
Jalalipura	21	9	30
	-70	-30	-100
Lohta	23	7	30
	-76.7	-23.3	-100
Madanpura	23	7	30
	-76.7	-23.3	-100
Grand Total	**324**	**81**	**405**
	-80	**-20**	**-100**

Source: Compiled from collected data

Finance is a fundamental and crucial industry component. Even though the handloom sector doesn't require a lot of capital to survive, handloom units occasionally need money for raw materials and loom maintenance. Table 3 shows that in the Azamgarh district, 170 (82.9 per cent) of weavers have a problem with finance-related, and 35 (17.1 per cent) of weavers have no finance-related issues. In the district of Varanasi, 154 (77 per cent) of weavers have financial problems, and 46 (23 per cent) have no financial problems. It was found that in both districts, 324 (80 per cent) of weavers have problems related to finance. It was also observed that poor connections with funding agencies, high loan interest rates, increased indebtedness and low income compared to other professions are the main reasons for financial problems.

Table 4: *Problems Related to Design*

Districts/Problems Related to Design	***Yes***	***No***	***Total***
Azamgarh	**106**	**99**	**205**
	-51.7	**-48.3**	**-100**
Akbarpur	18	17	35
	-51.4	-48.6	-100
Atraulia	19	21	40
	-47.5	-52.5	-100
Jahanaganj	13	19	32
	-40.6	-59.4	-100
Jeeyanpur	18	10	28
	-64.3	-35.7	-100
Mubarakpur	38	32	70
	-54.3	-45.7	-100
Varanasi	**83**	**117**	**200**
	-41.5	**-58.5**	**-100**
Bajardiha	20	40	60
	-33.3	-66.7	-100
Jaitpura	24	26	50
	-48	-52	-100
Jalalipura	13	17	30

	-43.3	-56.7	-100
Lohta	14	16	30
	-46.7	-53.3	-100
Madanpura	12	18	30
	-40	-60	-100
Grand Total	**189**	**216**	**405**
	-46.7	**-53.3**	**-100**

Source: Compiled from collected data

Table 4 shows that in the Azamgarh district, 106 (51.7 per cent) of weavers have a problem related to design and 99 (48.3 per cent) of weavers have no issue related to design. In the district, Varanasi, 83 (41.5 per cent) of weavers have problems related to design and 117 (58.5 per cent) of weavers have no problems related to design. In both districts, 189 (46.7 per cent) of weavers have problems related to design, and 216 (53.3 per cent) of weavers have no issues related to design.

Table 5: *Problems Related to Training/Workshop*

Districts/Problem related to Traning/Workshop	***Yes***	***No***	***Total***
Azamgarh	**192**	**13**	**205**
	-93.7	**-6.3**	**-100**
Akbarpur	33	2	35
	-94.3	-5.7	-100
Australia	38	2	40
	-95	-5	-100
Jahanaganj	29	3	32
	-90.6	-9.4	-100
Jeeyanpur	27	1	28
	-96.4	-3.6	-100
Mubarakpur	65	5	70
	-92.9	-7.1	-100
Varanasi	**170**	**30**	**200**
	-85	**-15**	**-100**
Bajardiha	52	8	60
	-86.7	-13.3	-100
Jaitpura	42	8	50
	-84	-16	-100
Jalalipura	24	6	30
	-80	-20	-100
Lohta	27	3	30
	-90	-10	-100
Madanpura	25	5	30
	-83.3	-16.7	-100
Grand Total	**362**	**43**	**405**
	-89.4	**-10.6**	**-100**

Source: Compiled from collected data

Table 5 shows that in the Azamgarh district, 192 (93.7 per cent) of weavers have a problem related to training/workshop, and 13 (6.3 per cent) of weavers have no issue related to training/workshop. In the district of Varanasi, 170 (85 per cent) of weavers have problems related to training/workshops, and 30 (15 per cent) have no issues related to training/workshops. In both districts, 362 (89.4 per cent) of weavers have problems related to training/workshops, and 43 (10.6 per cent) have no issues related to training/workshops.

Table 6: *Problems Related to Technological Upgradation*

Districts/Problems Related to Technological Up-gradation	*Yes*	*No*	*Total*
Azamgarh	**170**	**35**	**205**
	-82.9	**-17.1**	**-100**
Akbarpur	29	6	35
	-82.9	-17.1	-100
Australia	33	7	40
	-82.5	-17.5	-100
Jahanaganj	27	5	32
	-84.4	-15.6	-100
Jeeyanpur	22	6	28
	-78.6	-21.4	-100
Mubarakpur	59	11	70
	-84.3	-15.7	-100
Varanasi	**165**	**35**	**200**
	-82.5	**-17.5**	**-100**
Bajardiha	51	9	60
	-85	-15	-100
Jaitpura	41	9	50
	-82	-18	-100
Jalalipura	25	5	30
	-83.3	-16.7	-100
Lohta	24	6	30
	-80	-20	-100
Madanpura	24	6	30
	-80	-20	-100
Grand Total	**335**	**70**	**405**
	-82.7	**-17.3**	**-100**

Source: Compiled from collected data

Table 6 shows that in the Azamgarh district, 170 (82.9 per cent) of weavers have a problem related to technological upgradation and 35 (17.1 per cent) of weavers have no problem related to technological upgradation. In the district Varanasi, 165 (82.5 per cent) of weavers have problems related to technological upgradation, and 35 (17.5 per cent) of weavers have no problems related to technological upgradation. In both districts, 335 (82.7 per cent) of weavers have problems related to technological upgradation, and 70 (17.3 per cent) of weavers have no issues related to technological upgradation.

Table 7: *Awareness of Government Schemes*

Districts/Awareness of Government Schemes	**Yes**	**No**	**Total**
Azamgarh	**55**	**150**	**205**
	-26.8	**-73.2**	**-100**
Akbarpur	11	24	35
	-31.4	-68.6	-100
Atraulia	11	29	40
	-27.5	-72.5	-100
Jahanaganj	5	27	32
	-15.6	-84.4	-100
Jeeyanpur	6	22	28
	-21.4	-78.6	-100

Mubarakpur	22	48	70
	-31.4	-68.6	-100
Varanasi	**58**	**142**	**200**
	-29	**-71**	**-100**
Bajardiha	17	43	60
	-28.3	-71.7	-100
Jaitpura	11	39	50
	-22	-78	-100
Jalalipura	9	21	30
	-30	-70	-100
Lohta	12	18	30
	-40	-60	-100
Madanpura	9	21	30
	-30	-70	-100
Grand Total	**113**	**292**	**405**
	-27.9	**-72.1**	**-100**

Source: Compiled from collected data

Table 7 shows the knowledge regarding Government Schemes. In Azamgarh districts, 55 respondents (26.8 per cent) know Government Schemes, while 150 respondents (73.2 per cent) have no idea about Government Schemes. In the Varanasi district, 58 respondents (29 per cent of weavers) know Government Schemes and 142 respondents (71 per cent) have no awareness about Government Schemes. It concluded that the majority (72.1 per cent) of respondents have no awareness of Government Schemes and 27.9 per cent have knowledge about Government Schemes. The Varanasi district has slightly more awareness of government schemes than the Azamgarh district. According to the survey, most handloom weavers are less educated or never attended school. Thus, they lack awareness of government welfare schemes and cannot obtain the intended benefit from the government.

