Int j simul model 24 (2025) 3, 425-436
Review scientific paper

ERP-DRIVEN SIMULATION FOR PRODUCTION PLANNING AND CONTROL IN THE INDUSTRY 4.0: A REVIEW

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Abstract
In the context of Digital Transformation and Industry 4.0, Enterprise Resource Planning (ERP) systems are crucial for improving Production Planning and Control (PPC) and supporting simulation projects. This Systematic Literature Review (SLR) analyses studies from Scopus® and Web of Science® to examine how ERP systems aid decision-making in PPC. The findings highlight key benefits such as real-time data integration, enhanced predictive analytics, and improved production scheduling. ERP systems also support cross-functional optimization and better supply chain coordination. However, challenges remain, including model validation, integration complexity, and data requirements. Since 2017, there has been growing interest in discrete-event simulation (DES) and digital twins to enhance ERP-driven PPC. This review emphasizes the need for further research into simulation-based ERP models to improve adaptability and decision support in manufacturing environments.
(Received in March 2025, accepted in July 2025. This paper was with the authors 1 week for 1 revision.)

Key Words: Production Planning, ERP Systems, Simulation Modelling, Digital Transformation, Decision-Making

1. INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) is reshaping manufacturing by demanding more integrated, digitalized, and adaptive operations. In this scenario, Production Planning and Control (PPC) activities are critical to ensuring flexibility, responsiveness, and operational efficiency, especially given increasing product customization and rapidly evolving markets [1]. Enterprise Resource Planning or ERP systems play a central role by offering integrated platforms that support operational reconfigurations through adaptive methodologies and provide real-time data to enhance agile planning and responsiveness [2]. ERP-based PPC further enables predictive analytics and informed decision-making [3].

ERP integration is also key to building accurate and reliable simulation models. By consolidating real-time data across departments, ERP systems provide a robust foundation for tools such as discrete-event simulation (DES) and digital twins. This integration between simulation and real-time process data allows companies to periodically test production scenarios, identify bottlenecks, and simulate changes prior to implementation [4].

Improved decision-making is a major goal of ERP adoption, as integration across purchasing, production, sales, and finance enables a holistic view of operations and supports faster, coordinated decisions [5, 6]. Automation contributes to reducing rework and increasing process responsiveness [7], while inventory and production level optimization drives cost reduction and waste minimization [8, 9]. ERP systems support better demand forecasting and resource utilization, enhancing PPC strategies.

As ERP systems become integrated with technologies such as IoT, cloud computing, big data, AI, and cyber-physical systems, they reinforce real-time decision-making in dynamic industries like automotive and electronics [10], while enabling early failure detection through digital twins [5, 7]. Despite existing reviews on ERP or PPC, few explore their intersection with simulation. This SLR fills this gap and contributes to research and practice in Industry 4.0 and Digital Transformation environments.

2. A SYSTEMATIC LITERATURE REVIEW

Unlike traditional reviews, the Systematic Literature Review (SLR) adopts a structured approach with defined steps to answer specific research questions. As noted by Pinto et al. [11], it involves (i) a detailed examination of relevant literature and (ii) statistical techniques to enhance result accuracy. Based on the method proposed by the authors, the SLR is conducted in four phases: Planning (definition of objectives and questions), Search/Screening (literature selection using criteria), Analysis/Synthesis (interpretation of results), and Presentation (summary of conclusions and insights).

2.1 Planning

To define the research objectives and Research Questions (RQs), an initial exploratory search was conducted using the Scopus® database, known for its comprehensive multidisciplinary coverage [12]. The search combined the keywords "Digital Transformation", "ERP System", and "Production Planning and Control", focusing on peer-reviewed journals and conference proceedings. This preliminary phase included collaborative discussions with professors from three Brazilian universities with expertise in the field. These meetings helped identify critical gaps in the literature and guided the formulation of the RQs.

The main objective of this study is to conduct a comprehensive review of the literature on ERP systems and decision-making in Production Planning and Control (PPC), aiming to build a strong theoretical foundation and highlight emerging trends. The RQs were developed using the CIMO logic model proposed by Denyer et al. [13], which structures the investigation around four components: Context (sectors and regions of application), Intervention (decision-making objectives), Mechanism (ERP tools and techniques), and Outcomes (benefits, limitations, and future directions).

