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SCOPE OF OPERATIONS MANAGEMENT IN THE ERA OF INDUSTRY 4.0: IOT AND ERP TECHNOLOGY

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Abstract
This study aims to analyse the expansion of the scope of operations management in the Industry 4.0 era through the integration of Internet of Things (IoT) and Enterprise Resource Planning (ERP) technologies. This study uses a literature review research method. The results of the study show that IoT plays an important role in providing real-time data through sensors and connected devices to support machine condition monitoring, predictive maintenance, and supply chain optimisation, while ERP functions as an integrated system that processes operational big data into comprehensive managerial information for production planning, inventory control, and integrated inter-functional coordination. The integration of IoT and ERP has been proven to reduce downtime, lower operational costs, improve planning accuracy, and strengthen end-to-end visibility of operational processes, thereby driving a shift from reactive operations management to proactive and adaptive smart operations. These findings confirm that the synergistic use of IoT and ERP is a strategic prerequisite for organisations seeking to enhance their competitiveness and readiness for smart factories within the Industry 4.0 framework.
Keywords: Operations Management, Industry 4.0, Internet of Things (IoT), Enterprise Resource Planning (ERP), Smart Manufacturing.

Introduction

The Industry 4.0 revolution marks an era of profound digital transformation in operations management, where the integration of cyber-physical technologies such as the Internet of Things (IoT) and Enterprise Resource Planning (ERP) has become a key pillar for improving global production and supply chain efficiency. Traditional operations management, which relied on manual processes, has now evolved into smart manufacturing systems that utilise real-time data for rapid decision-making, reducing downtime by up to 25% through predictive monitoring based on IoT sensors connected directly to ERP platforms (Huang & Li, 2023) . This phenomenon is not only relevant in developed countries such as Germany, but also in Indonesia, where the Ministry of Industry is promoting the adoption of Industry 4.0 for the competitiveness of the manufacturing sector through the digitisation of supply networks.

The Industry 4.0 era was first introduced at Hannover Messe 2011, emphasising the convergence of the physical, digital and biological worlds, which changed the paradigm of operations management from reactive to proactive. IoT technology enables massive connectivity between devices, generating big data that is processed by ERP for resource optimisation, as demonstrated in the Siemens and Unilever Indonesia case studies, which showed a 25% increase in demand forecasting accuracy and a reduction in production errors to 0.001% (Ivanov et al., 2019) . Amid challenges such as high infrastructure costs and cyber vulnerability, this integration provides sustainable competitive advantages through operational efficiency and better quality management (Widodo, 2024) .

Operations management in this context covers a broad scope ranging from production planning and inventory control to distribution, where IoT acts as the eyes and ears of the system through sensors that continuously monitor machine conditions. Modern ERP systems, such as SAP or Oracle, consolidate data from various business units—production, finance, logistics—for real-time monitoring, enabling managers to detect anomalies and prevent downtime before it occurs. This application has been proven to significantly reduce operational costs, with IoT facilitating predictive maintenance that saves time and resources in the Indonesian manufacturing sector (E. Pratama, 2024) . One of the crucial impacts of IoT is supply chain optimisation, where sensors on delivery trucks and warehouses provide real-time asset tracking integrated into ERP, improving transparency and coordination between departments. In the logistics sector, this enables accurate delivery scheduling, reducing delays by up to 30% and increasing customer satisfaction through full visibility of the process(Sulaksono, 2022) .

ERP is no longer just an accounting tool, but rather an enabler of digital transformation that automates operational recording, replacing manual tasks with IoT sensors to reduce human error. For example, in food and beverage factories, IoT automatically detects machine performance and sends notifications via ERP, enabling

timely intervention that keeps production flowing without interruption. This integration also supports lean manufacturing through predictive data analysis, where companies can predict maintenance needs and dynamically optimise inventory (Sudarmi, 2024) .

The main challenges in adopting IoT and ERP include high initial investment costs and cybersecurity risks, but long-term benefits such as reduced energy consumption and increased productivity offset these concerns. In Indonesia, studies show that companies adopting this technology experience increased time efficiency and customer satisfaction through a more optimal supply chain. Therefore, a phased implementation strategy with human resource training is the key to overcoming these obstacles (Nugroho, 2024) .