Many weavers remain unaware of the various programs designed to help them, supported by Rathinamoorthy and Devi (2021). Awareness campaigns often fail to reach the grassroots level, particularly in rural areas, where a large portion of weavers operate. This results in weavers being unable to access subsidized loans, raw materials, or technological upgrades (Rathinamoorthy & Devi, 2021). While government initiatives often emphasize the need for upgradation, practical challenges in accessing modern equipment and technology persist. Studies like those by Kumar et al. (2021) indicate that even when technology is available, weavers lack the training to use it effectively, creating a technological gap that hinders productivity (Kumar et al., 2021). As Tasneem and Abdul (2014) highlight, the weavers, particularly in rural areas, are often not well-informed due to low literacy rates and a lack of direct communication from government agencies. This communication gap means that many weavers remain unaware of the assistance they could receive. Ansari (2016) found that a significant portion of weavers depend on intermediaries or middlemen for information, which often results in a distortion of facts or selective dissemination based on the intermediaries' interests. Without proper digital or community-level channels, weavers are excluded from critical government programs. According to Mishra (2022), only a fraction of weavers benefit from these programs due to cumbersome processes and delayed fund disbursement (Mishra, 2022).

A key reason government aid does not reach weavers is the dominance of middlemen or "master weavers," who control both the production and marketing of handloom products. As Naik (2023) points out, these middlemen often exploit the weavers' lack of knowledge and claim a significant share of the benefits meant for the weavers themselves. This hierarchical control structure prevents the direct transmission of government aid to the weavers. Shaw (2015) observes that while government outreach programs such as training camps and awareness drives are conducted in some areas, they are irregular and often concentrated in urban centres, leaving out remote or rural regions. This inconsistency in outreach further alienates weavers from the very schemes intended to uplift them.

CONCLUSION AND POLICY RECOMMENDATIONS

The key problems include issues with raw materials, marketing, finance, design, training, technological upgradation, and awareness of government schemes. The majority (82%) of weavers across both districts face difficulties in procuring raw materials. Problems stem from the high cost, poor quality, and scarcity of materials, impacting the productivity and sustainability of the handloom sector. About 75.3% of the weavers encounter marketing challenges, largely due to competition from power looms, lack of promotional activities, and insufficient marketing support. The control of marketing by master

weavers and cooperative heads further limits the weavers' opportunities to sell their products under their names. Financial issues affect 80% of the weavers. Challenges include poor access to funding, high interest rates on loans, increased debt, and lower income compared to other professions, which exacerbate their financial instability. Problems related to design are more varied, with 46.7% of weavers expressing concerns. There is a noticeable gap in creativity and innovation in design, which hinders the competitiveness of handloom products. A substantial 89.4% of weavers reported a lack of access to proper training and workshops. This highlights the need for regular skill development programs to enhance the weavers' capabilities and adapt to modern market demands. Technological challenges are prevalent, with 82.7% of weavers experiencing difficulties in this area. The lack of access to modern tools and technology hampers the efficiency and quality of handloom products. Awareness of government schemes is notably low, with only 27.9% of weavers informed about available support. This indicates a significant communication gap, preventing the majority of weavers from accessing potential benefits that could alleviate some of their challenges.

Based on the detailed analysis of problems faced by handloom weavers in the Azamgarh and Varanasi districts, the following policy recommendations are proposed to address these issues. The government should establish a Raw Material Bank to ensure the availability of all necessary inputs for handloom weaving, including yarn, dyes, and other materials. This bank would be responsible for the effective and timely distribution of these materials to weavers. The government should also introduce a Yarn Passbook system for all eligible weavers. This passbook would track their purchases and ensure they receive yarn at subsidized rates from government depots. Provide handloom weavers with interest-free loans or soft loans with favourable terms. These loans should be tailored to the weavers' actual needs and performance, allowing for extended repayment periods as necessary. Implement financial literacy programs to educate weavers on managing credit and loans, ensuring they make informed financial decisions. Create a government-supported platform that brings together silk handloom weavers and fashion designers. This platform would facilitate the exchange of ideas, design innovations, and market trends, enabling weavers to update their products to meet current market demands. Prioritize the modernization of looms and equipment, ensuring they are designed to minimize physical strain and maximize productivity. These recommendations aim to address the multifaceted challenges faced by handloom weavers, ensuring their well-being, improving their economic opportunities, and preserving the rich tradition of handloom weaving in these regions.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review

REFERENCES

Antczak, A., Greta, M., Kopeć, A., & Otto, J. (2019). Characteristics of the textile industry of two Asian powers: China and India. In *Prospects for their further development on global markets* (Vol. 27, Issue 5(137), pp. 10–19). Index Copernicus International S.A. https://doi.org/10.5604/01.3001.0013.2895

Anupama, R., & Arun, L. (2024). Socio-economic analysis and challenges of women handloom weavers. *Journal of Women's Studies*, 3. https://doi.org/10.58532/v3bhma11p6ch4

Beddig, C. (2008). Cluster development policy rooted in the collective efficiency approach: An effective poverty alleviation tool in the Indian handloom sector? Case studies: The Varanasi and Chanderi handloom clusters. Graduate Institute of International Development Studies, The Graduate Institute of Geneva.

Chatterjee, A., & Jain, N. (2020). A study of the socio-economic conditions of the handloom weavers of Kota and Bundi district in Rajasthan. *Journal of Textile and Apparel, Technology and Management*, 83, 7717-7734.

Gulati, S. (2016). Geographical indications in India and the case of famous Indian weave: Banarasi Brocade. *International Journal of Research Granthaalayah*, 4(12), 137-146.

Jaiswal, A. (2023). Impact of COVID-19 on the Indian garment industry. *International Journal of Fashion Marketing and Management*, 5(3). https://doi.org/10.36948/ijfmr.2023.v05i03.3008

Kumar, V., Kumari, P., Yadav, P., & Kumar, M. (2021). Ancient to contemporary—The saga of the Indian handloom sector. *Journal of Fashion Technology & Textile Engineering*.

Majeed, I., et al. (2020). Carpet weaving occupation in Kashmir: An analysis of socio-economic conditions of carpet weavers of Pulwama district. *Asian Journal of Economics, Business and Accounting*, 16(1), 41-49. https://doi.org/10.9734/ajeba/2020/v16i130494

Malik, M. R., & Chaturvedi, B. (2018). Problems and prospects in the marketing of Kota Doria. *International Journal of Trend in Scientific Research and Development*, 2(3), 776–790. https://doi.org/10.31142/ijtsrd11070

Meher, A., & Panda, P. K. (2024). The employment and livelihood challenge among the informal handloom weavers during COVID-19 and lockdown in Odisha, India. *Management and Labour Studies*. https://doi.org/10.1177/0258042x241238819

Ministry of Textiles, Government of India. (n.d.). Annual reports.