This study integrates a Systematic Literature Review (SLR) with the CIMO approach to assess how ERP systems support PPC decision-making. The resulting RQs are:

- RQ1: Which sectors and regions show greater ERP adoption (Context)?
- RQ2: What are the main decision-making objectives (Intervention)?
- RQ3: Which ERP tools are most effective, and how are they applied (Mechanism)?
- RQ4: What are the advantages, challenges, and future perspectives (Outcomes)?

2.2 Search / screening

The first step in conducting the Systematic Literature Review (SLR) was selecting reliable and comprehensive databases. For this study, Scopus® and Web of Science® were chosen due to their broad coverage of high-impact journals and conference proceedings. The keyword "ERP systems" was selected after preliminary analysis, as it broadly represents topics related to Enterprise Resource Planning, such as implementation, optimization, and performance.

The search strategy followed specific inclusion criteria: (i) terms had to appear in the title, abstract, or keywords; (ii) only peer-reviewed full articles and conference proceedings published up to July 2024 were included; (iii) articles had to be written in English; and (iv) only studies with practical applications in Production Planning and Control (PPC) were accepted, excluding literature reviews.

The initial search yielded 72 articles after duplicates were removed. These were screened through abstract analysis to assess alignment with the SLR objectives. Articles not meeting the criteria were excluded. At the end of this stage, 32 articles remained for full-text review. Fig. 1

presents the steps followed during the Planning and Search/Screening phases, illustrating the methodological rigor adopted in the selection process.

