ISSN 1840-4855
e-ISSN 2233-0046

Original scientific article
http://dx.doi.org/10.70102/afts.2025.1834.687

SUPPLY CHAIN INTEGRATION AND CLOUD BASED OPERATIONS MANAGEMENT FOR RESILIENT SMART MANUFACTURING SYSTEMS

Dr. Lalit Sachdeva[1*], Dr. Utkarsh Anand[2]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
e-mail: ku.lalitsachdeva@kalingauniversity.ac.in, orcid: https://orcid.org/0009-0002-2214-282X
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
e-mail: ku.utkarshanand@kalingauniversity.ac.in, orcid: https://orcid.org/0009-0007-2124-6666

Received: September 15, 2025; Revised: October 27, 2025; Accepted: December 01, 2025; Published: December 30, 2025

SUMMARY

The research introduces Cloud-SCIM (Supply Chain Integration and Cloud-Based Operations Management to Resilient Smart Manufacturing) model, which aims to solve the problems of the modern manufacturing system. The model leverages cloud computing, IoT, and AI analytics to harmonize supply chain operations, boosting efficiency, flexibility, and resilience. Cloud-SCIM helps ensure effective production, demand projections, inventory maintenance, and sustainability by enabling real-time monitoring, predictive analytics, and automated decision-making. Performance indicators were compared and tested between the suggested model and traditional systems, including Overall Equipment Efficiency (OEE), Mean Absolute percentage Error (MAPE), and inventory turnover. The outcomes indicate significant changes: OEE has improved by 20 points (65 to 85), MAPE decreased by half (15 to 8), and inventory turnover has increased (5 to 9 times a year). Besides, Cloud-SCIM decreases the number of stockouts, downtime and consumes less energy as well as increases the effectiveness of risk mitigation. This study demonstrates that Cloud-SCIM can successfully modify smart manufacturing systems to provide a scalable, flexible solution that enhances operational productivity, resilience, and durability.

Key words: *cloud-SCIM, supply chain integration, real-time monitoring, predictive analytics, manufacturing efficiency, risk management, IOT.*

INTRODUCTION

In the changing environment of contemporary production, supply chains are becoming more intricate and require active, real-time responses to swift shifts in market demand, production schedules, and working conditions [1]. Extremely inefficient, scaled-out, and siloed operations are a major concern to the traditional manufacturing systems in terms of efficiency, scalability and resilience [2]. In an attempt to adjust to a digital-first environment, integrating supply chain processes with the operations management framework of the cloud-based system has proved an essential tool for creating agile, resilient, and intelligent manufacturing systems. Supply chain integration is the smooth integration of the different stages of the production process, from the procurement of raw materials to the delivery of the product to the market [3][4]. This integration plays a critical role in ensuring that all links within the supply chain operate as efficiently as possible, enabling quicker decision-making, enhancing information flow, and using resources in the most effective manner [5]. Combining the modern system of manufacturing with the latest information technologies, the business can gain better visibility and control over the whole value chain.

The evolution of cloud computing has also changed the way manufacturing is conducted, so that businesses now have access to storing and processing large amounts of data from various sources in real time [6][7]. Granting cloud-based operations management enables real-time monitoring, predictive analytics, and automated decision-making, allowing manufacturers to be more responsive to market changes, streamline production, and, overall, optimize the effectiveness of the system. Moreover, cloud platforms can also ensure manufacturers' flexibility to increase or decrease operational volumes without complications and to incorporate new technologies, including the Internet of Things (IoT), machine learning, and big data analytics, into the production environment [8][9]. Supply chain integration and cloud-based operations management are major drivers of resilience in the context of smart manufacturing, which entails the application of advanced digital technologies to improve the efficiency and autonomy of manufacturing processes [10]. These technologies also allow manufacturers to adapt quickly to disruptions, better manage risks, and maintain production continuity. The potential to leverage cloud-based systems to coordinate and streamline both supply chain and operational technologies has become a decisive factor in developing a competitive edge and ensuring the industry's perpetual viability as manufacturing settings become more interconnected. In this paper, the author examines how supply chain integration and cloud-based operations management can be used to improve the resilience of smart manufacturing systems [11]. It will discuss the ways in which these technologies can be used to design more agile, efficient, and adaptive production spaces which can respond to unexpected disruptions and in which operational excellence is maintained.

Key Contribution

- Integrating the operations management supply chain with the cloud-based operations management enables manufacturers with real-time data accessibility throughout the production and distribution chain.
- There is also the fact that, because of this integration, it becomes easier to monitor in real-time and make decisions that are adaptive to the needs of the market or to supply chain issues, or other challenges that appear unexpectedly.
- The predictive analytics and automated systems decrease the risk of stockouts, surplus stock, and ineffectiveness, leading to a decrease in costs and an improvement in profitability.
- Using predictive analytics, manufacturers are able to lessen risks, including supply chain bottlenecks, unstable demand, or external threats, and maintain business continuity, which enhances the resiliency of the user-the-whole manufacturing ecosystem.

