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Emerging Technologies-Driven Operations Management for Flexible Manufacturing Systems on the Shop Floor

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ABSTRACT

Industry professionals are worried about resource utilization in operations management. Industry personnel use several strategies and advanced techniques to improve resource use by monitoring production activities. The advanced approach helps tackle the issues faced in the shop-floor operational scenario. In the current scenario, industry professionals are seeking a strategic approach to enhance operational outcomes while maximising resource contribution. The present study develops an innovative in the current-edge era. The study develops a novel architecture for controlling operational performance within limited constraints using advanced techniques. The strategy helps maintain and optimise operations by simultaneously monitoring workforce, machinery, and workflow performance in real time. The strategy uses emerging technologies for operational data management to achieve operational management excellence. The study showed that advanced techniques provide a human-centric approach to problem-solving, key to monitoring operations workflows and enhancing work-floor outcomes. The present study can provide a key to decision-making and resource utilisation for industry personnel in the current advanced operational monitoring environment. Operations managers can access the required data more efficiently and implement an appropriate action plan to eliminate potential failure points on the shop floor. The study helps industry professionals make decisions about operational and resource performance in a flexible manufacturing environment.

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1. Introduction

In the current industrial scenario, industry personnel focus on enhancing operational performance by maximising resource utilisation (Bristol-Alagbariya et al., 2022; Khosroniya et al., 2024). Several advanced techniques have been implemented to improve resource utilisation in operations management. The advanced industrial methods convince industry professionals to provide operational excellence (Arora et al., 2025; Saabye & Powell, 2024). So, industry professionals support the implementation of advanced techniques in operations management. Figures 1(a) and 1(b) show the advanced industrial techniques and their objectives used in the current scenario. Bright manufacturing concept is used to improve process outcomes by efficient planning and a suitable action plan (Mittal et al., 2020; Ozbiltekin-Pala et al., 2024). Researchers and industry personnel have used several innovative systems for controlling and monitoring production processes and activities (Gomaa, 2025; Liu et al., 2025; Shahin et al., 2020; Zhang et al., 2024). It has been observed by literature that researchers were emphasising the implementation of suitable advanced techniques for improving the manufacturing environment (Esmaeilian et al., 2020; Mourtzis & Vlachou, 2018; Tortorella et al., 2021). Ferrer et al. (Ferrer et al., 2018) discussed the three pillars critical to the adoption of an industrial cyber-physical system (CPS) of systems paradigm in the current innovative manufacturing environment, which included logistics, production lines, and facilities. The result showed that the study validated the selected technologies and verified the adoption of the presented CPS of systems for future Industry 4.0.