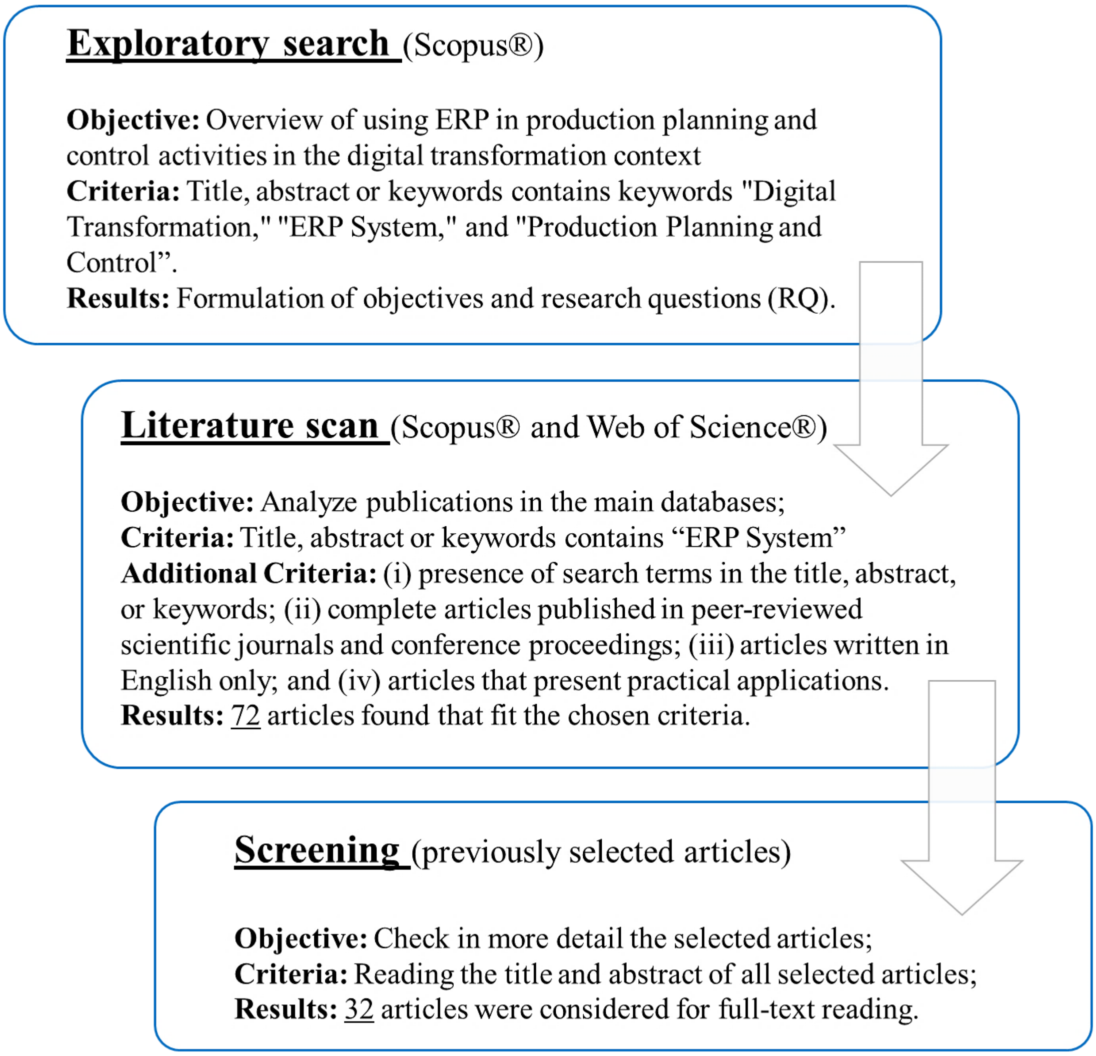

Figure 1: Procedures performed in the Planning and Searching / screening stages.

2.3 Synthesis of the analyses

The findings were analysed using a Microsoft Excel® spreadsheet, organizing data from 32 reviewed articles. Each study was systematically recorded based on predefined research questions (RQs), with data analysed through descriptive statistics. Section 3 presents the results, using tables and charts to summarize insights on ERP decision-making support.

3. FINDINGS AND DISCUSSION

3.1 State of the art

Among the 32 reviewed articles, it is observed that this research field is still emerging and relatively unexplored, as the oldest article examined was published in 2017. Furthermore, it is a promising area, evidenced by the increase in annual publications. It is worth noting that publications from 2024 were not significant for this analysis, as the review did not cover the entirety of the year. Fig. 2 illustrates the trends in annual publication of the analysed articles.

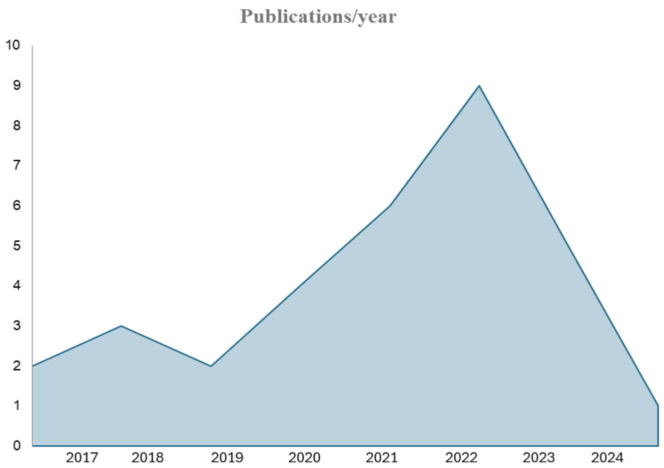

Figure 2: Publication rate over the years.

The studies were published in 24 scientific journals and one conference proceeding. Table I lists the top 10 sources, with the four leading journals accounting for 34.38 % of publications. Production Planning & Control is the most prominent, representing 15.63 % of analysed articles. Most journals had only one publication, highlighting the field's multidisciplinary nature and broad compatibility across research domains.

Table I: Top 10 sources of publication.

Journals	Publications	[%]
Production Planning & Control	5	15.63 %
Robotics and Computer-Integrated Manufacturing	2	6.25 %
Journal of Cleaner Production	2	6.25 %
Technological Forecasting and Social Change	2	6.25 %
Operations Management Research	1	3.13 %
IEEE Systems Journal	1	3.13 %
Long Range Planning	1	3.13 %
International Journal of Advanced Manufacturing Technology	1	3.13 %
International Journal of Technology Management	1	3.13 %
Others	16	50.00 %

3.2 Adoption of ERP systems across industrial sectors and geographic influences

This section addresses RQ1, which explores the industrial sectors and geographic regions with the highest ERP system adoption. The literature reveals a predominance of studies from Europe (46 %), driven by Industry 4.0 initiatives and manufacturing modernization. Asia (29 %), particularly China, India, and Taiwan, also shows strong engagement due to industrial digitalization efforts. South America (8 %), mainly Brazil, has fewer studies. Additionally, about 16 % of publications are classified as "Others" or "No Indication," reflecting broader or unspecified scopes. Fig. 3 highlights the dominance of Europe and Asia in ERP-related PPC research.