This paper is followed by the various sections. Section I introduces the topic and explains the work's key contribution. Section II describes the previous work based on the given topic. Section III explained the proposed architecture diagram, followed by demand forecasting, inventory optimization, and predictive production management. Data flow diagrams for the proposed model and algorithm. Section IV explained the dataset description, hardware and software configurations, evaluation metric analysis, and ablation study. Section V explained the main key findings of this research.

LITERATURE REVIEW

The incorporation of the latest digital technologies into the manufacturing industry has led to a paradigm shift in the production process, turning the traditional system into a smart manufacturing environment. The core of this change is the need for a smooth integration of supply chain operations and management with cloud-based characteristics, which can significantly enhance the efficiency, responsiveness, and resiliency of manufacturing systems [12]. Supply Chain Integration has become a serious factor in improving the operational performance in manufacturing systems. Supply chain functions, including procurement, production, inventory management, and distribution, are integrated to provide a seamless information flow and process coordination [13]. Manufacturers can gain real-time visibility into their operations by eliminating silos across supply chain processes. This visibility plays a crucial role in reaching the demand variations, risk management, and resource optimization [14]. Moreover, integrated supply chains can help manufacturers identify bottlenecks and inefficiencies in the production process, which can be proactively managed through data-driven decision-making.

Cloud-Based Operations Management is a key to enabling manufacturing systems transformation because the platform is flexible and scalable to handle complex operations. Cloud computing enables real-time data processing, remote access to information, and smooth communication among various stakeholders in the supply chain [15]. By means of integrating cloud-based technologies, a manufacturer has an opportunity to check and regulate the production processes in any place, and it guarantees more flexibility and a quicker reaction time. Besides, cloud-based solutions enable the implementation of such sophisticated technologies as Internet of Things (IoT), Artificial Intelligence (AI), and big data analytics, which can improve predictive abilities and decision-making.

Integration of cloud-based platforms into supply chain operational processes is associated with several benefits, specifically agility and scalability. With continuously changing market conditions and unforeseen disruptions to manufacturers' normal operations, cloud-based solutions enable scalable operations to meet needs [16]. Real-time dynamic capability to change the capacity of production can enable manufacturers not only to remain competitive and adaptable to the market conditions but also cut down operation expenses [17]. In addition, the scalability of cloud platforms also means that manufacturers do not have to invest heavily in infrastructure to facilitate growth; hence, it is a cost-effective solution to the contemporary manufacturing setting.

Cloud-based operations management is another significant advantage of the technology, as it contributes to resilience and risk management in the supply chain [18]. Manufacturing systems can be susceptible to a range of disruptions, including supply chain bottlenecks, machine malfunctions, and external factors such as natural disasters and political instability. Cloud-based solutions, together with advanced analytics, allow manufacturers to anticipate potential disruptions and take mitigation measures in advance [19]. Predictive maintenance, real-time monitoring, and automatic alerts can help detect and manage problems before get out of control, preventing production disruptions. Moreover, through offering a centralized platform in the management of various supply chain activities, the cloud systems enable the establishment of improved coordination and collaboration of the manufacturers, suppliers and other stakeholders; which enhances the overall risk management strategies [20].

Research Gap

Although there have been improvements in supply chain integration and cloud-based operations management, several research gaps remain. These include the absence of standardized principles for smooth assimilation across heterogeneous manufacturing settings, issues with real-time data matching and quality, and questions about whether cloud systems are reliable in large, complex operations. Moreover, although such relatively new technologies as AI and IoT have potential, their implementation in a cloud-based smart manufacturing system is unexplored. Besides, cybersecurity threats and the challenge of increasing resilience against disruptions are also issues. These gaps are important areas that need to be filled to facilitate the effectiveness and flexibility of cloud-based supply chain systems in smart manufacturing.