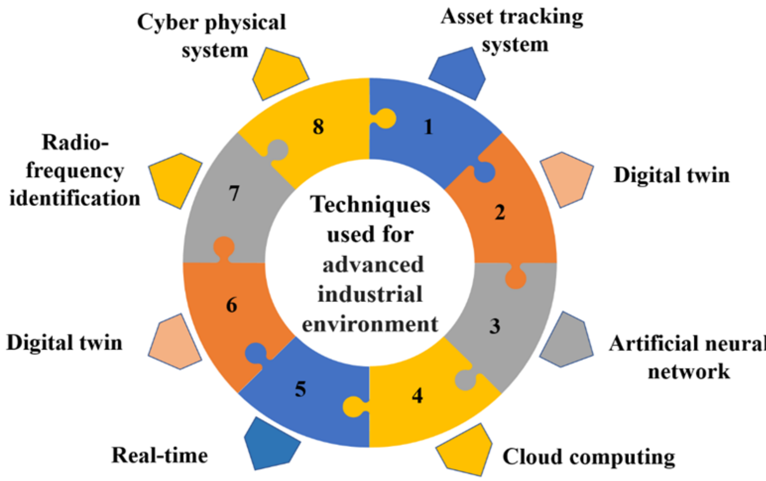

Figure 1: (a) Advanced Techniques in Emerging Operational Scenarios

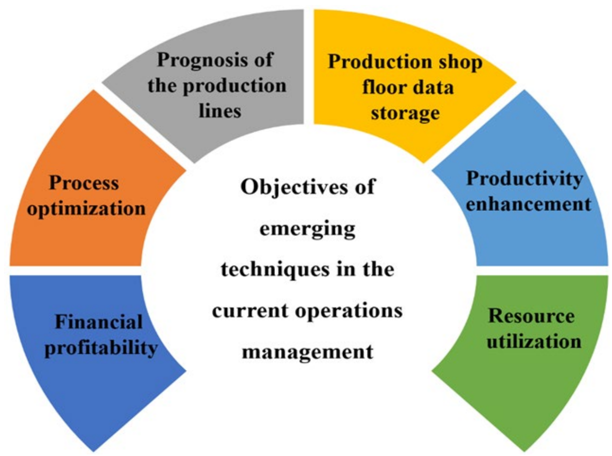

Figure 1: (b) Objectives of Emerging Techniques

Tao et al. (Tao et al., 2018) proposed a conceptual framework supported by a big data perspective for intelligent manufacturing and overviewed a historical view of the data lifecycle in manufacturing. The study used the autoregressive integrated moving average algorithm to analyse energy consumption. The study showed that the proposed framework could evaluate energy consumption and served as a preliminary exploration of data-driven smart manufacturing and its potential applications. Barenji et al. (Vatankhah Barenji et al., 2021) proposed a digital twin-driven approach for real-time optimization of motion planning in robotic cellular combined with agent-based decision-making. The proposed system established a connection between virtual and physical spaces to enable simulation analysis and autonomous decision-making in manufacturing workshops. The results showed that the proposed method could help enterprises make decisions effectively. Tripathi et al. (Tripathi, Saraswat, et al., 2022) developed a model for operations management using an artificial neural network (ANN) and value stream mapping. The study revealed that the developed model was efficient and highly adequate for prediction. A review of previous research indicates that researchers and industry personnel have focused on improving overall operational performance and condition by implementing advanced operational management techniques. Mzili et al. (Mzili et al., 2023) used the spotted hyena algorithm to solve scheduling problems in shop-floor work. This algorithm draws on the social behaviour and problem-solving techniques of spotted hyena packs. The method has outperformed traditional optimisation algorithms in terms of quality and convergence speed when optimising operational processes and achieving excellence. Monek and Fischer (Monek & Fischer, 2023) presented a modular digital twin framework which optimises the manufacturing processes through real-time collection and monitoring of the shop floor, conventional and automatic environment, detecting any faults and deviations and in turn generates advanced warning to shop floor executives, reducing the faults to a minimum. Table 1 illustrates the outcomes achieved by implementing several advanced techniques and approaches in operations management.

Table 1: (a) Description of the Literature Considering Objectives, Techniques, and Outcomes

Authors	Source	Advanced Techniques /Tools Used	Objective	Outcome
(Miragliotta et al., 2014)	IEEE	Internet of Things (IoT)	Proposed an approach for energy management based on the IoT.	Internet of Things (IoT)
(Wang et al., 2016)	Elsevier	CPS	Presented a framework for an intelligent factory that incorporates cloud, industrial network, and supervisory control terminals with smart shop floor objects, including products, conveyors, and machines.	The results showed that the framework could prevent deadlocks by multi-occurrence operations in the smart factory.
(Chen et al., 2017)	IEEE	Cloud computing, IoT	Proposed a hierarchical architecture for smart factories and analyzed key technologies from the network layer, resource layer, and data application layer.	The result showed that overall equipment effectiveness was improved by implementing the proposed architecture in a laboratory prototype platform
(Ren et al., 2019)	Springer	Radio frequency Identification system (RFID), big data, Apriori-based association analysis	Developed a framework for shop floor material delivery.	The proposed framework could guide manufacturers in making decisions to improve shop-floor material-delivery performance by leveraging multi-source, real-time manufacturing big data.
(Frontoni et al., 2018)	Springer	CPS	Proposed CPS architecture for real-time visualization of complex industrial processes.	The presented CPS architecture demonstrated strong performance in virtual reality, real-time behaviour, usability, WebGL-based visualisation features, and readability.
(Leusin et al., 2018)	MDPI	IoT	Proposed a data exchange framework for eliminating job-shop scheduling problems.	The result showed that the proposed framework could provide scalability, flexibility, and efficiency through data exchange between factory layers.
(Wang et al., 2020)	Taylor & Francis	IoT	Proposed a shop floor material management system.	The presented system could enhance efficiency and compliance with the just-in-time principle and also lead to cost reduction.