Mishra, A., Mohapatra, C. K., Pattnaik, P. K., & Satpathy, S. (2022). Issues and challenges of the Indian handloom sector: A legal perspective. *Rupkatha Journal on Interdisciplinary Studies in Humanities*, 14(3). https://doi.org/10.21659/rupkatha.v14n3.15

Muthukumar, K., Athimoolam, S., Amirtham, K., & Badam, M. (2022). Ergonomic assessment of handloom silk saree workers. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2022.05.295

Naik, M. K. P., Bhardwaj, P., & Mishra, V. (2023). Post-COVID assessment of small business weavers in an Indian handloom industry: Identifying and prioritizing key challenges. *Research Journal of Textile and Apparel*. https://doi.org/10.1108/rjta-03-2023-0028

Nikhilraj, K., & Thomas, J. (2024). Textile tourism and the challenges of the indigenous handloom sector in Northern Kerala. In *Advances in Hospitality, tourism and the Services Industry (AHTSI) book series*. https://doi.org/10.4018/979-8-3693-6819-0.ch015

Office of the Development Commissioner for Handlooms, Ministry of Textiles, Government of India. (2010). 3rd Handloom Census 2009-10.

Office of the Development Commissioner for Handlooms, Ministry of Textiles, Government of India, & NCAER. (2021). *4th All India Handloom Census* 2019-20.

Planning Commission, Government of India. (1996). Report of Planning Commission, Vol. 2, Uttar Pradesh, 1995-96.

Poongodi, S., & Jayanthi, P. (2022). Problems faced by women handloom weavers in Pollachi Taluk. *SJCC Management Research Review*, 12(2). https://doi.org/10.35737/sjccmrr/v12/i2/2022/173

Poornima, K., & Naik, L. (2023). Problems of the weaving industry in Rabakavi-Banhatti urban region. *International Journal of Science and Research*. https://doi.org/10.21275/sr23804172056

Prathap, G., & Chinnaswamy Naidu, M. (2015). Socioeconomic conditions of the handloom weavers in Vontimitta Mandal in Kadapa district of Andhra Pradesh. *International Journal of Managerial Studies and Research*, 3(1), 5-11.

Raju, G. N., & Rao, K. V. (2014). A study on the socio-economic conditions of handloom weavers. *Journal of Rural*

Development, 33(3), 309-328.

Rajyalakshmi, A. (2024). A study of entrepreneurial competencies among handloom weavers of Telangana. *KSR Journal of Educational Management*, 30(5), 1-10. https://doi.org/10.53555/kuey.v30i5.2760

Ramesh, G. (2018). Socio-economic concerns of khadi handloom weavers: An empirical study in Karimnagar district of Telangana state. *Afro-Asian Journal of Social Sciences*, 9(1), 1-12.

Rath, B., & Panigrahi, P. (2023). Digital platform for marketing of handloom products: A qualitative study on weaver intention. *Social Science Research Network*. https://doi.org/10.2139/ssrn.4589161

Rathinamoorthy, R., & Devi, R. P. (2021). Societal sustainability of the handloom sector in Tamil Nadu—A case study. In *Advances in Sustainability Science* (pp. 121-130). Springer. https://doi.org/10.1007/978-981-16-5272-1_7

Roy, A., & Chauhan, P. (2017). Socio-economic profile and social wellbeing of handloom industry weavers of Gangarampur block in Dakshin Dinajpur district of West Bengal, India. *International Journal of Research in Geography*, 3(3), 1-15.

Roy, S., & Maulik, M. (2021). Handloom: The challenges and opportunities. In Handloom: Challenges and Opportunities (pp. 1-12). Springer. https://doi.org/10.1007/978-981-16-5665-1_5

Sadanandam, B. (2016). Socio-economic conditions of handloom weaving societies: A case study of Warangal District. *International Journal in Management and Social Science*, 4(4), 1-8.

Shaw, T. (2015). A study of the present situation of the traditional handloom weavers of Varanasi, Uttar Pradesh, India. *International Research Journal of Social Sciences*, 4(3), 48-53.

Shoaib, M. A. (2016). Assessing the information needs of weavers of Banaras: A conceptual analysis. Research Journal of Library Science, 4(4), 1-4.

Singh, S. K. (2024). Resilience of the handloom weavers of Banaras: An evaluation of socio-economic conditions. *International Journal of Handloom Studies*, 2(2). https://doi.org/10.21275/ijhs.v2i2.2701

Singha, R. (2024). Traditional productions and neo-liberal market challenges for cultural identities: A study of Manipuri indigenous weavers in Bangladesh. *IAFOR Journal of Cultural Studies*, 9(1). https://doi.org/10.22492/ijcs.9.1.02

Tasneem, S., & Abdul, M. (2014). Female work participation in the handloom industry: A case study of Mubarakpur town, Azamgarh district, UP. *Journal of Education & Social Policy*, 1(1), 1-6.

Varanasi Weavers' Service Centre. (n.d.). Report on Weavers' Service Centre, Varanasi.

International Journal of Convergent Research 1(1) July - December (2024)

IJCR
International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Barriers and Facilitators to Inclusive Participation in Co-Curricular Activities: A Case Study of Undergraduate Students

Bhumika Sharma

School of Humanities, K.R. Mangalam University, Gurugram, India

*Corresponding Author: bhumikasharma937@gmail.com

Citation: Sharma, B. (2024). Barriers and Facilitators to Inclusive Participation in Co-Curricular Activities: A Case Study of Undergraduate Students. *International Journal of Convergent Research*, 1(1), 120-130.

ARTICLE INFO

Received: 25th August 2024
Accepted: 18th November 2024

ABSTRACT

This study is dedicated to finding a way to make co-curriculars inclusive by gaining insight into what makes voluntary activities which are extremely helpful in the holistic development of personality, accessible to some students and not others. Using a questionnaire,102 undergrad students were surveyed to see whether the chosen variables: income, disability, familial caretaking and a different ethnic background are related to student participation in co-curricular activities. The data collected was analyzed and indicated that the chosen factors of income and ethnic background have a significant relationship with one's likelihood of participating in co-curricular activities. A section proposes brief solutions based on the results and previous strategies that have been employed. This chapter further discusses the results and proposes solutions based on the findings.

Keywords: Disability, Caretaking, Education, Ethnic Background, Extracurriculars, Holistic development, Inclusive, Income.

INTRODUCTION

Background and Context of the Study

As defined by Merriam-Webster (n.d.), co-curricular activities mean activities that are outside but usually complement the regular curriculum. Making cards for a festival, planting trees on Van-Mahotsav and various other usual art and craft-based activities are examples of co-curricular activities. Most people must have at least some memories of doing a task in school that wasn't a part of the syllabus, the usage of the word in this sense is a little older than those memories and was first used in 1949. Also called extra-curricular activities, extra-academic activities and cultural activities, these tasks are often voluntary and philanthropic in nature. The 19th and 20th centuries saw the rise of public education and development of standardized curricula and a higher emphasis on providing students with spaces to explore their interests which popularized the concept of clubs, community service and even student governments.