PROPOSED MODEL ARCHITECTURE

To interpret below Figure 1 describes the Cloud-SCIM (Supply Chain Integration and Cloud-Based Operations Management towards resilient Smart Manufacturing) model is the model that combines the latest technologies to maximize manufacturing processes, make them more resilient, and simplify supply chain processes. At its center is a centralized cloud-based system that stores, processes, and analyzes information of different processes in the production and supply chain processes. It enables real-time data and communication, facilitating smooth coordination among suppliers, production, logistics, and retail through integrated systems, e.g., ERP, WMS, and CRM. IoT-powered sensors are placed throughout the manufacturing facility to get real-time information on the equipment working conditions, inventory levels and the environment and reflect it back to the cloud to generate immediate insights and monitor. This data is analyzed by the AI analytics engine to predict demand, optimize production timelines, and detect potential threats such as machine malfunctions or supply shortages, enabling action in advance. Also, the resilience and risk management module evaluates and manages risks through predictive analytics, enabling ongoing operations despite disruptions. The unified control dashboard of the system enables the decision-makers to have an overall idea of real-time data and helps in gathering key performance indicators, automated notifications, and adaptive decisions based on the current manufacturing state. The integrated architecture provides increased visibility, efficiency, and flexibility in smart manufacturing, establishing a more resilient, adaptable production environment that can flex with dynamic market changes and disruptions. In the mathematical model of Supply Chain Integration and Cloud-Based Operations Management for Resilient Smart Manufacturing Systems, it can identify key elements such as inventory optimization, demand forecasting, production scheduling, and risk management. It is intended to create a model that will connect the flow of materials, information, and demand in the integrated supply chain, as well as cloud-based data processing to achieve resilience.

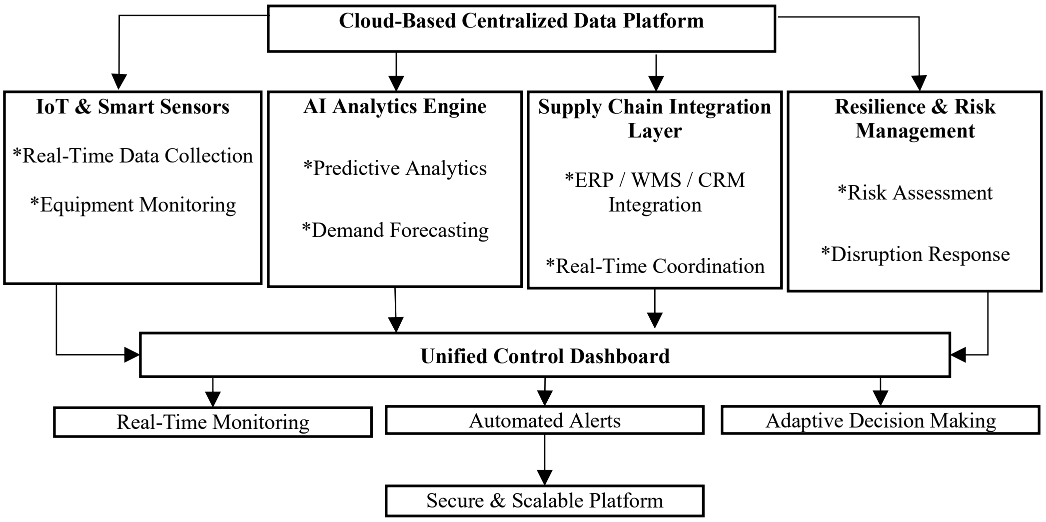

Figure 1. Proposed model architecture

Demand Forecasting Using Time Series Analysis

To forecast the demand for products in a smart manufacturing system, AutoRegressive Integrated Moving Average (ARIMA) models are commonly used. Let the demand D_t at time t modeled as,

$$D_t = \emptyset_1 D_{t-1} + \emptyset_2 D_{t-2} + \cdots \dots\dots\dots\dots. \emptyset_P D_{t-p} + \theta_1 \in_{t-1} + \cdots \dots\dots\dots.. \epsilon_t \quad (1)$$

From the above Equation (1) describes the D_t consider as the demand time at t. $\emptyset_1, \emptyset_2, \dots\dots. \emptyset_p$ consider as the autoregressive parameters. $\theta_1, \theta_2, \dots\dots \theta_q$ consider as the moving average parameters. ϵ_t is the term followed by the time t.

The ARIMA model, it is possible to forecast future demand using past data and therefore the manufacturing system can adopt production schedule and inventory control in order to fulfill the anticipated demand.

Inventory Optimization

Inventory management in an integrated supply chain system can be modeled using an optimization approach that minimizes cost while meeting demand. Let the inventory $I_t$at time $t$be governed by the following equation (2),

$$I_t = I_{t-1} + P_t - D_t \quad (2)$$

From the above Equation (2) noted as I_t consider as the inventory at the time of t, P_t mentioned as the production about quantity at the time of t. D_t consider as the demand at the time t.

Production Scheduling and Optimization

For smart manufacturing, production scheduling is essential to determine the optimal production quantity for each item at each time period. Let x_{it} should represents the quantity of the product i with the time of t. The objective function of production scheduling as,

$$Minimize\ Z = \sum_{t=1}^{T} \sum_{i=1}^{N} C_i x_{it} \tag{3}$$

From the above Equation (3) represents the c_i defined as the production cost per unit of item i. x_{it} represents the quantity of product i produced at the time of t. N is the number of products and T is the number of time periods.

