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Research Article

AI And CMMS: A Powerful Duo For Enhanced Maintenance In Manufacturing

Lakshmi Shankar[1*], Chandan Deep Singh[2], Ranjit Singh[3]

[1*]Department of Mechanical Engineering, Punjabi University Patiala, Punjab,147002, India, shankar@pbi.ac.in
[2]Department of Mechanical Engineering, Punjabi University Patiala, Punjab,147002, India, chandandeep@pbi.ac.in
[3]Department of Mechanical Engineering, SGGSWU, Fatehgarh Sahib, Punjab,140413, India, ranjitsingh@sggswu.edu.in

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ABSTRACT

The paper investigated the integration of Artificial Intelligence (AI) with Computerized Maintenance Management Systems (CMMS) in manufacturing industries to enhance maintenance performance. By leveraging AI algorithms, including machine learning and predictive analytics, CMMS can predict equipment failures, optimize maintenance schedules, and automate asset management processes. The study is descriptive and conducted with the help of secondary data. Research papers, books, journals, newspapers, and continuing academic working papers are the sources of secondary data. This proactive approach minimizes downtime, reduces operational costs, and extends asset lifespan. The literature review highlights key themes such as AI's impact on maintenance performance metrics and the limitations of current technologies. Despite benefits, challenges like high implementation costs and workforce displacement concerns exist. The study concludes that AI-enhanced CMMS streamlines maintenance work-flows, improves decision-making, and enhances overall equipment effectiveness. Future research opportunities include refining AI algorithms, optimizing technology integration, and exploring sustainability impacts. This research contributes to understanding the transformative potential of AI in manufacturing maintenance.

Keywords: Artificial Intelligence (AI), Computerized Maintenance Management System (CMMS), Manufacturing Industries.

1. Introduction

"Artificial intelligence" has revolutionized contemporary manufacturing, profoundly impacting various facets of the industry. Through advanced algorithms and machine learning techniques, AI has become instrumental in boosting productivity and product quality while simultaneously reducing costs (Buchmeister, et al., 2019). One of the primary contributions of AI lies in predictive maintenance, where AI-powered systems analyze vast amounts of data to forecast maintenance requirements, thereby preventing unexpected downtime and optimizing production schedules. Additionally, AI facilitates customization through virtual reality (VR) and augmented reality (AR) technologies, allowing manufacturers to tailor products according to individual customer needs (Arinez, et al., 2020). Moreover, the integration of AI in manufacturing has facilitated the creation of networked factories, enabling real-time monitoring and coordination across multiple production units. By identifying defects and anomalies in the production process, AI enhances quality assurance, ensuring that only products of the highest standards reach the market (Khan, and Javaid, 2022).

Integrating AI into manufacturing operations requires a deliberate approach that involves multiple critical components. Identifying appropriate applications of AI in the production process is essential for leveraging its advantages. This entails evaluating areas where AI can provide the most substantial enhancements in productivity, quality, and efficiency. It is crucial to have a strong data architecture to allow AI systems to analyze and extract valuable insights from the large volumes of data produced in the manufacturing process. It is essential to train a skilled workforce that can properly use AI technologies (Crain, 2003). This entails equipping personnel with the essential skills and expertise to operate AI-driven systems and analyze the insights they provide. technology is crucial to think about the ethical consequences of using AI to make sure technology is used responsibly and to reduce hazards related to automation and data-driven decision-making. Manufacturers may fully utilize AI by focusing on five important factors to improve their operations and stay competitive in the constantly changing manufacturing industry (Rastegari, and Mobin, 2016).

1.1 Artificial Intelligence in Manufacturing Maintenance

AI is the technology that enables computers to mimic human thinking and reasoning. AI originates from robotics, computer vision, natural language processing, cloud computing, and other related fields. AI technologies are transforming manufacturing maintenance through predictive maintenance tactics that use real-time data analysis to forecast asset failures, improve maintenance schedules, and boost operational efficiency. AI technologies in manufacturing industries evaluate usage patterns, vibration, and noise to predict machine breakdowns, allowing for preventative maintenance to save downtime and improve asset performance (Hrnjica, and Softic, 2020). Manufacturers may enhance production processes, lower maintenance expenses, and enhance workplace safety by incorporating AI-powered predictive maintenance solutions to anticipate and prevent equipment breakdowns. Implementing AI in manufacturing maintenance signifies a significant change toward proactive and data-driven methods that improve asset reliability and performance, reduce costs, enhance workplace safety, and boost operational efficiency in the manufacturing sector (Javaid, et al., 2022).