Geographical factors, such as industrialization levels, technological infrastructure, and government policies, significantly influence ERP adoption. Europe, especially Germany, leads due to initiatives like Industry 4.0, which promotes production system integration to boost competitiveness [10, 14]. Finally, Programs such as the EU's H2020 Framework also support ERP-driven modernization [15].

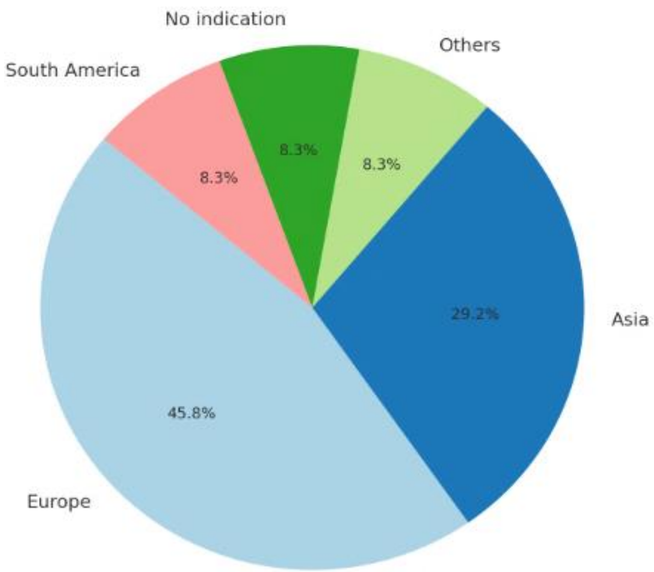

Figure 3: Geographical distribution of ERP and PPC research studies.

In Latin America, Brazil stands out, notably in the automotive and manufacturing sectors, where ERP improves operational efficiency [16, 17]. However, adoption is hindered by limited infrastructure and high costs. In Asia, countries like India, China, and South Korea show strong ERP uptake. In India, industrial expansion has driven ERP use [18], while in China, ERP is central to modernizing industry [19], and, finally, in South Korea, sectors such as foundries use ERP to integrate data and enhance productivity [20].

Fig. 4 presents a Pareto chart of ERP and PPC research by sector. Manufacturing leads with 28.96 %, followed by logistics & supply chain (15.79 %) and services (11.85 %), emphasizing ERP's strong role in industrial contexts. The cumulative curve indicates that a small number of sectors concentrate most studies, while fields like consumer goods, aerospace, and clothing are less explored, highlighting potential areas for future investigation.