Risk Management with predictive Analysis

Risk management within a cloud-based system of operations is related to anticipating disruption and identifying mitigation measures. The system predicts the likelihood of disruption (i.e. supply delays or machine failures) using predictive analytics, and is based on historical data. A basic risk model may be as follows,

$$R_t = P_{failure} * C_{failure} + P_{delay} * C_{delay} \tag{4}$$

From the above Equation (4) defined as R_t consider as the risk at the time t. $P_{failure}$ represents the probability of machine failure at the time of t. $C_{failure}$ should be noted as cost associated with the machine failure. P_{delay} represents the probability of supply chain delays with the time t. C_{delay} should represented the cost associated with delays.

Data Flow Diagram for Supply Chain Integration and Cloud-based Operations Management for Resilient Smart Manufacturing

The below Figure 2 represents the Cloud-Based Operations Management Platform, which is the core of a robust smart manufacturing system that is able to add data from various sources, including suppliers, IoT sensors, and production systems. It gathers live data, such as raw materials, inventory, and equipment positions, and feeds it to an AI Analytics Engine to make demand predictions and spot anomalies. This will allow the system to anticipate demand and detect any deviations or inefficiencies in the supply chain or the production process. The AI engine's knowledge is applied to improve production planning and update inventory control, ensuring production adjusts to projected demand and inventory is maintained. Live data coordination between logistical and process states will ensure smooth integration across the supply chain, including raw materials, production, and delivery. Also, supplier information is constantly updated to give precise information about the availability of materials and the timing of its delivery, which helps in the planning of production. The crucial part of the platform is the risk assessment and response module, which oversees possible disruptions, including delays in the supply chain or machine malfunctions, and creates mitigation strategies and alerts to assist the decision-makers in reacting promptly. On the whole, the platform offers a universal solution for supply chain operations, efficiency, and risk management in manufacturing systems, ensuring real-time coordination and promoting active risk management.

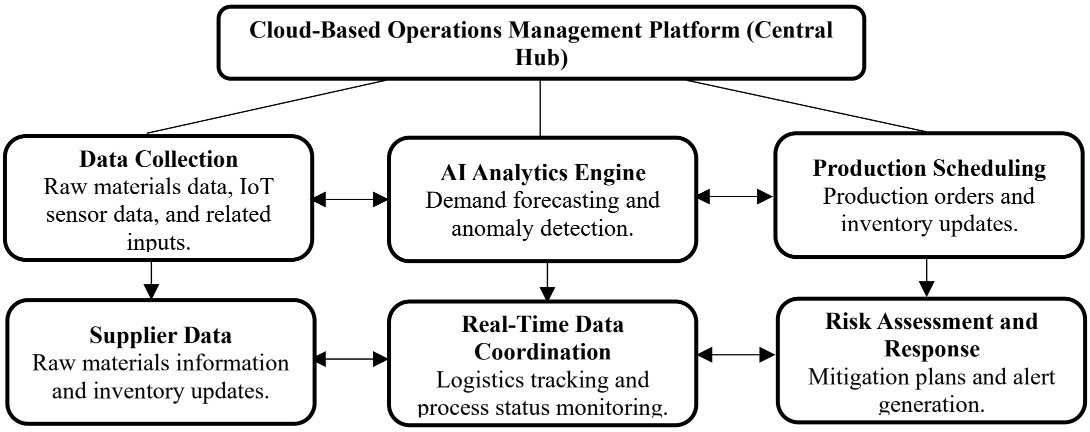

Figure 2. Data flow diagram for the proposed model

Proposed Algorithm

$step: 1\ Data\ collection\ from\ IoT\ sensors\ and\ Suppliers$

$def\ collect - data\ ();$

$sensor - data = collect - sensor - data();$

$production - data = collect - production - data();$

$cloud - data = store - in - cloud(sensor - data, supplier - data, production - data)$

$return\ cloud - data$

$step: 2\ Data\ preprocessing\ and\ Integration$

def $preprocess - and - integrate - data(cloud - data);$

$Step: 3\ AI\ Analytics\ for\ demand\ forecasting\ and\ Anomaly\ Detection$

$def\ ai - analytics(integrated - data)$

$step: 4\ production\ scheduling\ and\ Inventory\ control$

$production - schedule, updated - inventory = production - scheduling\ and\ inventory$

$step: 5\ Real\ time\ coordination\ of\ data\ Exchange$

$coordinated - data = realtime - coordination()$

$step: 6\ Risk\ Assessment\ and\ Mitigation$

$mitigation - plan = risk - assessment - and - response\ (integrated - data, anomalies)$