AI technologies are revolutionizing maintenance procedures and improving equipment reliability in different industries. An AI-driven predictive maintenance system can help avoid asset malfunctions and unexpected periods of inactivity. An AI-driven predictive maintenance system is a potent tool that aids maintenance and reliability experts in efficiently extracting valuable insights from machine health and performance data to enhance manufacturing processes (Zonta, et al., 2020). AI systems use predictive maintenance to examine past equipment data and forecast possible failures, allowing for proactive maintenance actions that reduce downtime and enhance asset efficiency. Advanced technologies enable enterprises to transition from reactive to proactive maintenance strategies, allowing for prompt interventions to prevent unforeseen breakdowns and optimize maintenance schedules (Dhyani, 2021). AI-driven predictive maintenance offers advantages such as higher equipment availability, lower operational expenses, better safety, and increased overall productivity. AI systems use machine learning algorithms and real-time data analysis to predict equipment malfunctions in advance, enhancing safety and reliability in manufacturing operations and optimizing asset lifespan and operational efficiency (Kobbacy, 2012).

1.2 Computerized Maintenance Management Systems

A CMMS is a software tool designed to assist corporations in overseeing and preserving their tangible assets, including automobiles, machinery, and infrastructure. The system arranges maintenance data and simplifies maintenance operations, enabling improved management of budgets, expenses, and maintenance activities (Stazić, et al., 2023). CMMS systems can be either on-premise or cloud based. They assist teams in planning, monitoring, and reporting maintenance tasks, tracking work orders, and scheduling maintenance. They are utilized in diverse sectors like manufacturing industries, health care, and facilities management to improve maintenance procedures and handling of assets (Zemmouchi, et al., 2020). CMMS encompasses essential elements and functions such as:

i) **Asset Management**: A CMMS helps manage assets by monitoring details such as purchase date, price, owner, user, and manufacturer's warranty.
ii) **Labor Resource Management:** The system enables monitoring of employee personnel records, skill levels, billing rates, contact information, attendance, productivity, and overtime hours.
iii) **Preventive Maintenance:** Automates work orders by utilizing usage, time, or triggered events to prevent breakdowns and prolong asset lifespan.
iv) **Inventory Management:** Monitors inventory levels and spare component locations, automatically sending alerts for low stock to facilitate timely maintenance chores.
v) **Work Order Management**: Oversees work orders by managing order numbers, outline, priority, order type (repair, substitute, or schedule), and asset data.
vi) **Facilities Management:** Concentrates on repairing and maintaining facilities to ensure they are in good condition by promptly addressing any concerns that emerge.
vii) **Reporting and Analysis:** Facilitates rapid data access for analysis to detect vulnerabilities and save downtime by conducting routine inspections and preventative maintenance.

1.3 Importance of CMMS in Streamlining Maintenance Processes in Manufacturing

CMMS is essential for optimizing maintenance procedures in industrial facilities by providing a centralized system to effectively oversee maintenance tasks (Shankar, et al., 2021). Here are the primary reasons why CMMS is crucial in manufacturing:

i) **Streamlined Work Order Management**: CMMS software offers maintenance managers a consolidated platform to efficiently manage work orders from submission to completion. This automation streamlines the process, improves communication, minimizes errors, and increases overall efficiency.
ii) **Preventive Maintenance and Equipment Reliability**: CMMS software allows manufacturing firms to efficiently schedule preventive maintenance work, reducing unexpected downtime and enhancing equipment reliability. CMMS helps prolong equipment lifespan and enhance factory productivity by overseeing inspections, servicing, and part replacements in advance.