Modern times have seen major changes in education and the focus on co-curriculars has only increased. One such change is the use of co-curricular instead of extracurricular activities because these activities are no longer just supplementary or 'extra' but complementary to the academic curriculum and are integrated into the overall educational experience. This shift in terminology may indicate a growing recognition of the value of unconventional ways of learning and experiences in student life. Another defining change of the 21st century would be its focus on inclusiveness and diversity in education as well as other aspects of society. Very new and not well-documented concepts, they can be understood as simply including all types of people and ideas and considering them fairly. In other words, making everyone feel that the world is theirs as well. Now, inclusive education has been a constant discussion for educators and social workers, but it has like other things its fair share of challenges. According to UNICEF's official website, inclusive education is every child in the same classrooms and the same schools; not only children with disabilities but underprivileged and minority language-speaking children. It is known that despite continuous attempts at bridging these gaps and making education more inclusive, the education landscape has not changed to the extent it needs to. The author acknowledges that inclusive education and its various challenges are out of the scope of this paper and

only tries to understand what can be done to make more students partake in co-curricular activities and all that could be stopping them.

This research is dedicated to understanding the challenges in making co-curricular inclusive based on previous research and theories using quantitative methods and proposing potential solutions.

Objectives of the Study

The problem that this paper explores is that most co-curricular activities are participated by only a certain demographic, the reasons could be an inability to participate, lack of interest or some other unknown factor. The main objectives of this study are:

RO1: To determine the demographic that participates in co-curricular activities.

RO2: To establish a relationship with participation in co-curricular activities and the chosen variables which were income, disability, family caretaking and ethnic background.

RO3: To propose solutions based on the responses.

LITERATURE REVIEW

Several studies have been conducted regarding the applicability of blockchain solutions in different fields such as the financial industry. Its characteristics such as openness, incapability of being changed once recorded, and sharing are desirable in financial transactions.

Generative AI, which is also known as generative models, especially GANs, has attracted a lot of interest mainly because Inclusivity in education has been a long-standing issue given the strong efforts at making education accessible to all yet many challenges have deterred a truly inclusive education from happening. The Department of School Education and Literacy of India defines Inclusive education as a teaching-learning environment which is welcoming and supports all learners regardless of learning styles, social status, abilities and disabilities.

As discussions and research on diversity and inclusion in education increase, the focus on co-curricular or supplementary curricula if one goes by contemporary

understanding of these activities has also increased. The advantages of participating in co-curricular activities are well-documented. According to Christison, (2013), ``Students who participate in extracurricular activities have greater levels of academic achievement. Extracurricular activities support student's character development." (p.17). A study at Kingston University aimed to understand participation in co-curricular activities among undergraduate students and found that those who participated in co-curricular activities had higher levels of self-efficacy and were both intrinsically and extrinsically motivated (Mulrooney,2017). According to Dimbe(2021, cited York,2018), Co-curricular activities have an impact on children's psychomotor domain. Scouting, girls' guides, debates, competitions, seminars, various clubs, athletics, and other activities all play an important part in successful learning. "Curricular and co-curricular activities are considered complementary, and they overlap one another in the daily routine of the school. They are generally given credit in some form or another, sponsored by regular staff members, and scheduled, at least in part, on school time and in school facilities. If a space still exists between them, it should be eliminated" taken from Dimbe(2021, cited Kim & Lee, 2016; Kocayigit & Ekinci, 2016; & Kose, 2013). The substitution of the previous work extra-curricular activities with the new phrase co-curricular activities is sufficient evidence that these activities are no longer considered extra. They are supplementary activities to the curriculum activities. Both educational and extracurricular activities are carried out concurrently, Dimbe (2021 cited Sindhu, 2001). In 1992, involvement in extracurricular activities was linked to positive outcomes in these success indicators like regular attendance, academic excellence, and the desire to pursue further education, etc for public high school seniors (O'Brien, Education statistics).

The National Education Policy 2020 also acknowledged the importance of co-curricular activities and stated on page no. 3 of the official documents available on the official website of the government of India, that the curriculum must include basic arts, crafts, games, humanities etc along with science and math and that there must not be any "hard separations between curricular and extracurricular activities." on page no. 5.

The author assumed the challenges that inclusive education faces must also be the challenges that inclusive participation in co-curricular activities faces and found that it was indeed the case but not entirely which will be discussed later on. "For many teachers, extracurricular participation seems to be perceived as something that takes place during leisure time and may seem insignificant when it is compared with academic engagement" (Temesgen,2018). A few other types of research have similar findings, disabled students' lack of interest, and teachers who don't wish to organize the activity are all things that make co-curricular activities exclusive, along with social inequalities of course.

The independent variables decided to test were income, disability, familial caretaking and ethnic background while the

dependent variable was participation in co-curricular activities. To find a relationship between these factors and the dependent variable, a survey of thirteen questions (excluding introductory questions) was sent out to undergraduate students of K.R. Mangalam University and a total of 102 responses were recorded.

METHODOLOGY

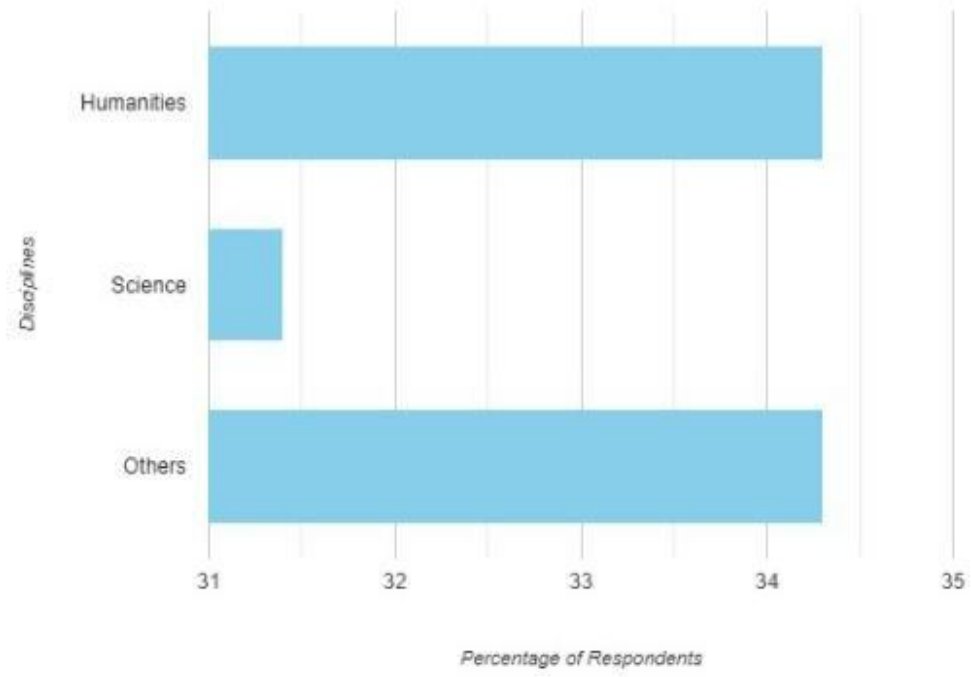
A survey was conducted and distributed among undergraduate students. The collected data was then categorized into two groups: Set A, comprising 48 responses from individuals who had not participated or had marginally participated in co-curricular activities, and Set B, which included 47 responses from individuals who regularly participated in such activities. Incomplete responses were excluded from further analysis. The mean responses to various questions for both sets were calculated and compared to determine the presence or absence of specific variables within the participative and non-participative groups. Subsequently, the data from both sets was recombined to facilitate further statistical analysis. Pearson's correlation coefficient was calculated for the variable of income, and chi-square tests were applied to examine the rest of the categorical variables.