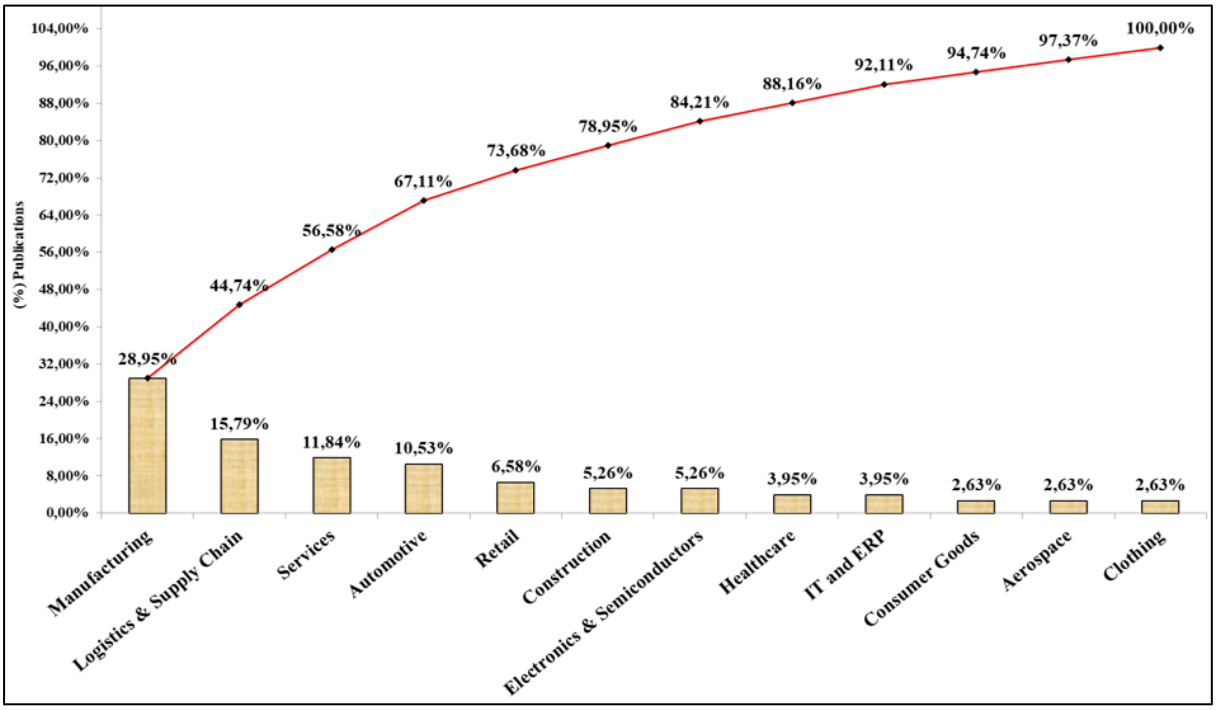

Figure 4: Sectoral distribution of ERP and PPC research studies.

ERP systems are applied across diverse industrial sectors, each with distinct needs that justify their adoption. The manufacturing sector is a leading adopter, with studies highlighting ERP's role in optimizing production, integrating data, and enhancing quality control [1, 9, 10]. Even SMEs in this sector benefit from ERP to manage process complexity [2]. The automotive industry shows strong ERP integration due to the complexity of production and logistics. Studies by Pozzi et al. [14], Shukla and Shankar [18], and Llopis-Albert et al. [21] underline ERP's effectiveness in enabling real-time management and inventory optimization. Similarly, in logistics and supply chain, ERP enhances efficiency, supports inventory control, and streamlines logistics processes. Authors like Ribeiro and Björkman [15] and Lyngstadaas and Berg [22] emphasize ERP's importance for real-time traceability and responsiveness.

In the semiconductor industry, ERP is key for managing highly complex operations. Research by Kuhnle et al. [5] and Nuhu et al. [23] demonstrate its value in resource planning and process coordination. In the retail and service sectors, ERP supports inventory management, demand responsiveness, and integration with logistics [24, 25]. The aerospace sector also adopts ERP widely due to its need for extensive data management, supplier coordination, and traceability. Studies by Ottogalli et al. [26] and Ahmed et al. [27] identify ERP as essential for ensuring quality and operational control in these demanding environments.

3.3 ERP and Production Planning and Control (PPC): decision-making objectives

This section addresses the decision-making objectives related to ERP use in production planning and control. As shown in Fig. 5, the main goals are to improve efficiency, responsiveness, and transparency. The leading objectives include Information Integration, Real-time Control, and Process Visibility (each with 16 %), followed by Cost Reduction and Data Quality (each with 10 %), underscoring the relevance of both financial performance and reliable information management in ERP-supported PPC.