iii) **Inventory and Spare Parts Management**: Effective inventory control is essential for maintaining continuous factory operations. CMMS software helps optimize inventory levels by tracking spare parts, issuing purchase orders, and maintaining supplier information to avoid stock outs and lower carrying costs.
iv) **Enhanced Reporting and Analytics**: CMMS software provides strong reporting and analytics features that enable maintenance managers to make decisions based on data. CMMS offers useful insights for continuous improvement by producing detailed reports on maintenance activities, equipment downtime, prices, and performance trends.
v) **Compliance and Regulatory Requirements**: Manufacturing facilities must comply with multiple regulatory standards and safety protocols. A CMMS streamlines compliance management by consolidating documentation, inspection records, and maintenance logs to ensure efficient adherence to laws.
vi) **Asset Performance Monitoring**: CMMS offers immediate insight into asset performance and condition by gathering data from sensors, equipment readings, and maintenance records. This allows for predictive maintenance plans, early issue detection, and efficient maintenance actions to minimize downtime and improve equipment dependability.

This review paper examines the “role of artificial intelligence (AI) in enhancing maintenance performance within manufacturing industries through the integration of CMMS”. It assesses how AI solutions like predictive maintenance and improved scheduling can boost equipment durability, decrease downtime, and improve operational efficiency.
The seven sections that make up this review study are as follows. The initial segment showcases an introduction to the impact of emerging technologies on organizational structure, its definitions, and its significance. A review of the literature is given in the second section. The third section provides the objectives of the present review paper. The fourth section is applied to the research methodology that describes the study's overall approach, and data collection methods. This is followed by the fifth section which presents the discussion by previous authors on the objectives of the present review paper. The sixth section presents the conclusion which summarizes the main findings and significant aspects of the study. Future scope are presented in section seven.

2. Literature Review

The study employed adaptive structuration theory in a quick evidence evaluation that investigated the impact of artificial intelligence and predictive maintenance on reducing costs in facility operations programs. The study quickly evaluated predictive maintenance and artificial intelligence in facility operations by analyzing peer-reviewed scholarly articles published in the past 5 years through a systematic review approach. The rapid evidence assessment identified three key topics that address the research issue. The primary focus revolved around artificial intelligence, which processed data and provided impartial investment and maintenance suggestions. The study identified a lack of data as the primary obstacle to fully using AI in facility operations programs, a finding that was surprising(Scaife, A. D., 2023).
The paper attempted to assess the existing level of digitalization in energy-intensive sectors and suggested a framework to facilitate the implementation of sustainable smart manufacturing in "energy-intensive sectors" (EIIs). The study showcased the utilization of different software tools for various layers. The study's results showed that the suggested digital life-cycle framework aided energy-intensive industries in achieving sustainable smart manufacturing by enhancing their comprehension of energy-intensive processes. The study enhanced comprehension of the incorporation of process mining, simulation, and modeling in the setting of EIIs (Chinnathai, and Alkan, 2023). The study revealed numerous AI-LCE studies focusing on Sustainable Development Goals, particularly Industry, Innovation, and Infrastructure; Sustainable Cities and Communities; and Responsible Consumption and Production. The study provided an overview of the various AI techniques utilized in LCE. The most researched LCE sub fields were production design, maintenance, and repair, whereas logistics and procurement were the least researched subareas. AI-LCE research was mostly focused on a small number of powerful countries that have significant research budgets and a specific emphasis on Industry 4.0. Germany was distinguished by numerous publications (Rahman, et al., 2022).
The author investigated the effects of AI applications in manufacturing and industrial production to offer guidance to engineering managers. The ramifications of adopting AI techniques in manufacturing and industrial production systems were examined in terms of political, economic, social, and technical (PEST) issues. This study did not introduce a new engineering management model. The study was designed to help engineering managers without expertise in AI or data science evaluate the implications of using AI in various applications (Akinsolu, 2022).
Some authors put efforts on creating and confirming a framework for a data-based tool to measure the criticality of machines. The tool facilitated prioritizing and planning maintenance decisions with the specific aim of enhancing productivity. Four empirical instances were analyzed using a multiple-case research methodology. The framework offered guidance for maintenance decision-making by integrating Manufacturing Execution System and CMMS data from a systems perspective. Utilized data-driven decision