The development of IoT has revolutionised manufacturing with the concept of smart factory automation, where interconnected devices generate massive data for in-depth analytics via ERP. This enables accurate fact-based decision making, such as real-time production schedule adjustments based on sensor data, thereby increasing output without adding manpower (Abdullah, 2024) . In this era, operations management must be flexibility-oriented, where ERP provides an integrated dashboard for end-to-end visibility of business processes.

Globalisation is accelerating the need for IoT-ERP integration, especially in developing countries such as Indonesia, which is transitioning towards Making Indonesia 4.0. This technology supports vertical and horizontal collaboration in the value chain, where IoT data from suppliers is fed into a central ERP for inventory synchronisation. As a result, companies gain a competitive advantage through high responsiveness to dynamic market demand (Ivanov & Dolgui, 2024) .

The IoT enhances factory automation efficiency by focusing on equipment condition monitoring, while ERP ensures that this data is translated into strategic action. The combination of the two creates an adaptive operational environment, where machine failure predictions can be made with high accuracy, significantly reducing financial losses. This approach is in line with the principles of Industry 4.0, which emphasises interconnectivity for continuous innovation (B. Pratama & Sari, 2024) .

In specific sectors such as manufacturing, IoT-ERP integration facilitates efficient production process management, with sensors detecting performance declines and ERP coordinating preventive maintenance. Case studies show cost reductions of up to 20-30% through resource optimisation, making this technology essential for business continuity in the digital age. In addition, real-time data transparency strengthens operational governance and regulatory compliance.

Research Methods

This research methodology uses a systematic literature review to analyse the scope of operations management in the Industry 4.0 era, focusing on IoT and ERP

technologies. References for this research were taken from literature relevant to the research title in books, national and international journals ; (Okoli & Schabram, 2010) .

Results and Discussion

IoT Integration in Operations Management

The integration of the Internet of Things (IoT) in the management of Industry 4.0 operations is revolutionising the traditional production paradigm into a real-time data-driven smart manufacturing system, where sensors and devices are massively connected to monitor machine conditions, temperature, vibration, and material flow to instantly detect anomalies, thereby reducing downtime by up to 30% through predictive monitoring that replaces time-based routine maintenance schedules (. This technology enables connectivity between physical devices and the internet, generating big data that is processed to optimise operational processes, such as in Indonesian manufacturing plants where IoT improves supply chain efficiency through continuous asset tracking, reducing inventory errors and accelerating responses to market demand fluctuations. A literature review shows that IoT integration not only increases productivity but also creates an adaptive ecosystem that supports lean manufacturing with waste minimisation through predictive data analysis (Ramadhan, 2023) .

One of the main applications of IoT is predictive maintenance, where sensors on production equipment measure performance parameters in real time and send data to an analytics platform to predict failures before they occur, enabling companies such as Unilever Indonesia to record a 20% reduction in maintenance costs and a significant increase in machine life. This process involves machine learning algorithms that process historical and current data patterns to generate automatic notifications, enabling operations managers to intervene in a timely manner without halting the entire production line (Soori et al., 2023) . In the Indonesian context, the adoption of predictive maintenance via IoT has been proven to save up to 15% in energy in the manufacturing sector, aligning with the Making Indonesia 4.0 initiative that promotes digital transformation.

IoT also optimises the supply chain by integrating RFID and GPS sensors into logistics vehicles and warehouses, providing end-to-end visibility from suppliers to customers, reducing delivery delays by up to 30% and increasing inventory accuracy to 99% through automatic data synchronisation. In operations management, this facilitates more accurate demand forecasting by combining external data such as weather and traffic with internal inputs, allowing companies to dynamically adjust stock without overstocking or stockouts. A case study in warehousing shows that IoT-based automated robots improve picking and packing effectiveness, reducing labour costs while accelerating operational throughput (Ben-Daya et al., 2019) .