DATA ANALYSIS AND FINDINGS

Demographic Profile of the Respondents

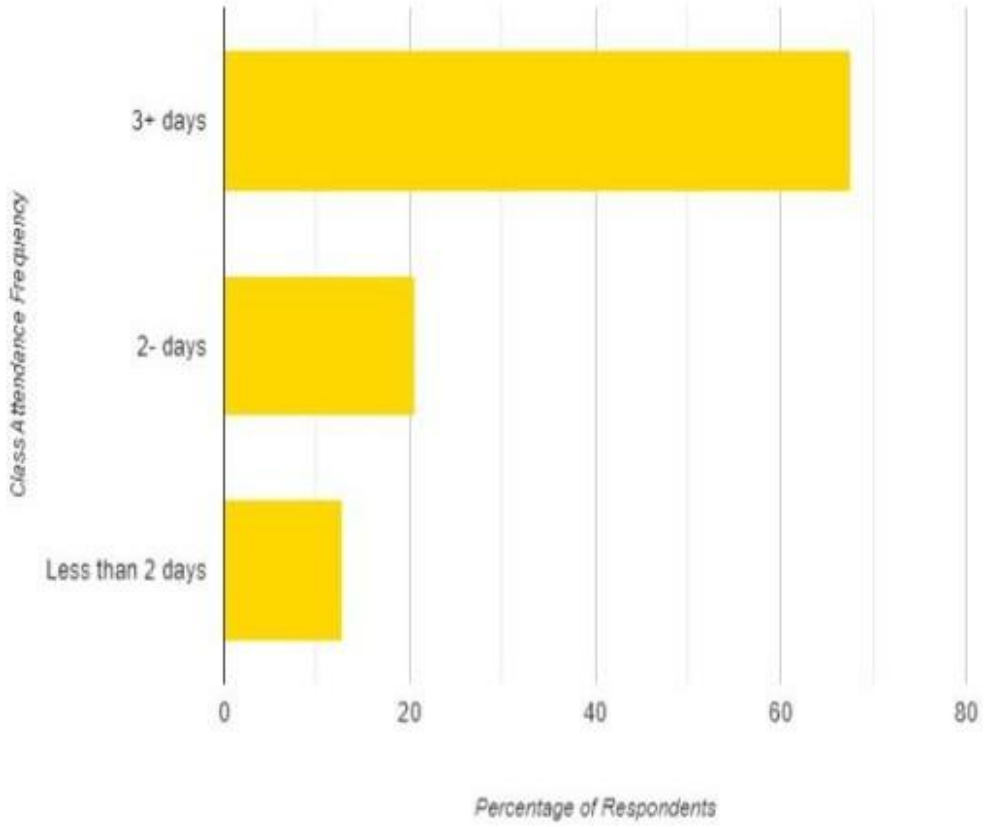
The 102 respondents primarily consisted of undergraduate students from K.R. Mangalam University, with 70% identifying as female and belonging to the 18-20 age group. The majority of respondents were from the fields of humanities (34.3%) and science (31.4%), though students from other disciplines were also represented. According to the data collected, a significant portion of these students demonstrated regular attendance, with 67.6% reporting that they attended classes on three or more days per week, while only 12.7% admitted attending classes fewer than two days per week.

Figure 1: *Distribution of Respondents by Discipline*



Source: Author’s Compilation

Figure 2: *Class Attendance Frequency of Respondents*



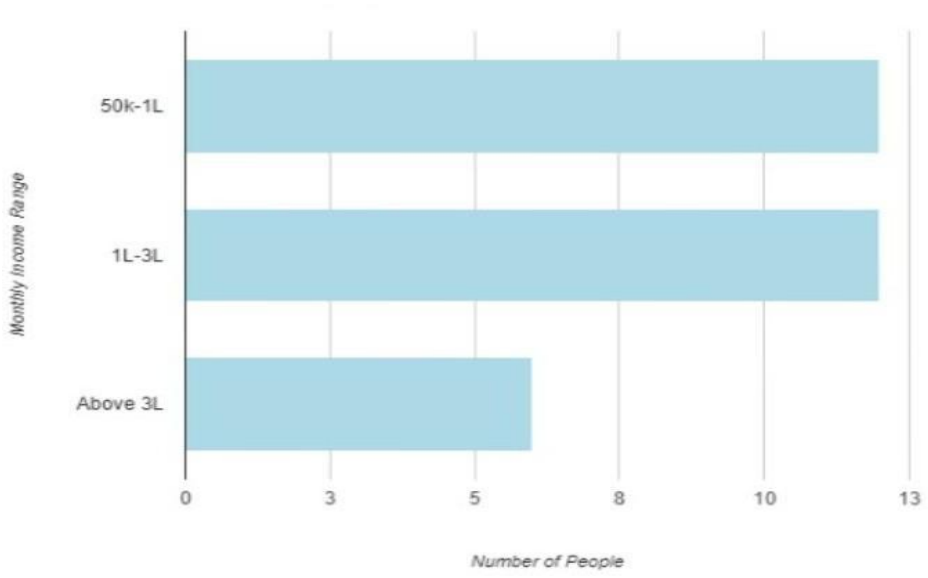
Source: Author's Compilation

By examining these underlying factors, targeted solutions can be developed to improve reliability and optimize network performance about participation patterns. The data analysis revealed that the average mean of respondents with disabilities in Set A (non-participative group) was 27.5, while Set B (participative group) recorded a lower average mean of 20.5. Furthermore, respondents who reported serving as primary caretakers for their families showed a mean value of 18.33 in Set A and 13.33 in Set B.

In terms of family income, most respondents in Set A reported a monthly family income in the range of ₹50,000 to ₹1 lakh, whereas, in Set B, respondents were evenly distributed between ₹50,000 to ₹1 lakh and ₹1 lakh to ₹3 lakh categories, with 12 responses recorded in each. Although there was no substantial difference observed in the means of respondents from different ethnic backgrounds across the two sets, it is important to note that the number of responses from individuals representing diverse states and ethnicities was exceptionally low.