support in maintenance organizations that enhanced productivity in current digitalized manufacturing systems (Gopalakrishnan, et al., 2022).
Researchers emphasized on the importance of artificial intelligence and the need for a well-defined plan and strategic financial commitment in this field. The advancement of AI from science fiction to a leading edge of transformative technologies necessitates a methodical approach to its development and integration to realize its full potential in the upcoming era of industrial systems, particularly Industry 4.0. This study provided an understanding of the state of AI technologies at the moment and the environment required to use AI effectively in industrial applications (Lee, et al., 2018).
Researchers outlined the contribution of AI in the implementation of Industry 4.0. that it leads to increase in productivity and efficiency of the machine and equipment, at the same time it reducing the operation cost of the industry by collaborating between human and robots. AI provide the warning of malfunction of the machines and suitable information for informed decisions. For this data from the AI connected machines are collected by internet of things for processing purpose and promptimg for the informed decision. AI also helps the industries in achieving desired goals of the Industry 4.0. (Javed, Mohd, et al., 2022)
Digital maintenance concept is elaborated with the help of input factors like condition monitoring sensors, data repository and directly from users are processed to achieve output as maintenance recommendation, information to others working areas and automatic actions. Digital maintenance is supposed to act as system processor. Features of digital maintenance like modularity in design, decentralization, scalability decentralization, interoperability, digitization, economic key performance indicators and real-time ability are explored to achieve output from the digital maintenance (Algabroun, H., et al., (2022).
Some researchers have explored the application of machine learning in the planning of prediction maintenance for manufacturing industries. Recurrent neural network is used for the development of the Predictive maintenance planning model which are executed in following stages firstly data cleaning, data normalization, after that optimal feature selection decision network then prediction (Abidi MH et al,. 2022).
In oil and gas sector, AI is employed to assess the number of accidents for process safety purpose and ultimately to reduce the incidents with AI application. AI helped to improve the asset integrity and reliability by following step wise classifying, prioritizing, ranking or ordering the resources for reducing the accidents and enhancing safety through theoretical framework (Sattari, F., et al., 2022). In the health care department, AI also employed for the maintenance management and performance prediction of the machinery and equipment. The explored benefits of AI in maintenance management to reduce downtime and to optimize operations, better security , cost saving and better user experience (Pokvić, L. G., et al., 2023). AI when integrated with CMMS led to decrease the breakdowns in off-shore operations known as BASSNET. The shortcomings of BASSNET also proposed. PREDIX and HDP (hybrid data platform) modules of AI are used to remove the shortcomings (Pandey, D. K., et al., 2020).
It is observed from the literature review that application of AI with CMMS will lead to multiple benefits to the many organizations by enhancing the productivity, reducing downtime, reducing accidents, reducing energy consumption, and increasing the availability of assets and enhancing the asset integrity management and reliability through digitization, smart manufacturing, internet of things, internet of service, cyber-physical system and industrial internet of things.

3. Objectives

a) To investigate the integration of AI technologies with CMMS in Manufacturing Industries.
b) To assess the impact of AI-enhanced CMMS on maintenance performance metrics.
c) To discuss the limitations of current AI technologies and CMMS platforms.

4. Methodology

The Role of Artificial Intelligence in Enhancing Maintenance Performance through CMMS in Manufacturing Industries aims to describe thoroughly and explore the effect of AI on enhancing maintenance performance in manufacturing industries by using CMMS. The study is conducted with the help of secondary data. Research papers, books, journals, newspapers, and continuing academic working papers are the sources of secondary data. The purpose of this study is to provide insights and recommendations that may be put into action to improve maintenance procedures in manufacturing industries through the strategic integration of artificial intelligence with CMMS.