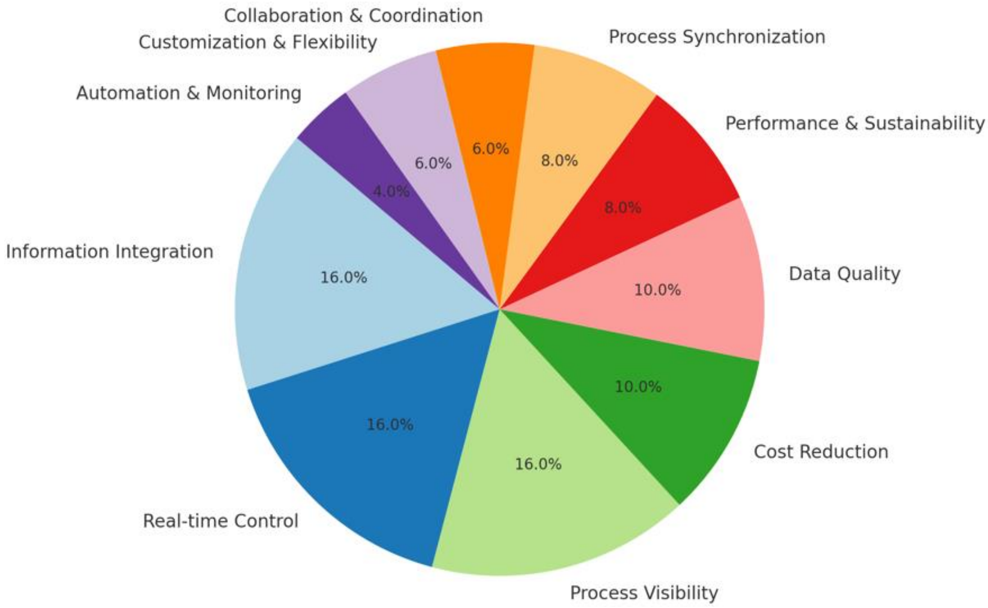

Figure 5: Key factors in process optimization with ERP systems.

One of the main barriers to ERP adoption is the high implementation cost, especially for small and medium-sized enterprises, along with the complexity of integrating emerging technologies such as IoT and Artificial Intelligence [6, 10]. However, as these technologies become more accessible, the creation of smart and autonomous factories is becoming increasingly feasible [28]. A key objective of ERP adoption is operational efficiency, with a strong focus on automation and real-time responsiveness, enabling agile decision-making and a holistic view of operations across departments like procurement, production, and finance [5, 6, 14]. The strategic integration of data through ERP supports fast, informed decisions, particularly important in environments with high demand variability.

Cost reduction is another widely mentioned goal, linked to the optimization of production processes. ERP systems help minimize delays, reduce production costs, and improve inventory control, increasing production capacity and customer satisfaction [8, 9]. They also help prevent bottlenecks by adjusting work-in-process levels and promoting efficient resource use. Moreover, real-time decision-making is a key benefit, especially in volatile sectors such as automotive and electronics [5, 29]. When combined with IoT and AI, ERP enables faster adjustments to production plans [7, 10].

Additionally, sustainability is an emerging goal, reflecting efforts to incorporate energy efficiency and sustainable practices [7]. Automation and demand forecasting tools, supported by predictive analytics and Business Intelligence (BI), enhance flexibility and adaptability [18].

3.4 ERP techniques and tools

This section addresses RQ3, focusing on the ERP techniques and tools that have proven most effective in enhancing Production Planning and Control (PPC). ERP systems are essential in PPC by integrating diverse methodologies and technologies that boost operational efficiency. Through the analysis of selected studies, key tools and their applications across different industries are identified, demonstrating how they optimize planning, scheduling, and resource management. Table II summarizes the main ERP techniques and their practical use in various industrial contexts, emphasizing their contribution to improved PPC performance.

Table II: ERP techniques and applications in PPC.

Papers	System implementation	Sector	Region
[14]	Smart Factory	Manufacturing companies	Italy
[3]			UK / India
[10]		Cyber-physical production system	Namibia / India
[24]			UK
[6]	Supply Chain Management	Plastic industry	Turkey
[30]	Building Information Modelling	Precast concrete manufacturers	Singapore
[31]	Industrial Augmented Reality	Gearbox manufacturer	UK
[2]	Reconfigurable Manufacturing System	Automotive components manufacturing	South Korea
[28]	Production Control API	Cyber-physical production system operations	USA
[25]	Smart Manufacturing Recommendation Model		Taiwan
[15]	Automation Solutions & Smart Factory		Sweden
[32]	Environmentally-sustainable manufacturing	Manufacturing companies	France / Brazil
[16]	DfAM and Master Sample Procedure	Automotive manufacturing industry	Brazil
[26]	Aircraft Final Assembly Line	Aircraft manufacturing industry	Spain
[33]	Manufacturing Process Planning	Integrated shoe last design & manufacturing	Italy
[1]		Manual assembly work	Belgium
[17]		Rotor blades manufacturing industry	Germany / Belgium
[34]	DfAM & Energy Comparison: Additive vs. Conventional	Stainless manufacturing industry	USA
[8]	Manufacturing & Operations Control	Interconnected manufacturing stations	Brazil
[35]	Production Planning	Metallurgical manufacturing industry	Slovakia / Poland
[9]		Telecommunication equipment manufacturing industry	China