$Step: 7\ Decision\ support\ and\ Reporting$

$Step: 8\ Continuous\ feedback\ loop$

$updated - system - state = continuous - feedback - loop$

$return\ updated - system - state$

Algorithm Explanation

The Supply Chain Integration and Cloud-Based Operations Management of Resilient Smart Manufacturing Systems algorithm listed above starts with data collection, in which real-time information from IoT sensors, the production system, and suppliers is collected and stored in a centralized cloud system. This is then preprocessed and incorporated to make it clean and ready for analysis. To make the production schedule and manage inventory, the AI analytics engine predicts demand and identifies anomalies, which are used to generate insights and optimize resource utilization. The system will guarantee real-time coordination of data flow between production, logistics, and inventory, keeping the supply chain in step. Risk assessment helps identify potential disruptions, and mitigation plans are activated to eliminate risks in advance. Decision support and reporting provide decision-makers with essential key performance indicators and operational insights, and a continuous feedback loop allows the system to learn from past performance and adjust forecasts, schedules, and risk strategies to achieve continuous optimization. Such a synergistic solution improves the efficiency, resilience, and flexibility of the manufacturing system, enabling it to effectively respond to disruptions and operate smoothly.

RESULTS AND DISCUSSION

Dataset Description

Supply Chain Integration and Cloud-Based Operations Management Data and Resilient Smart Manufacturing Systems have three primary elements of the dataset: IoT Sensor Data, Supplier and Inventory Data, and Production and Logistics Data. IoT Sensor Data contains real-time data on sensors on machine performance, environmental data, and inventory data, which is necessary to monitor and optimize manufacturing operations. Supplier and Inventory Data give information about raw materials, components, delivery dates, inventory and lead times that help in planning production and controlling stocks. Production and Logistics Data gather production performance, machine state, work orders and logistics information, useful in streamlining scheduling and resources management throughout the supply chain. The datasets are coupled with a cloud-based platform, which allows real-time analytics, demand-related forecasting, risk management, and decision-making, which contribute to the overall better efficiency, resilience, and responsiveness of the manufacturing system.

Hardware and Software Configuration

Table 1. Hardware and software configuration

Category	Hardware Configuration	Software Configuration
IoT Sensors and Devices	Temperature, Humidity, Vibration, and Pressure Sensors	IoT Platforms (e.g., ThingSpeak, Losant, AWS IoT Core) for data collection
Computing Hardware	Edge Computing Devices (e.g., NVIDIA Jetson, Raspberry Pi)	Cloud Servers (e.g., AWS, Azure, Google Cloud)
Networking Equipment	Ethernet, Wi-Fi, 5G/LPWAN networks for communication	APIs for integration between IoT devices, ERP, and cloud platforms
	Virtual Private Network (VPN) for secure communication	Communication Protocols (e.g., MQTT, HTTP, CoAP)
Manufacturing Equipment	Automated Machines and Robotics for production	Middleware Solutions for facilitating communication
Cloud Platform	Cloud Computing Infrastructure (e.g., AWS, Azure, Google Cloud)	Cloud IoT Management (e.g., AWS IoT Core, Google Cloud IoT, Azure IoT Hub)
Cybersecurity	IoT security devices, secure gateways	Encryption and Authentication Solutions (SSL/TLS, MFA)
Integration Software	IoT Devices (e.g., IoT-enabled smart machines)	API Management Tools (e.g., Apigee, AWS API Gateway)

The Hardware and Software Configuration (Table 1) describe Supply Chain Integration and Cloud-Based Operations Management to Resilient Smart Manufacturing Systems, which is created in order to seamlessly integrate the IoT devices, cloud infrastructure, and manufacturing systems. The hardware setup includes temperature, humidity, vibration, and pressure sensors and devices, as well as IoT sensors and machines to control the environment and the machine's operation. Ethernet, Wi-Fi, and 5G/LPWAN networks provide networking that can guarantee a stable communication system, and VPNs are employed to transmit data securely. The system includes automated manufacturing machines and robotics, whereas cloud platforms such as AWS IoT Core and Google Cloud IoT handle IoT devices and ensure data flow without delay. To ensure security, secure gateways and IoT security devices are deployed in conjunction with encryption and authentication (e.g., SSL/TLS, MFA) to secure the sensitive data. Lastly, integration software like API management tools (e.g., Apigee, AWS API Gateway) allows the IoT devices to communicate without difficulty with the ERP systems and cloud platforms resulting in an uninterrupted supply chain. Such integrated design guarantees effective data flow, safe communication and real-time decision-making of smart manufacturing systems, which ultimately results in greater resilience and performance.