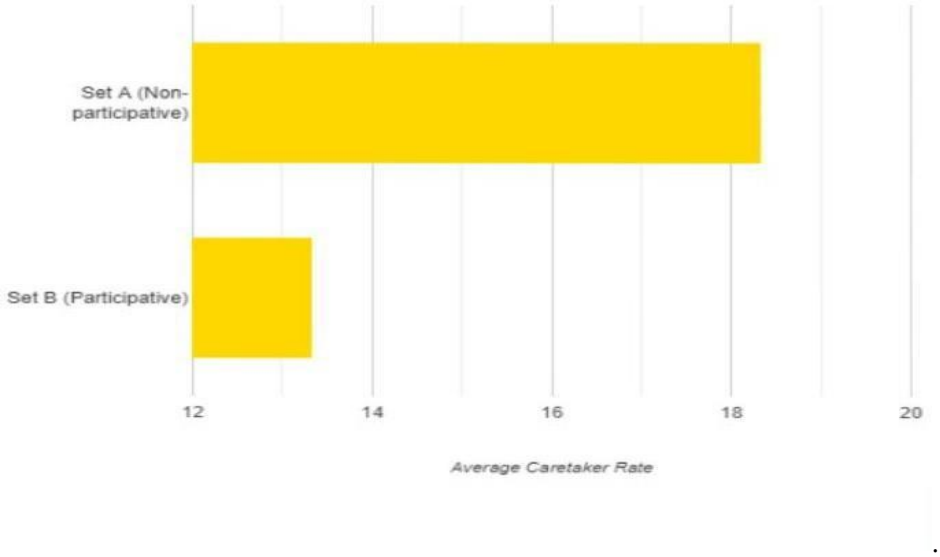
To address the first research question, the data suggests that, on average, individuals who actively participate in co-curricular activities tend to be able-bodied, 18-20-year-old female undergraduate students from the humanities or science streams. These students typically do not bear the responsibility of serving as primary family caretakers and are predominantly located within the Gurgaon or Delhi region. They also tend to come from families with medium to high monthly incomes. This demographic profile offers critical insights into the factors that influence co-curricular participation, laying the groundwork for further research and policy recommendations to enhance engagement in these activities among diverse student populations.

Figure 3: *Distribution of Monthly Income in Set B*



Source: Author's Compilation

Figure 4: *Average Caretaker Rate in Different Sets*



Source: Author's Compilation

Income Analysis

To see if these findings are valid to the data collected, the author calculated Pearson's correlation coefficient for the variable of income. The data was not treated separately for the next section of analysis. Below is the data collected in a table format, through the survey, this was not a required question and thus people who were comfortable sharing their monthly family income answered it and a total of 68 responses were recorded.

Table 1: *Income Range and Participation Data*

Income Range	*Participated*	*Did Not Participate*	*Total*
Below 50K	5	6	11
50K-1L	12	15	27
1L-3L (and above)	16	14	30
Total	*33*	*35*	*68*

Source: Author's Compilation

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

… eq. (1)

Putting the values of table 1 in eq(1) we get the Pearson's correlation coefficient.

The r or Spearman's coefficient was approximately r = 0.892, which indicates a strong positive correlation between income range and participation status which means that there is a tendency for individuals with a higher income range to participate more compared with those who have a lower one. The result was in line with what has been found in previous research; the correlation might have been even stronger if the sample size were greater.

Disability

Disability is another factor that could be a potential barrier to student participation, looking at the lack of infrastructure and awareness for disabled people. Despite efforts at making students with disabilities participate, the level of participation was low due to a lack of resources as well as teachers who knew how to cater to the different needs of such students (Castellary-López,2023). Another study found something similar, participation in extracurriculars for students with intellectual and developmental disabilities was valued by special educators and parents but still, very few students participated. (M. Argon, 2017).

To find a relationship between disability and participation in co-curricular so to decide whether this documented gap was relevant to this data, the author performed a chi-square test. The survey included mental health issues, PCOS and other hormonal disorders along with physical impairments, injuries and intellectual disabilities.

Table 2: *Disability Status and Participation*

Disability Status	*Participated*	*Did not Participate*	*Total*
Disabled	5	10	15
Not disabled	42	38	80
Total	47	48	95

Source: Author's Compilation

The chi-square (X^2) statistic is then used to find the p-value. The p-value is equal to one minus the area under the curve corresponding to the chi-square test statistic. A p-value equal to or less than .05 means the relationship between the variables is statistically significant.

Null hypothesis: There is no relationship between disability and participation in co-curricular activities.

The chi statistic, $X^2(1, N=95)= 1.856$, p= .173 (approx).

Since the p-value is greater than the significance level (.05), the null hypothesis cannot be rejected. This result may have been due to a small sample size and inappropriate sampling which means the survey simply did not reach more disabled students who could've given the necessary data, rather than there being no relationship between the two variables.

Ethnic Background

As Hamm and Brown cite, "Although adolescents in ethnically diverse school settings still tend to befriend peers from their ethnic background (Hamm, 2000; Joyner & Kao, 2000; Quillian & Campbell, 2003; Way & Chen, 2000)".

This statement might also imply that students would participate more if they saw people like them participating in extracurricular activities. Co-curricular activities are ideal to foster better multiethnic friendships in school goers, However, the author could not find many studies that explored if ethnicity played a role in participation. Some researchers found lesser participation and 'connection' from non-white students but not in the Indian context.

There are many students from the northeastern part of India in the university who are not very familiar with Hindi- the language spoken commonly. There are also students from other states and from Haryana itself who are not as familiar with English.

These linguistic and cultural barriers could be a factor in the lack of participation.

So to find a relationship between ethnic background and participation in co-curricular, a chi-square test was performed again.

Table 3: *Participation Based on Ethnic Background*

Ethnic background	*Participated*	*Did not participate*	*Total*
Different	5	20	25
Not different	42	28	70
Total	47	48	95

Source: Author's Compilation

Null hypothesis: There is no relationship between ethnic backgrounds and participating in co-curricular activities.

$X^2(1, N=95)= 11.7908$, $p= .00595$ (approx) Which is less than the significance level (.05). This means that we can reject the null hypothesis. The relationship between one's ethnic background and participation in co-curricular activities is statistically significant.

The p-value could've been even lower had the sample size been greater and the 'different ethnic background' been defined and made clearer to the respondents. It is to be noted that a chi-square test does not establish a correlation and does not deny it either.

Caretaking for Family

Research directly exploring the specific relationship between caretaking and participation in co-curricular activities is very limited. However, it is a general concept that caretaking and co-curricular activities have a symbiotic relationship with each other, helping in the holistic development of the individual. Naturally, caretaking for a family member is time-consuming and exhaustive and hence can be the reason for reduced participation for a certain group of people. The author could not find a piece of work that directly explored this problem. To find a relationship between being a caretaker and participation, a chi-square test was performed again.

Table 4: *Participation Based on Caretaker Status*

Caretaker	*Participated*	*Did not participate*	*Total*
Yes	14	17	31
No	33	31	64
Total	47	48	95

Source: Author's Compilation

Null hypothesis: There is no relationship between familial caretaking and participation.

$X^2(1, N=95)= .3423$, $p= .55$ (approx)

The p-value is greater than the significance level and thus is insufficient to reject the null hypothesis. This result might be explained by the fact that Indian families are collectivistic and bigger and thus become a source of financial as well as emotional support thus, the students even when they must take on caregiving roles, it is not as impactful in both academic and co-curricular performance. But it is important to note that even in such a small sample size and young undergrad students, 32% of people are caretakers for their family in some way and most institutions do not have that in mind. It is then a great possibility that with a greater or older sample size, the p-value could be statistically significant.