Table 1: (b) Description of the Literature Considering Objectives, Techniques, and Outcomes

Authors	Source	Advanced Techniques /Tools Used	Objective	Outcome
(Dalenogare et al., 2018)	Elsevier	Big data, cloud	Investigated the benefits of Industry 4.0-related technologies for three industrial metrics, including operational, product, and side effects, through surveying 2225 companies in the Brazilian industry.	The survey revealed that the Brazilian industry had not benefited from advanced techniques, such as cloud-based manufacturing and big data analysis of products.
(Saqlain et al., 2019)	MDPI	Industrial Internet of Things (IIoT)	Developed a framework for IoT-based industrial data management to support inline monitoring, control smart manufacturing, and manage industrial data.	The framework could improve the prognosis and productivity of production lines by converting collected data into useful information.
(Lee et al., 2021)	Elsevier	Digital twin, CPS	Proposed a time machine approach for utilizing the historical data in the process of digital twin design.	The study showed that the proposed approach ensured that a new system on the shop floor could meet short- and long-term business needs and deliver expected, predictable results.
(Peças et al., 2021)	MDPI	Cloud computing, CPS, digital twin	Proposed a conceptual approach and showed how the industry 4.0 technological concept was used to enhance continuous improvement.	This study increased the knowledge of the continuous improvement area and how it could have supported the move towards the industry 4.0 industrial paradigm.
(Beliatis et al., 2021)	MDPI	IIoT, RFID	Investigated the suitability of digital traceability technologies in a metal manufacturing industry.	The results revealed that the proposed road map was suitable and could enable Industry 4.0 traceability to be deployed in other metal manufacturing industries.
(Tripathi, Chattopadhyaya, et al., 2022)	MDPI	IoT	Developed an innovative production management system for the enhancement in industrial sustainability by identifying issues faced in operations management.	The developed production management improved operational excellence by optimizing the utilization of resources.

A review of the literature found that the researchers focused on developing an efficient strategy for work floor scheduling and production management. The developed strategies did not provide clarity on achieving excellence in operations management and scheduling within confined assets. The studies could not help industry personnel understand how to improve operational performance efficiency through a unique problem-solving and decision-making key. Operations management teams face challenges in maintaining workflow efficiency in flexible manufacturing systems and achieving resource excellence through real-time technological integration on the shop floor. The present study uses advanced techniques to develop a novel architecture method for intelligent operations management. The extended plan has been prepared by thoroughly reviewing operational management conditions and scenarios in previous research. This research provides a decision-making strategy to enhance resource utilisation efficiency. The study also develops a novel architecture for controlling operational performance within limited constraints using advanced techniques. The author of the present research believes that the developed method would prove a milestone for operations scheduling and management in Industry 4.0.

2. Technological Advancements for Flexible Manufacturing Systems

The current industrial landscape requires the development of unprecedented technologies to optimise operational performance with the resources available. Furthermore, unparalleled technology helps operations management teams develop a robust production plan. Previous researchers have proposed several frameworks for improving operations management using various advanced technologies. The contributions of advanced techniques at an earlier research are shown in Figure 2. Terrazas et al. (Terrazas et al., 2019) presented a framework of a novel big data approach and analytics for analysing and managing machine-generated data in the cloud. The result shows that the presented framework minimises complexity, reduces infrastructure costs, and provides on-demand access to unlimited computing power, storage, and network resources. Bag et al. (Bag et al., 2021) developed a theoretical model for connecting critical resources to adopt Industry 4.0. The study identified thirty-five resources as essential for adopting Industry 4.0. The study's findings showed that management leadership, project management, production systems, green design, human resources, big data analytics, information technology, and collaborative relationships were vital for adopting Industry 4.0.