Evaluation Metric Analysis

The effectiveness and performance of the Supply Chain Integration and Cloud-Based Operations Management system are measured using a set of key metrics that assess factors such as efficiency, accuracy, sustainability, and resilience in manufacturing and supply chain operations.

Efficiency Metrics

Production Efficiency

This is a unit of time which is used to measure the production rate to determine the efficiency of the use of production resources as in Equation (5).

$$production\ Efficiency = \frac{Total\ Units\ Produced}{Production\ Time} \tag{5}$$

Accuracy Metrics

Demand Forecasting Accuracy (MAPE)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} |\frac{D_{actual} - D_{forecast}}{D_{actual}}| * 100 \tag{6}$$

From the above equation (6) describes the D_{actual} as actual demand, $D_{forecast}$ as forecasted demand, n is the number of periods.

Metric Evaluation of Existing Model Vs Proposed Model

Table 2. Metric evaluation of existing model vs proposed model

Metric	Existing Model (Traditional-SCMS)	Cloud-SCIM (Proposed Model)
Overall Equipment Efficiency (OEE) (%)	65	85
Mean Absolute percentage Error (MAPE) (%)	15	8
Inventory Turnover (Times/year)	5	9
Stockout Frequency (%)	20	5
Perfect Order Rate (%)	75	92
Downtime Impact (%)	20	8
Risk Mitigation Effectiveness (%)	65	88
Energy Efficiency (kWh/unit)	0.8	0.4
Cost Per Unit ($)	6	3.5
Lead Time (Days)	6	3

To interpret Table 2 and Figure 3, Cloud-SCIM (Proposed Model) outperforms the Existing Model (Traditional-SCMS) across all key performance metrics. OEE also increases to 85 from 65, indicating improved equipment efficiency, while MAPE decreases to 8 from 15, indicating more accurate demand forecasting. Inventory Turnover increases to 9 times/year, and Stockout Frequency decreases to 5, indicating more efficient inventory management and fewer stockouts. Perfect order rate increases by 75

% to 92 % and this means that the order fulfillment becomes more certain. With more effective predictive maintenance, the Downtime Impact is cut by 20 to 8 and Risk Mitigation Effectiveness goes up by 65 to 88 because the risk management is more effective. The Energy efficiency is enhanced to 0.4 kWh/unit-1, and the energy consumption is reduced to 0.8 kWh/unit-1, while the Cost Per Unit is reduced to 0.350 000, with cost savings as the focus. Lastly, Lead Time will be reduced from 6 to 3 days, enabling orders to be fulfilled more quickly. All in all, the Cloud-SCIM model can make a big impact in the manufacturing and supply chain processes in terms of efficiency, accuracy, and sustainability.