5. Discussion

i) To Investigate the Integration of AI Technologies with CMMS in Manufacturing Industries

Integrating AI in manufacturing can enhance productivity, and flexibility, minimize errors, and provide real-time optimization of operations. Integration is the amalgamation of all components of the production system, which includes machines, products, and control systems, by utilizing sensors and actuators. These elements are then linked with other essential entities like customers, suppliers, logistics, transportation, maintenance, and production management (Pillai, et al., 2022). Integrating AI technology with CMMS in manufacturing

industries signifies an enormous shift in maintenance techniques. By integrating AI algorithms and “Internet of Things” sensors into CMMS software, firms may transition from reactive to proactive maintenance strategies (Shaheen, and Németh, 2022). AI-powered predictive maintenance enables early identification of equipment concerns to save downtime and avert expensive breakdowns. This predictive capability is powered by machine learning models that examine historical data, equipment performance measurements, and environmental conditions to correctly forecast maintenance needs. Furthermore, automating maintenance schedule using AI improves efficiency by optimizing maintenance chores according to current equipment status, usage patterns, and past maintenance data (El Maraghy, et al., 2021).

From the above discussion, it is clear that integrating AI with CMMS improves maintenance efficiency and transforms asset management methods in industrial companies. ‘Internet of Things’ based devices collect a large data that AI algorithms may analyze to identify trends, patterns, and irregularities in equipment performance. This data-centric method enables maintenance teams to make well-informed decisions on asset conditions, usage rates, and life cycle management (Durbhaka, 2021). Companies may use AI insights to prioritize important maintenance chores, distribute resources efficiently, and prolong the lifespan of their assets. Integrating "augmented reality" (AR) and "virtual reality" (VR) technology into CMMS systems enables remote maintenance chores, facilitating technicians in identifying issues and seeking assistance from specialists regardless of their location (Rojek, et al., 2023).

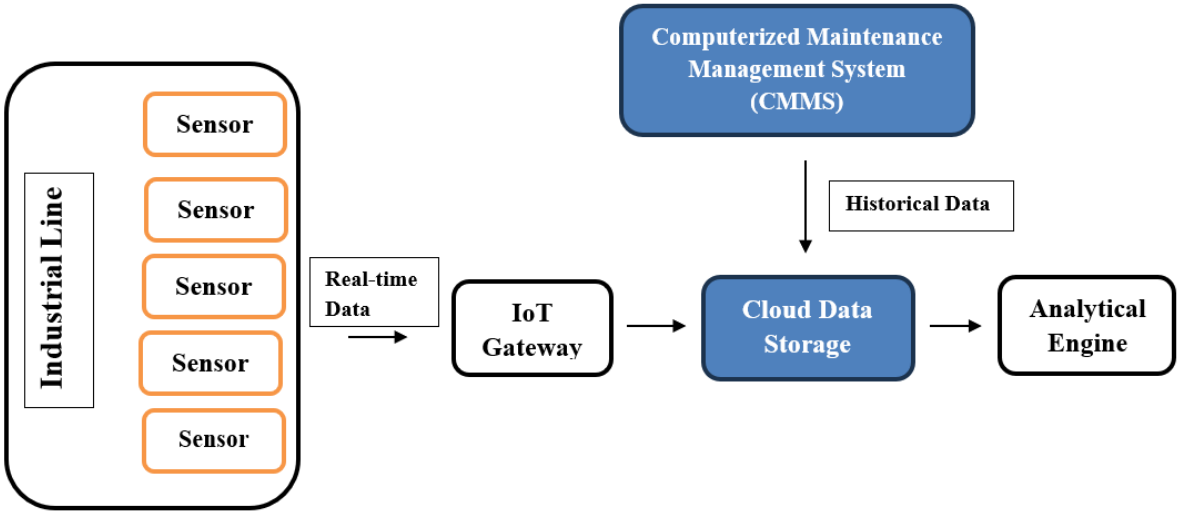

Figure 1.1: Predictive Maintenance IT Infrastructure
Source: Hassan, et.al., (2021)

ii) To assess the impact of AI-enhanced CMMS on maintenance performance metrics.