In the production process, IoT supports the digital twin concept, which replicates physical assets virtually for scenario simulation, enabling testing of process changes

without real risk, such as optimising assembly line flow, which increases output by up to 25% in a 4.0 manufacturing laboratory. This technology connects machines via protocols such as MQTT or OPC UA for secure data exchange, creating smart factories that are adaptive to demand variations, where operations management can run mass customisation production with mass production efficiency. This integration also minimises human error by automating repetitive tasks, allowing human resources to focus on high-value activities such as innovation (Ben-Daya & Hassini, 2017) .

Energy efficiency is a key focus of IoT in operations management, where smart sensors monitor electricity consumption per machine and automatically adjust loads, resulting in savings of up to 15-20% in industrial facilities through AI-based optimisation algorithms (Singh & Kumar, 2025) . In Indonesia, this application supports sustainability goals by integrating IoT into SCADA systems for production environment control, such as HVAC settings based on real-time occupancy, which is in line with national green manufacturing regulations. Empirical studies confirm that IoT promotes a circular economy by tracking recyclable materials and sustainably reducing operational waste (Wijaya, 2024) .

Operational security is enhanced through IoT with end-to-end data encryption and blockchain authentication to prevent cyber attacks on production networks, where AI-based intrusion detection systems block threats in real time without disrupting operations. Key challenges such as vendor interoperability are addressed with Industry 4.0 standards such as RAMI 4.0, ensuring compatibility of sensors from different manufacturers within a single operations management ecosystem. In Indonesia's manufacturing sector, training human resources to manage IoT is crucial for risk mitigation, with ROI realised within 12-18 months ((et al., 2023) .

Data-driven decision-making is revolutionised by IoT, which provides integrated real-time dashboards where operations managers can visually access KPIs such as OEE (Overall Equipment Effectiveness) for rapid response to production bottlenecks. For example, in factory automation, IoT triggers autonomous maintenance where machines self-diagnose and reorder spare parts via API, reducing lead time from days to hours. This enhances operational agility, essential in the post-pandemic era of volatility where demand changes drastic(& Sari, 2024) .

Vertical and horizontal collaboration in the value chain is made possible by IoT, where data from suppliers is fed into a central system for just-in-time inventory synchronisation, increasing supply chain throughput by up to 25%. In Indonesia, platforms such as the Indonesia IoT Initiative facilitate secure data sharing between companies, creating a collaborative industrial ecosystem that is globally competitive. This integration also supports product traceability for regulatory compliance such as Halal or ISO 9001(Kumaat, 2024) . The impact on product quality is significant, with IoT continuously monitoring process parameters for six sigma level control, detecting defects upstream and preventing costly rework. Vision sensors and AI-powered

automated inspection increase yield rates to 98%, supporting zero-defect manufacturing in the 4.0 era. A food manufacturing case study demonstrates reduced product recalls through real-time batch tracking ((et al., 2025) .

Production flexibility is enhanced by IoT through rapid software-based machine reconfiguration, allowing switching from one product variant to another in minutes, not hours. This supports servitisation business models where operations focus on outcomes such as SLA uptime, rather than asset ownership. In the ASEAN market, this competition is a key advantage for early adoption of(& Tumewu, 2024) . Operational costs are drastically reduced thanks to IoT, with a quick ROI from reductions in energy, material and time waste, reaching break-even in 1-2 years. Total cost of ownership analysis shows cumulative savings of 20-40% post-implementation. A phased strategy, such as a pilot project on one production line, minimises risk. Customer satisfaction increases through IoT-enabled customisation, where preference data is integrated into operations for fast personalised delivery. Predictive analytics anticipates demand spikes, maintaining a 99% service level. In e-commerce integrated manufacturing, this accelerates the order-to-cash cycle(Romansyah, 2025) .

Infrastructure challenges in developing countries such as Indonesia are overcome with IoT edge computing, which processes data locally to reduce latency and cloud dependency. The hybrid cloud-edge model is a scalable solution for manufacturing SMEs. The future of IoT integration is moving towards 5G-enabled operations for ultra-low latency, supporting safe cobot-human collaboration on the shop floor. AIoT fusion enhances the operational intelligence of autonomous (Sari, 2024) .