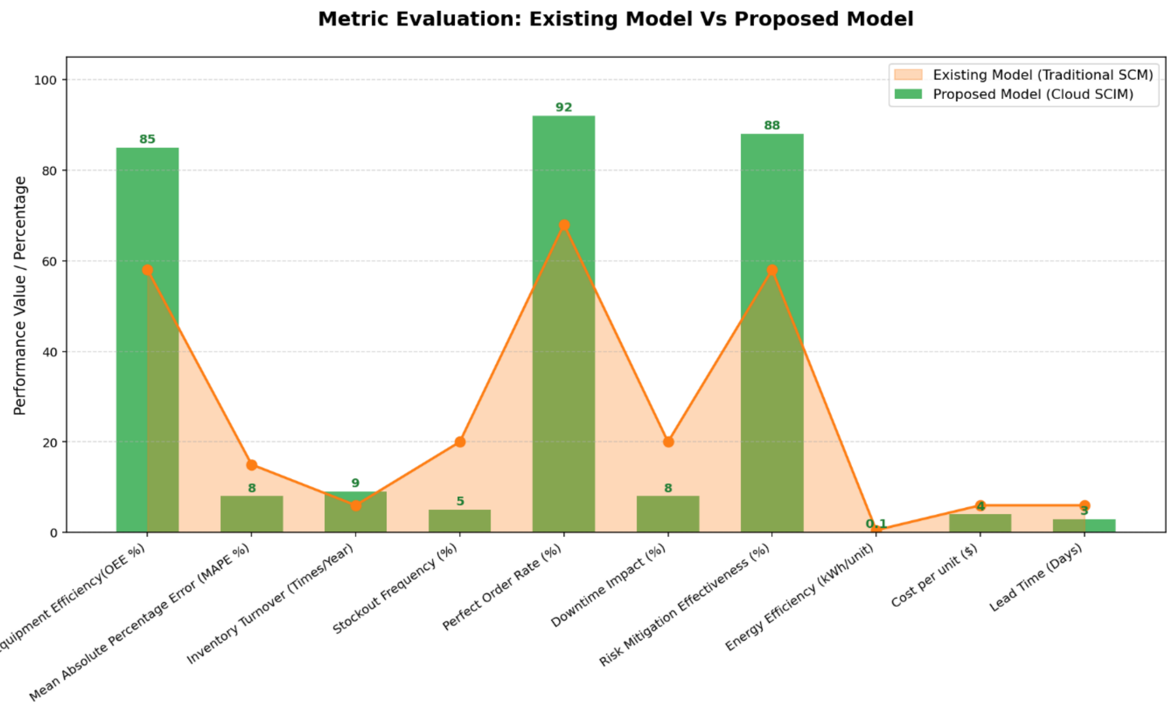

Figure 3. Metric evaluation of existing model vs proposed model

Ablation Study Analysis

Performance Metric Analysis of Proposed Model

Table 3. Performance metric analysis of proposed model

Metric	Existing Model (Traditional)	Cloud-SCIM (Full System)	Test 1: No IoT Sensors/Real-Time Data	Test 2: No AI Analytics	Test 3: No Cloud Platform
Overall Equipment Efficiency (OEE) (%)	65%	88%	60%	72%	75%
Mean Absolute percentage Error (MAPE) (%)	18%	9%	21%	25%	16%
Inventory Turnover (Times/Year)	5	9	4	5	6
Stockout Frequency (%)	22%	6%	30%	35%	20%
Perfect Order Rate (%)	78%	92%	72%	80%	83%
Downtime Impact (%)	18%	7%	23%	20%	15%
Risk Mitigation Effectiveness (%)	65%	88%	60%	72%	70%
Energy Efficiency (kWh/unit)	0.75	0.4	0.85	0.75	0.7
Cost Per Unit ($)	$6.50	$3.50	$7.00	$6.25	$6.00
Lead Time (Days)	6	3	7	6	5

To interpret above table 3 describes Cloud-SCIM (Full System) has a high level of performance compared to the Existing Model (Traditional) on all metrics, such as Overall Equipment Efficiency (OEE), demand forecasting (MAPE), inventory turnover, and frequency of stockout, and the Perfect Order Rate and Downtime Impact are improved. It minimizes the use of energy and unit cost and accelerates the Lead Time. Nevertheless, the ablation experiments indicate that when either of the three socio-technical elements are eliminated (iot sensors, AI analytics, or the cloud platform), the performance deteriorates observably. These findings underscore the paramount significance of every constituent in the realization of optimal system performance, efficiency and resilience in smart manufacturing systems.

CONCLUSION

Cloud-SCIM (Supply Chain Integration and Cloud-Based Operations Management to Resilient Smart Manufacturing) model has shown a significant enhancement to efficiency and sustainability, as well as resilience of manufacturing systems. The comparative analysis demonstrated that Cloud-SCIM model is better than traditional systems in the key performance metrics: Overall Equipment Efficiency (OEE) was increased up to 85% and Mean Absolute percentage Error (MAPE) decreased to 8 as compared to 15% and inventory turnover was increased to 9 times per year, respectively. The frequency of stockouts halved to 5 %, while the Perfect Order Rate increased by a quarter to 92 %. The proportion of downtime impact dropped by 20 to 8% and the effectiveness of risk mitigation rose by 65 to 88, which is the latitude of the model to optimize the production process and mitigate the disruptions. The model also resulted in cost savings, with the cost per unit reducing from $6 to $3.50, and improved energy efficiency, resulting in a reduction in consumption from 0.8 kWh/unit to 0.4 kWh/unit. These findings suggest that Cloud-SCIM can transform manufacturing systems by incorporating real-time data from IoT sensors, AI-powered analytics, and cloud platforms to improve how companies operate. Future research ought to work towards integrating more sophisticated machine learning practices like deep reinforcement learning in enhancing predictive maintenance and demand prediction. Increasing the model's capabilities across various industries, enhancing the cybersecurity of IoT systems and cloud computing, and incorporating blockchain to improve supply chain traceability will also be key to expanding the model's scalability and reliability. Finally, Cloud-SCIM becomes the door to the future of smart manufacturing, offering a path to more robust, efficient, and sustainable production settings.