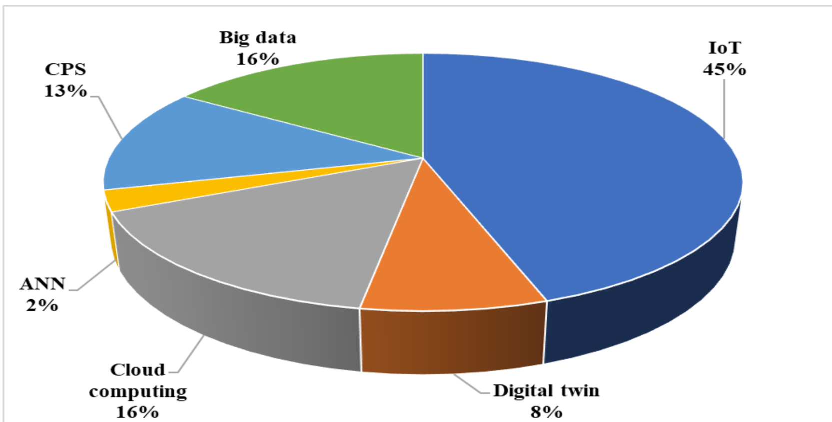

Figure 2: Contribution of the Advanced Techniques in the Literature

It has been observed that technological advancement has provided novel directions in the current industrial environment. Figure 3 shows the advantages of technological advancement in the current operational landscape of operations management

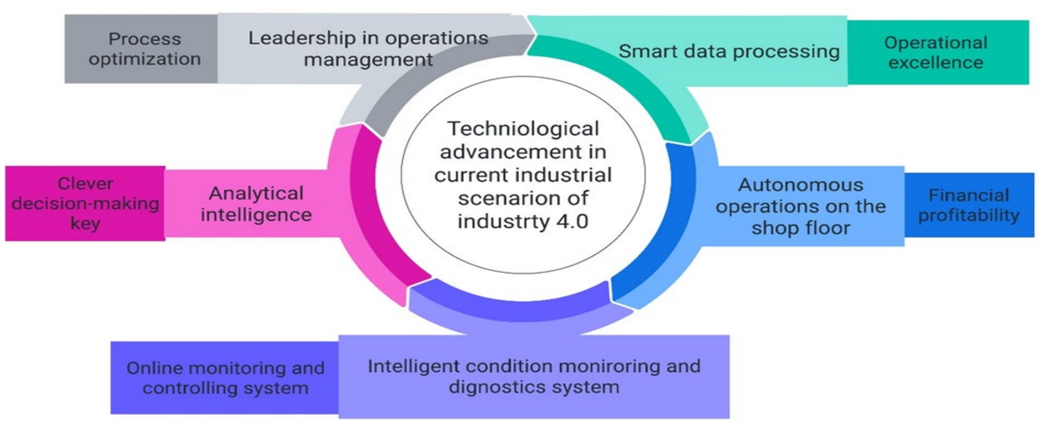

Figure 3: Technological Advancement in the Current Advanced Industrial Era

3. An Innovative Strategy for Operations Works Floor

Industry personnel and researchers face difficulties controlling operational activities. A novel operational strategy for shop-floor management has been developed through a detailed investigation of operational performance and conditions in prior research. The developed approach helps sustain operational excellence in dynamic activities. The developed strategy emphasises improving operational performance by optimising resource utilisation. Figure 4 illustrates the phases of the developed plan. There are four phases in the approach developed in this research. The first phase focuses on investigating decision-making factors to understand the current operational management system. Operations teams analyse the workplan and constraints using an ANN and a digital twin. The analysis helps in precise planning within available resources on the work floor. In the second stage, the received data is structured and analysed, and the information is uploaded to various servers to control production activities on the production floor. The teams encrypt the data and direct for alignment of resources and access remotely. The planning teams harness real-time analysis to support a flexible manufacturing environment. The third phase helps plan the architecture for production processes and resource activities on the work floor by providing instructions via various intelligent devices. Operations teams receive data from multiple sources, including workforce, machinery, and materials, to improve operational performance.