Overall, IoT expands the scope of operational management into a hyper-connected ecosystem that is resilient, innovative, and competitive in the Industry 4.0 era, with this study synthesising empirical evidence for an implementation roadmap.

The Role of ERP in the Industry 4.0 Era

Enterprise Resource Planning (ERP) plays a central role in the Industry 4.0 era as a digital backbone that integrates all operational processes from production planning to distribution, enabling real-time data synchronisation between departments to increase efficiency by up to 25% through workflow automation and the elimination of traditional information silos. Modern ERP systems such as SAP S/4HANA or Oracle Cloud ERP have evolved from accounting modules into advanced analytics platforms that process big data from IoT, supporting AI-based decision-making for supply chain optimisation in Indonesian manufacturing.(Nugraha, 2024) .

Integrated production planning is a key strength of ERP, where the MRP (Material Requirements Planning) and MPS (Master Production Schedule) modules accurately predict raw material requirements based on real-time demand forecasting, enabling companies such as PT Unilever Indonesia to achieve up to a 25% increase in

accuracy and a reduction in overproduction. Integration with IoT sensors enables ERP to dynamically adjust production schedules to actual machine conditions, avoiding bottlenecks and maximising factory capacity utilisation by up to 95%. In the national context, ERP supports Making Indonesia 4.0 with local modules for regulatory compliance such as BPOM and Halal, which are essential for the food and beverage sector (Hidayat, 2023) .

Inventory management is optimised by ERP through a perpetual inventory system that continuously tracks stock via IoT-connected RFID barcodes, reducing stockouts by up to 30% and overstocking that causes high holding costs. ABC analysis and EOQ (Economic Order Quantity) algorithms automatically calculate reorder points based on historical data and market trends, facilitating just-in-time delivery in line with Industry 4.0 lean manufacturing principles. A manufacturing case study shows inventory cost savings of up to 20% through an ERP visual dashboard that monitors turnover ratios in real-time ((et al., 2022)). Integrated quality control is achieved through the Quality Management System (QMS) module in ERP, which integrates IoT inspection data for Six Sigma compliance, detects defects in upstream processes, and prevents costly rework. ERP generates automated non-conformance reports with AI-based root cause analysis, increasing the yield rate to 98% on automated production lines. In Indonesia, this integration supports ISO 9001 certification with end-to-end product traceability, crucial for manufacturing exports (Manavalan & Jayakrishna, 2019).

Supply chain management is enhanced by ERP with a vendor portal collaboration that shares real-time data, enabling supplier management scorecards and vendor performance analytics to mitigate disruption risks. The SCM (Supply Chain Management) module predicts delivery delays through predictive analytics, optimises logistics routing and reduces total landed costs by up to 15%. Platforms such as SAP Ariba integrated with ERP facilitate transparent e-procurement, in line with the national digitalisation initiative (Huang & Li, 2023) .

Real-time data analysis is a differentiator for ERP in the 4.0 era, where embedded analytics and BI tools provide KPI dashboards such as OEE, cycle time, and throughput for instant decision-making by operations managers. Integration with machine learning enables anomaly detection in production processes, triggering proactive alerts that reduce downtime from days to hours. In Indonesia's manufacturing sector, cloud-based ERP offers scalability for SMEs, with ROI realised within 12-18 months (Ivanov et al., 2019).

Business process automation through ERP replaces manual tasks with robotic process automation (RPA), reducing human error by up to 90% in recording operational transactions such as goods receipt and invoice matching. Digital workflow approval accelerates the procurement cycle time from weeks to days, increasing operational agility in a VUCA (Volatility, Uncertainty, Complexity, Ambiguity) environment. This

transformation frees up human resources to focus on strategic matters such as product innovation (Widodo, 2024) . Data security and compliance are enhanced by ERP with AES-256 encryption, role-based access control, and a complete audit trail for GDPR or Indonesian PDP regulations, protecting sensitive operational data from cyber threats. The risk management module monitors integrated IoT endpoint vulnerabilities, ensuring operational resilience. In the digital era, ERP serves as a fortress supporting business continuity planning (E. Pratama, 2024) .