REFERENCES

[1] Smina N, Gahi Y, Gharib J. Data Management in Smart Manufacturing Supply Chains: A Systematic Review of Practices and Applications (2020–2025). Information. 2025 Dec 27;17(1):19. https://doi.org/10.3390/info17010019

[2] Giannakis M, Spanaki K, Dubey R. A cloud-based supply chain management system: effects on supply chain responsiveness. Journal of Enterprise Information Management. 2019 Jun 18;32(4):585-607. https://doi.org/10.1108/JEIM-05-2018-0106

[3] Challouf K, Alhloul A, Nemeth N. Mapping the role of industry 4.0 technologies in green supply chain management: a bibliometric and structured text analysis. Discover Sustainability. 2025 Dec;6(1):1-32. https://doi.org/10.1007/s43621-025-01827-0

[4] Frank AG, Dalenogare LS, Ayala NF. Industry 4.0 technologies: Implementation patterns in manufacturing companies. International journal of production economics. 2019 Apr 1;210:15-26. https://doi.org/10.1016/j.ijpe.2019.01.004

[5] Zhu Q, Sarkis J, Geng Y. Green supply chain management in China: pressures, practices and performance. International journal of operations & production management. 2005 May 1;25(5):449-68. https://doi.org/10.1108/01443570510593148

[6] Yang D, Li R, Liu S. Exploring the Influence of Cloud Computing on Supply Chain Performance: The Mediating Role of Supply Chain Governance. Journal of Theoretical and Applied Electronic Commerce Research. 2025 Apr 10;20(2):70. https://doi.org/10.3390/jtaer20020070

[7] Yenugula M, Sahoo S, Goswami S. Cloud computing in supply chain management: Exploring the relationship. Management Science Letters. 2023;13(3):193-210. https://doi.org/10.5267/j.msl.2023.4.003

[8] Ivanov D, Dolgui A, Sokolov B. Cloud supply chain: Integrating Industry 4.0 and digital platforms in the “Supply Chain-as-a-Service”. Transportation Research Part E: Logistics and Transportation Review. 2022 Apr 1;160:102676. https://doi.org/10.1016/j.tre.2022.102676

[9] Al-Fuqaha A, Guizani M, Mohammadi M, Aledhari M, Ayyash M. Internet of things: A survey on enabling technologies, protocols, and applications. IEEE communications surveys & tutorials. 2015 Jun 15;17(4):2347-76.

[10] Surucu-Balci E, Iris Ç, Balci G. Digital information in maritime supply chains with blockchain and cloud platforms: Supply chain capabilities, barriers, and research opportunities. Technological Forecasting and Social Change. 2024 Jan 1;198:122978. https://doi.org/10.1016/j.techfore.2023.122978

[11] Zheng X, Zhang X. Robustness of cloud manufacturing system based on complex network and multi-agent simulation. Entropy. 2022 Dec 27;25(1):45. https://doi.org/10.3390/e25010045

[12] Aron C, Sgarbossa F, Ballot E, Ivanov D. Cloud material handling systems: A cyber-physical system to enable dynamic resource allocation and digital interoperability. Journal of Intelligent Manufacturing. 2024 Dec;35(8):3815-36. https://doi.org/10.1007/s10845-023-02262-6

[13] Rasheed A, San O, Kvamsdal T. Digital twin: Values, challenges and enablers from a modeling perspective. IEEE access. 2020 Jan 28;8:21980-2012. https://doi.org/10.1109/access.2020.2970143

[14] Su N, Huang S, Su C. Elevating smart manufacturing with a unified predictive maintenance platform: The synergy between data warehousing, apache spark, and machine learning. Sensors. 2024 Jun 29;24(13):4237. https://doi.org/10.3390/s24134237

[15] Romero D, Stahre J. Towards the resilient operator 5.0: The future of work in smart resilient manufacturing systems. Procedia cirp. 2021 Jan 1;104:1089-94. https://doi.org/10.1016/j.procir.2021.11.183

[16] Fowler DS, Epiphaniou G, Higgins MD, Maple C. Aspects of resilience for smart manufacturing systems. Strategic Change. 2023 Nov;32(6):183-93. https://doi.org/10.1002/jsc.2555

[17] Parhi S, Joshi K, Wuest T, Akarte M. Modelling resilience dynamics for smart manufacturing systems: quantification and empirical analysis. International Journal of Computer Integrated Manufacturing. 2025 Nov 2;38(11):1538-59. https://doi.org/10.1080/0951192X.2024.2438934

[18] Farooq MS, Riaz S, Helou MA, Khan FS, Abid A, Alvi A. Internet of things in greenhouse agriculture: a survey on enabling technologies, applications, and protocols. IEEE access. 2022 Apr 11;10:53374-97. https://doi.org/10.1109/access.2022.3166634

[19] Parhi S, Kumar S, Joshi K, Akarte M, Raut RD, Narkhede BE. Evaluation of operational transformations for smart manufacturing systems. Journal of Global Operations and Strategic Sourcing. 2024 Aug 27;17(3):541-73. https://doi.org/10.1108/JGOSS-06-2022-0070

[20] Sofic A, Rakic S, Pezzotta G, Markoski B, Arioli V, Marjanovic U. Smart and resilient transformation of manufacturing firms. Processes. 2022 Dec 12;10(12):2674. https://doi.org/10.3390/pr10122674