Finally, the fourth phase helps tackle operational issues across departments by real-time assessment of the operational workflow. Industry professionals can investigate operations, products, and resource outcomes using suitable sources within the limitations of operations management. The strategy uses several layers to thoroughly analyse operational conditions and management. The layers establish safety, forecasting, and provide production virtual reality and real-time resource behaviour for a flexible manufacturing environment.

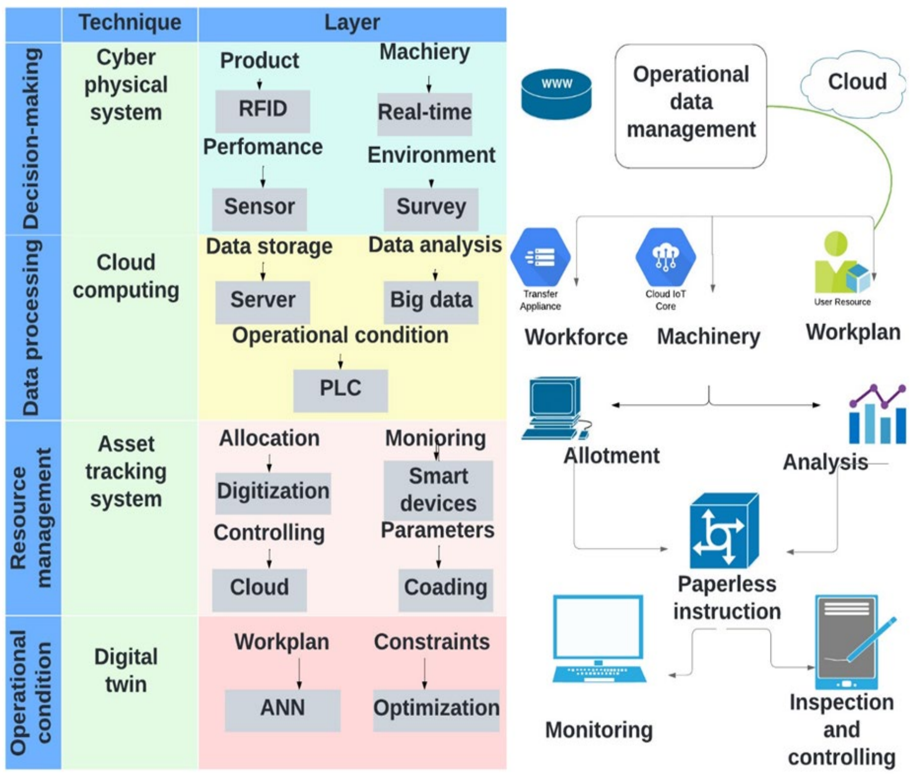

Figure 4: Developed Strategy

Industry professionals assessed the effectiveness of the developed strategy in real-life operational management scenarios. The professionals belonged to different industry sectors, and they assured that the developed strategy can tackle the operational issues by real-time data analytics on the shop floor

4. Summary and Discussion

The previously developed strategies provided an idea to improve operational conditions with suitable advanced technology (Grassi et al., 2021; Khan et al., 2025; Lee et al., 2021; Mourtzis et al., 2017; Tripathi et al., 2025; Yang & Takakuwa, 2017). Researchers have faced severe problems in controlling resource utilisation (Enrique et al., 2022; Guo et al., 2021). The current study develops a novel strategy to maximise resource utilisation efficiency in operations management on the shop floor. The developed approach can eliminate the problems faced in controlling operational conditions and activities. Figure 5 describes the architecture for operations management based on the plan developed in the present study. This architecture could enhance the efficiency of operations management systems and to improve resource utilisation.