The scalability of cloud ERP enables operational expansion without major hardware investments, with a pay-as-you-go model that is suitable for fast-growing Indonesian manufacturing start-ups. Hybrid deployment accommodates gradual legacy system migration, minimising disruption during the transition to Industry 4.0. Local vendors such as HashMicro or NCI provide customised ERP for national regulations(Sulaksono, 2022) .

Integrated operational financial reporting in ERP connects cost accounting with activity-based costing (ABC) for accurate cost allocation per production process, supporting real-time margin-based pricing decisions. Automatic variance analysis compares actual vs budget, identifying cost overruns early for corrective action. This enhances sustainable operational profitability (Sudarmi, 2024) . Inter-departmental collaboration is facilitated by ERP through a single source of truth, where production, sales, and finance data are synchronised for cross-functional KPI alignment, improving overall equipment effectiveness (OEE) (Nugroho, 2024) . Mobile access enables remote monitoring, essential for distributed manufacturing.

ERP-IoT integration creates closed-loop operations where sensor feedback directly updates MRP and scheduling, realising the Industry 4.0 autonomous factory vision. Siemens, for example, has reduced maintenance costs by 20% through predictive alerts. In Indonesia, Unilever has adapted this model for local efficiency. ERP implementation challenges are overcome through change management and human resource training, where ROI depends on a user adoption rate above 80% to maximise the benefits of . A phased rollout from pilot plants to full scale minimises risk. Local vendor support accelerates time-to-value. The future of ERP is moving towards AI-native and blockchain integration for smart contracts in the supply chain, supporting hyper-automation of operations. In ASEAN, ERP is key to sustainable manufacturing competitiveness (Ivanov & Dolgui, 2024) .

Overall, the role of ERP in the Industry 4.0 era expands the scope of operational management to become a resilient and innovative intelligent enterprise, with this synthesis providing a strategic roadmap for adoption in Indonesia.

Conclusion

The synergistic integration of IoT and ERP technology expands the scope of operations management in the Industry 4.0 era into a hyper-connected smart

manufacturing ecosystem, where IoT provides real-time data from physical sensors for predictive maintenance and supply chain optimisation, while ERP processes this big data into strategic insights for accurate production planning, just-in-time inventory management, and AI-based decision-making that reduces downtime by up to 30% and operational costs by 20-25% based on comprehensive literature reviews. This transformation not only improves process efficiency from upstream procurement to downstream distribution, but also supports mass customisation flexibility, six sigma quality, and sustainability through energy savings and circular economy principles, as evidenced in Indonesian manufacturing case studies such as Unilever, which achieved an OEE of over 95% post-adoption. Overall, the combination of these two technologies creates a proactive operational paradigm that is resilient to global market volatility.

The main challenges in implementation include high initial investment costs, cyber security on IoT-ERP networks, and human resource limitations in developing countries such as Indonesia. However, long-term benefits such as a 12-18 month ROI, increased global competitiveness, and national regulatory compliance (Making Indonesia 4.0) offset these risks through a phased rollout strategy and digital literacy training. A literature review confirms that companies that have successfully integrated IoT-ERP have experienced a 25% increase in customer satisfaction through end-to-end visibility and high responsiveness, causing the scope of operations management to evolve from reactive to autonomous operations. In the local context, government initiatives are accelerating adoption in priority manufacturing sectors.

Research recommendations include developing a phased implementation roadmap starting with a pilot project on one production line, collaborating with local ERP vendors such as HashMicro for customisation, and investing in upskilling human resources through Industry 4.0 certification to address the skills gap, so that operations management practitioners can realise the full potential of this technology in increasing national productivity. Further research is recommended to adopt mixed methods with empirical case studies in Indonesian SMEs to validate the generalisation of the findings of this literature review. Ultimately, the adoption of IoT-ERP is a strategic imperative for competitive sustainability in the digital era.

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