RESULTS AND DISCUSSIONS

The paper established that only two dependent variables had a relationship with participation in co-curricular activities. It was found that there was a weak negative correlation between income and participation, alongside a statistically significant relationship between different ethnic backgrounds and participation. Notably, the most frequent responses to the question, "Why do you not participate in co-curricular activities?" included, "I become anxious" and "We have classes during the activities," followed by "The activities are uninteresting." This trend is consistent with prior studies, where similar reasons were cited as significant deterrents to student participation.

Schools often face numerous challenges, including staff shortages and infrastructure limitations, which contribute to a limited range of co-curricular programs. The predominant focus on academic achievement, coupled with a tendency to replicate activities from other institutions, has hindered the variety and uniqueness of co-curricular offerings. Participation and interest in such activities have also been stifled by factors such as financial constraints, an increased focus on academic responsibilities, time pressures, and a general perception of low value associated with these activities. Other significant barriers include the

remote location of schools and the denial of opportunities for students. Furthermore, requirements for uniforms and materials have deterred students from engaging in co-curricular activities (Dimbie, 2021). Despite these challenges being frequently mentioned in various contexts, they have not been extensively studied in existing literature.

To enhance inclusivity in co-curricular activities, a multifaceted approach must be considered. Reducing the competitive nature of co-curricular programs is critical. A significant number of students (42) reported anxiety as a major barrier to participation, linked to feelings of discomfort and self-consciousness in competitive settings. Social anxiety, which often begins during early adolescence around the age of 13, combined with introversion—an established personality trait—further exacerbates these feelings. To address this, activities should be designed with a reduced emphasis on competition and social interaction. By fostering less pressure-intensive environments, schools can encourage students prone to anxiety or introversion to participate more comfortably.

The provision of a diverse range of activity options is also essential for fostering broad participation. Educational institutions should extend their co-curricular offerings beyond traditional choices to include artistic, cultural, and niche activities that appeal to varied interests, talents, and cultural backgrounds. By expanding these options, schools can encourage a wider range of students with different preferences and abilities to engage, thereby creating a more inclusive environment.

Accessibility must be a core consideration for promoting inclusivity. This includes both physical and financial aspects. Institutions need to ensure that co-curricular activities are accessible to all students, regardless of financial capacity or physical ability. Providing resources such as transportation, necessary equipment, and accommodations for students with disabilities is crucial. Additionally, addressing financial barriers through measures such as scholarships or free participation can ensure that students from all backgrounds have the opportunity to engage in co-curricular life.

Recognizing the demanding schedules that students often face, schools should consider flexible participation options to accommodate diverse commitments. Offering activities at various times, providing alternative formats such as online or hybrid options, and coordinating activities to fit around students' academic and personal schedules can help reduce the pressure of competing obligations. This flexibility promotes inclusivity by allowing more students to participate without feeling overwhelmed.

Integrating co-curricular activities into the formal curriculum could significantly elevate the importance of these programs. This integration might involve awarding academic credit for participation or weaving co-curricular experiences into coursework. Such strategies emphasize the value of these activities and ensure that all students are encouraged to participate. By treating co-curricular engagement as an essential part of the educational experience, schools can promote a culture that supports holistic development.

Raising awareness through targeted campaigns is also fundamental for fostering inclusivity. Students need to be informed about the range of co-curricular activities available to them and motivated to explore activities beyond their usual interests. Highlighting success stories of students from diverse backgrounds can inspire participation and help potential participants feel more confident in their involvement. Awareness campaigns should also provide clear information on how students can get involved, which may reduce any initial hesitation or uncertainty.

Sensitizing teachers and students to diversity is crucial for genuine inclusivity. Educators and student leaders must be aware of the cultural, religious, caste, and linguistic diversity present among students. Furthermore, understanding how various disabilities affect participation is essential. Since teachers, coaches, and student leaders often facilitate these activities, their awareness and sensitivity to the challenges faced by diverse student groups are necessary for fostering a supportive environment. Training programs aimed at equipping facilitators with the knowledge to accommodate unique needs can help create a welcoming and inclusive space for all students.

Finally, co-curricular activities should be designed to cater to different personality types and learning styles. Students with introverted personalities may prefer individual or reflective activities, while extroverted students might enjoy group settings. Similarly, activities should incorporate various learning preferences, such as experiential, visual, or auditory approaches. By considering the diverse personality traits and learning styles of students, schools can foster an environment that makes participation more appealing and comfortable for all.

In conclusion, promoting inclusivity in co-curricular activities requires a comprehensive approach. By reducing the competitive nature of activities, offering a diverse range of options, ensuring accessibility, providing flexible participation opportunities, and integrating these activities into the curriculum, educational institutions can create a more supportive and inclusive environment. Raising awareness about available activities and sensitizing faculty and students to the needs of their peers can help remove participation barriers. These concerted efforts will lead to a richer and more inclusive co-curricular experience for students.

FUTURE RESEARCH DIRECTIONS

While the current study highlighted significant relationships between income, ethnic background, and participation in co-curricular activities, several vital factors remain underexplored and merit further investigation. Future research should build upon these findings by examining the intricate ways in which psychological and personality-related aspects—such as different personality traits and social anxiety—intersect with socioeconomic factors to influence students' participation in co-curricular activities.

One promising direction for future research is to delve into the role that personality traits and social anxiety play in student engagement in co-curricular programs. Introverted students, for example, may face heightened discomfort in group activities or competitive environments, which may discourage them from participating. Social anxiety, which is particularly common in adolescents, may further inhibit students' willingness to join co-curricular activities. Investigating how these psychological factors interact with social and economic conditions could provide a more nuanced understanding of barriers to participation. Moreover, studies assessing the effectiveness of co-curricular programs specifically designed to support students who are introverted or prone to social anxiety could offer practical insights for improving participation rates.

In addition to personality traits, the impact of caretaking responsibilities and ethnic background on co-curricular participation deserves further examination. Previous research has shown that socioeconomic factors influence participation; however, understanding how life circumstances such as caregiving duties interact with ethnic background to impact student engagement could provide deeper insights. For instance, students from minority ethnic backgrounds may face additional challenges, including cultural expectations, language barriers, and financial constraints, that could hinder their participation. Similarly, students who serve as primary caregivers for family members may struggle to find time for co-curricular involvement. Future empirical studies that investigate these intersections can offer more comprehensive insights into the multi-faceted influences on participation and help educational institutions develop better support mechanisms.

While the current study has addressed income and ethnic background, future research should focus on quantifying other specific barriers to participation. Factors such as lack of interest, tight academic schedules, and various disabilities—both visible and hidden—require further exploration. Empirical research using surveys and data analysis could yield targeted strategies for overcoming these obstacles. For instance, studies could investigate how these barriers differ across demographics and evaluate whether alternative solutions, like flexible or hybrid participation options, help alleviate time constraints experienced by students with heavy academic or personal responsibilities.

The long-term effects of co-curricular involvement on student development is another area that requires more in-depth investigation. While many studies have focused on short-term outcomes, longitudinal research could reveal how participation impacts students' academic success, personal growth, and mental health over time. Such studies could follow students to determine whether early participation in inclusive co-curricular programs contributes to sustained academic achievement, stronger social skills, and overall well-being, particularly for those facing socio-economic or psychological challenges.