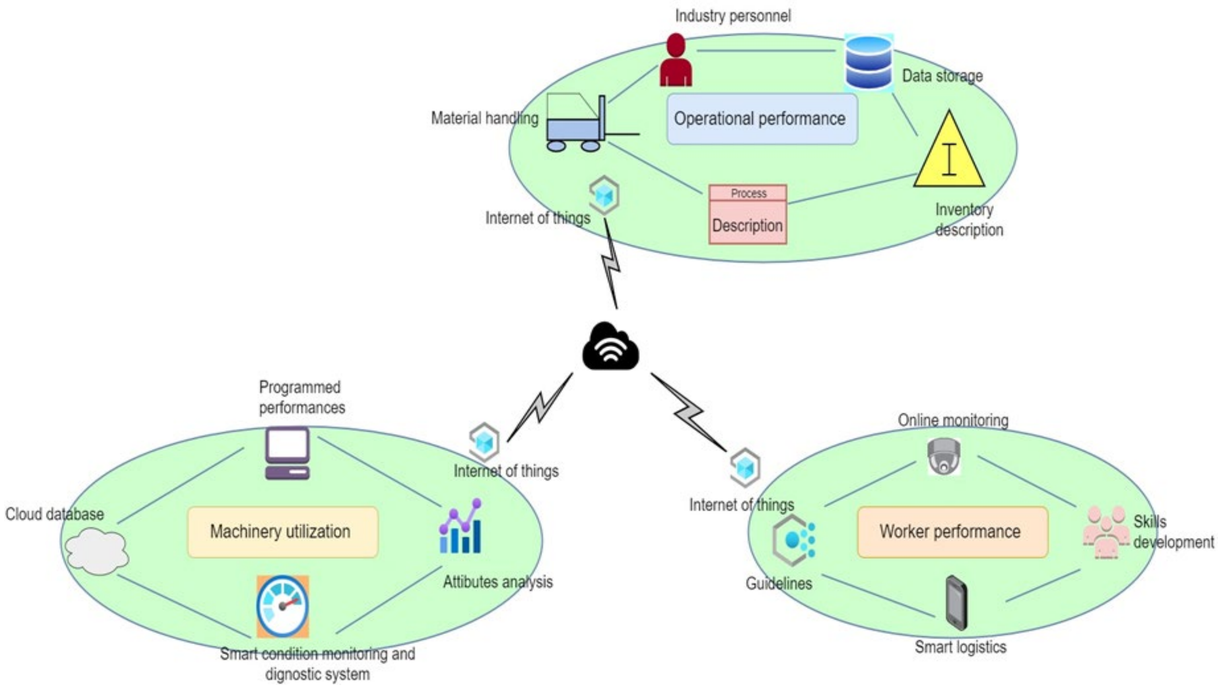

Figure 5: Architecture for Advanced Operations Management Platforms

The study presents an architecture to improve operational flow by enhancing resource utilisation. The architecture helps industry professionals set work plans, allocate resources, manage constraints, ensure quality control, and define operational conditions. In addition, the architecture demonstrates how industry personnel can efficiently control and monitor operational performance in production processes by implementing advanced techniques. Similar results have been found by Zhang et al., (Zhang & Ming, 2021) who proposed a reference architecture for intelligent manufacturing information systems by surveying 42 enterprises. The result revealed that the proposed reference could guide the industry in planning, setting up, designing, and implementing an innovative manufacturing information system. Cheng et a. (Cheng et al., 2018) proposed the architecture of the IIoT based on 5G. 5G was used as a communication network and provided richer capabilities. Furthermore, the study revealed that high reliability, high transmission rate, low latency, and high coverage were required to achieve real-time transmission and processing of massive data in production processes in the manufacturing scenario. The present study develops an intelligent system to improve resource utilisation in the operational floor area. The study also develops a novel architecture for controlling operational performance within limited constraints using advanced techniques. The developed strategy helps industry professionals in the decision-making phase for maintaining resource performance in a flexible manufacturing environment. The architecture mitigates the risk of malfunctions and enhances resource efficiency through a precise workflow. Industry professionals can tackle the challenges in emerging technology-based operations management scenarios.