AI provides the manufacturing sector with strategies to remain competitive and effective in a constantly evolving environment. Manufacturers are finding new ways to improve operations, increase efficiency, and lower costs, thus revolutionizing the business. AI enhances digital technology and enhances manufacturers' core operations in the era of smart manufacturing. It facilitates more efficient work by enhancing human capabilities, fostering collaboration between humans and machines rather than replacing human workers (Bonada, et al., 2020). Artificial Intelligence is transforming the manufacturing sector by improving efficiency, quality, and decision-making procedures. Manufacturers are progressively utilizing AI technologies to enhance operations, cut costs, and boost productivity. AI-powered robots and cobots are working alongside human workers to efficiently manage repetitive chores, enhancing worker safety, and enabling people to concentrate on more intricate tasks. AI-driven automation optimizes processes by reducing or eliminating repetitive tasks, allowing staff to focus on high-value activities, thereby enhancing efficiency and cutting costs (Shao, et al., 2022).

From the above discussion, it is clear that "artificial intelligence" enables ongoing enhancement through data analysis from several sources to pinpoint chances for optimization, efficiency improvements, and product upgrades, fostering innovation and maintaining manufacturers' competitive edge. Furthermore, "artificial intelligence" is helping manufacturers improve agility and quality by using predictive analytics, agile manufacturing methods, and predictive quality control (Makridakis, 2017). AI-generated insights enable factory leaders to make informed decisions based on data, offering connections, tools, and automation to enhance precision and excellence in operations. Manufacturers may utilize AI for predictive maintenance to efficiently schedule repair work, improve understanding of downtime, and reduce wasteful energy use by optimizing process scheduling during peak resource usage periods. Integrating AI into industrial processes is essential for maintaining competitiveness, agility, and innovation in the changing manufacturing industry (Talib, and Crook, 2023).

iii) To discuss the limitations of current AI technologies and CMMS platforms.

Artificial intelligence (AI) and CMMS have revolutionized the industrial sector by offering predictive maintenance, boosting operational efficiency, and optimizing manufacturing processes. While these technologies provide several benefits, they also include inherent constraints that need to be addressed (Al Maqbali, et al., 2021). Manufacturing businesses face challenges such as high implementation costs, a shortage of "artificial intelligence" (AI) talent, vulnerabilities to counterattacks, and data quality difficulties when trying to efficiently utilize AI and CMMS platforms. The cost of financial investment for AI deployment, along with the necessity for experienced personnel and strong cyber security measures, might deplete resources and impede general adoption in the sector (Nadikattu, 2021).

From the above discussion, it is clear that the dependence on artificial intelligence (AI) raises concerns about possible workforce displacement and the necessity for an equilibrium between automation and human supervision in decision-making procedures (Sony, 2020). AI can enhance operational efficiency and production optimization, but firms need to address data quality issues and ensure that human employees can effectively operate alongside AI technologies. Overcoming these constraints by implementing strategic planning, investing in training programs, and enhancing cybersecurity measures is essential for optimizing the advantages of AI and CMMS platforms and reducing risks in the ever-changing industrial sector (Fujimaki, 2021).

6. Conclusion

The research proposes that combining artificial intelligence (AI) with CMMS enhances maintenance performance in industrial companies. AI techniques like machine learning and predictive analytics empower CMMS to identify equipment failures, enhance maintenance timetables, and automate asset management processes. An AI-enhanced Computerized Maintenance Management System reduces downtime and operational costs while prolonging the lifespan of assets by detecting issues proactively. This integration of AI with CMMS streamlines maintenance processes, improves decision-making skills, and increases overall equipment effectiveness (OEE). Manufacturers may improve productivity, reliability, and competitiveness and attain sustainability by using AI-powered CMMS to analyze real-time equipment health data from IoT sensors, enabling a move from reactive to proactive maintenance strategies in the manufacturing sector.

7. Future Scope

Future studies will focus on enhancing AI algorithms to improve the accuracy of predictive maintenance models in CMMS. Research might prioritize enhancing the integration of future technologies such as block-chain and edge computing to improve data security and processing efficiency. The project will investigate how AI-driven CMMS affects sustainability initiatives, namely in reducing energy usage and minimizing waste, which may be a potential focus for future research.

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