Furthermore, it would be valuable for future research to examine how institutional policies and practices around co-curricular programs can be restructured to enhance inclusivity. Understanding how different program structures—whether voluntary or compulsory, competitive or non-competitive—affect diverse student groups, particularly those underrepresented in such activities, would be insightful. Additionally, assessing the success of various inclusivity measures, such as incorporating co-curricular activities into the curriculum, offering financial aid, or providing a range of options that cater to diverse interests, would enable institutions to develop more evidence-based strategies for fostering inclusivity.

Applying an intersectional approach to the study of co-curricular participation is also crucial for future research. Students have complex, intersecting identities that influence their experiences in educational settings. Exploring how multiple factors—such as gender, socio-economic status, ethnicity, personality traits, and mental health—interact to affect co-curricular engagement could yield a more holistic understanding of the barriers that students encounter. This approach would be particularly beneficial for identifying doubly disadvantaged students, such as those from low-income backgrounds who also experience social anxiety, and developing tailored solutions that meet their unique needs.

In conclusion, while this study has provided valuable insights into the socio-economic influences on co-curricular participation, further research is needed to explore the psychological and personality-related dimensions of student engagement. Investigating personality types, social anxiety, caretaking roles, and specific disabilities, and how these elements intersect with ethnic and socio-economic backgrounds, will provide a more thorough understanding of the barriers students face. Such research can inform the development of more inclusive and supportive co-curricular programs, ensuring that all students have the opportunity to thrive.

CONCLUSION

This research aimed to find what would make co-curricular activities more inclusive and accessible to people with varying

needs. From increasing the academic performance, and self-efficacy of students to making them more career-ready; co-curricular activities have established themselves as more than just extra activities that are optional and are also great places to foster multicultural friendships. But despite their well-known value, only a few people participate voluntarily. Social inequalities have been deterring inclusive education and the author assumed similar challenges must be making it difficult for students to participate in these supplementary activities. Previous research and analysis of the data collected by the author are consistent with the finding that low income is correlated with low participation. However, Pearson's coefficient indicated a very weak correlation which might have been due to a small sample size. The second variable that the author successfully proved was related to participation in co-curricular activities was a different ethnic background. Even for a small sample size the chi-square statistic indicated a statistically significant relationship between the variables which the author has observed personally as well. This chapter could not establish a relationship between familial caretaking and disability with participation in co-curricular activities, which can be attributed to a small sample size, possible confusion of respondents as to what constitutes disability, caretaking etc and inappropriate sampling. It is in the author's opinion, a more likely possibility that the survey simply did not reach people with disability and familial responsibility rather than there being no relationship between the said factor and student participation because there is a noticeable difference in the means of set A and B, indicating that there are more disabled and caretaking people in the non-participative set. The analysis also revealed that more reasons for non-participation may be lack of interest, social anxiety and a busy timetable but whether they have more influence on participation than the variables tested cannot be said. There is certainly more to this story than just social inequality that needs more digging. The author concludes by acknowledging the various limitations of this chapter that caused it to not fully fulfil its objectives and hopes that despite the flaws this paper added something valuable to the process of making co-curricular activities more inclusive.

ETHICAL DECLARATION

Conflict of interest: The author declares that there is no conflict of interest regarding the publication of this paper**.**
Financing: This research received no external funding.
Peer review: Double anonymous peer review.

REFERENCES

Agran, M., Wojcik, A., Cain, I., Thoma, C., Achola, E., Austin, K. M., Nixon, C. A., & Tamura, R. B. (2017). Participation of students with intellectual and developmental disabilities in extracurricular activities: Does inclusion end at 3:00? *Education and Training in Autism and Developmental Disabilities*, *52*(1), 3–12. https://www.jstor.org/stable/26420371

Castellary-López, M., Figueredo-Canosa, V., Muñoz-Muñoz, J. R., & Ortiz-Jiménez, L. (2023). Participation of students with special educational needs (SEN) in extracurricular activities in compulsory education. *Education Sciences*.

Christison. (2013). The benefits of participating in extracurricular activities. *ERIC*. https://files.eric.ed.gov

O'Brien, E. (n.d.). Extracurricular participation and student engagement. *National Center for Education Statistics*. https://nces.ed.gov

Hamm, J. V., Brown, B. B., & Heck, D. J. (2005). Bridging the ethnic divide: Student and school characteristics in African American, Asian-descent, Latino, and White adolescents' cross-ethnic friend nominations. *Journal of Research on Adolescence*.

Kim, S. Y., & Lee, M. K. (2016). A study on students' perceptions and needs about college extracurricular programs. *Journal of Learner-Centered Curriculum and Instruction.*

Kocayiğit, A., & Ekinci, N. (2020). Evaluation of extracurricular activities implemented in high schools according to teachers' opinions. *OPUS International Journal of Society Researches*.

Köse, E. (2013). A suggestion for the classification of extracurricular activities in educational institutions. *International Journal of Turkish Literature, Culture, and Education*.

Mulrooney. (2017). Exploring participation in co-curricular activities among undergraduate students. *ERIC*. https://files.eric.ed.gov

YÖK (Council of Higher Education). (2007). *Teacher education and faculties of education (1982−2007)*. Higher Education Board Publication.

Lareau, A. (2011). *Unequal childhoods: Class, race, and family life*. University of California Press.

Dimbie, M., Kafui, A. S., & Eduam, M. A. (2021). School-based co-curricular activities and teachers' challenges in Ghana. *Indiana Journal of Arts & Literature*.

Olsson, E. (2007). The economic side of social relations: Household poverty, adolescents' resources, and peer relations. *European Sociological Review*, *23*(4), 471–485.

Sidhu, K. S. (2001). *School organization and management*. Sterling Publishers Pvt. Ltd.

Hjalmarsson, S. (2023). Pay to play? Economic constraints and participation in extracurricular activities. *European Sociological Review*, *39*(4), 586–600. https://doi.org/10.1093/esr/jcac061

Temesgen. (2018). School factors against co-curricular participation of students with mobility problems. *ERIC*. https://files.eric.ed.gov

University of Bath. (2019, July 19). Huge disparities in participation in extracurricular activities depending on social background. *University of Bath Announcements*. https://www.bath.ac.uk/announcements/huge-disparities-in-participation-in-extra-curricular-activities-depending-on-social-background/

Additional Reading

UNICEF. (n.d.). *Inclusive education.* https://www.unicef.org/education/inclusive-education

SOU 2008:59. (2008). *Föreningsfostran och tävlingsfostran – En utvärdering av statens stöd till idrotten*.

The Swedish Agency for Youth and Civil Society. (2014). *Fokus 14: Ungas fritid och organisering*.

Jonsson, J. O., & Mood, C. (2014). *Poverty and welfare among children and their families 1968-2010*. Institute for Futures Studies.

Wright State University. (2007). *Inclusive education in India*. https://corescholar.libraries.wright.edu

International Journal of Convergent Research (IJCR)
Telephone No.: +91 70426 57038,
Phone No.: +91 88606 72581
mail: editorinchief@ijcres.in, managingeditor@ijcres.in
https://ijcres.in/index.php/ijcr