5. Contribution of the Developed Strategy in the Current Advanced Industrial Scenario

Industry personnel emphasized developing a unique methodology for enhancing the operational efficiency of operations management systems (Kurdve & Bellgran, 2021; Qu et al., 2012). The researcher faces severe problems in controlling the operating performances of production processes and activities with available resources (Khan et al., 2019; Zhong et al., 2013). The issues were mainly identified in resource utilization in operational workflow (Aytug et al., 2005; Chan et al., 2006; Tripathi & Bhadauria, 2025). The developed novel strategy would help industry professionals eliminate problems faced in controlling operating conditions. Figure 6 describes the contribution of the developed system in the present advanced industrial scenario.

Findings of the previous research studies in enhancing shop floor management efficiency (Mourtzis et al., 2017; Ren et al.,2019; Saqlain et al., 2019; Wang et al.,2020; Peças et al., 2021; Monek And Fisher, 2023)	Outcomes of the developed strategy in the present research work
• Developed strategies for improving operational conditions on the shop floor for enhancing operational performance. • Provides instructions to industry individuals in controlling movements in production processes on the shop floor. • Reduced infrastructure costs by eliminating difficulties faced in operations management. • Enhanced productivity by implementing new working setups on the shop floor. • Applicable in the specific working scenarios with limited production conditions.	• Developed a novel strategy for improvement in operations management by enhancing resource utilization. • Provides a decision-making guideline for achieving economic sustainability on the shop floor in Industry 4.0. • Enhanced financial profitability by process optimization on the work floor. • Provides an intelligent manufacturing system for controlling and monitoring operational activities within limited constraints • Applicable in flexible and cutting-edge operational work scenarios.

Figure 6: Contribution of the Developed Strategy

The present study developed an emerging technologies-driven strategy for operations management in flexible manufacturing systems, considering mechanical and industrial system design. The plan aims to establish an innovative condition-monitoring system and layout to enable seamless workflow on the shop floor. The approach uses a centralised operations monitoring system to monitor machinery performance and optimise operational activities on the work floor. Operations teams can effectively monitor machinery, workforce, and workflow performance and develop an appropriate action plan to address issues encountered in advanced shop floor platforms. The study revealed that the strategy can resolve operational issues by identifying mechanical and industrial system issues in a flexible manufacturing shop-floor scenario.

6. Conclusion

The current study has developed a smart strategy to enhance operational excellence within confined assets. The authors summarized the findings obtained by the present research study:

i. The developed innovative system has been observed to be competent in enhancing resource utilization in an advanced industrial scenario.

ii. In the current dynamic shop floor trend, advanced technologies like CPS, digital twins, radiofrequency identification systems, real-time cloud computing, and ANN networks have emerged.

iii. The developed innovative system and architecture help control the workflow for the production processes and activities using advanced and efficient action plans.

iv. The study provides a human-centric problem-solving key for efficient operations management in the current advanced shop floor platforms.

v. The study provides revolutionary changes in systems used to enhance resource utilization efficiency in operations management.

7. Future Scope

The present work develops an innovative strategy for managing operational activities through architectural design and enhances resource utilisation on the shop floor within confined assets. In future research, the innovative system's efficiency could be further improved by addressing other operational management factors, such as energy consumption, ergonomics, human resources, and shop-floor environmental waste. Further, the applicability of the developed system can be enhanced by validating it across different industrial sectors where industry professionals emphasise real-time data analytics and resource efficiency on the shop floor. Advanced techniques in various operating conditions.

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