[5]	Production Control	Semiconductor manufacturing industry	Germany
[27]	Manufacturing Capability Analysis & Process Planning (MCAPP)	Threading tap manufacturing industry	Australia / Poland
[23]	Fault Diagnosis	Semiconductor manufacturing industry	Turkey, South Africa, and Saudi Arabia
[18]	CSF for SME Smart Manufacturing Implementation	Auto-component, apparel, food, furniture, paper, and energy industries	India
[29]	Production Control API	Machinery manufacturing industry	Taiwan
[20]	Energy Management System	Energy-intensive industry	South Korea
[7]		Manufacturing companies	Italy
[21]	Business Performance Models	Automotive industry	Spain
[19]	Configuration & Transformation Capability	Chinese clothing manufacturing industry	UK / China

The Smart Factory paradigm, especially cyber-physical systems (CPS), is prominent in manufacturing, improving automation, real-time monitoring, and decision-making in countries like Italy, Namibia, India, the UK, and Sweden [3, 10, 14, 15, 24]. Production Control using APIs is widely adopted in semiconductor and machinery industries in Germany, Taiwan, and the USA [5, 28, 29]. In South Korea, Reconfigurable Manufacturing Systems (RMS) enhance flexibility in automotive components [2], while Manufacturing Process Planning (MPP) supports assembly optimization in Italy, Germany, Belgium, and China [1, 17, 33]. Energy Management Systems (EMS) contribute to sustainability goals in Italy and South Korea [7, 20], while environmentally sustainable manufacturing practices are noted in France and Brazil [32].

Several industry-specific ERP applications stand out: Building Information Modelling (BIM) in precast concrete (Singapore) [30], Industrial Augmented Reality (IAR) for gearbox manufacturing (UK) [31], and ERP optimization in aircraft final assembly (Spain) [26]. Additional methods include MCAPP in threading tap production (Australia, Poland) [27], business performance models for the automotive industry (Spain) [21], and ERP-based configuration resources and transformation capability in the clothing sector (China, UK) [19]. These studies show that ERP-based PPC solutions are diverse and context-specific, with recurring themes of automation, integration, real-time control, and sustainability as key drivers of efficiency across sectors and regions.

3.5 Advantages, challenges, and open issues

RQ4 explores the advantages, challenges, and future perspectives of ERP use in production planning and control. ERP systems notably improve operational efficiency through data integration and process automation, enhancing coordination across departments and reducing errors. Studies also emphasize ERP's ability to provide real-time visibility across production phases, enabling faster and better-informed decisions [14, 20]. These benefits are especially valuable in dynamic and complex environments. Table III outlines key research questions, as well as opportunities and challenges identified in the analysed literature, offering insights for future investigation.

One of the key advantages of ERP systems is their ability to integrate data across multiple departments, creating a unified information base essential for supporting organizational simulations and strategic decision-making [6]. By connecting production, finance, logistics, and sales, ERP enables managers to model real-world operational dynamics more accurately, enhancing production planning and control. This integrated environment also facilitates the identification of bottlenecks and process inefficiencies, providing critical inputs for simulation modelling [7]. ERP systems further contribute to cost reduction by optimizing inventory management, resource allocation, and material usage [26]. Shorter manufacturing cycle times also improve operational agility and reduce expenses [28], simulated and forecasted through data-driven modelling approaches.

Table III: Main findings related to the use of ERP for PPC.

Features	Findings
Advantages	• **Operational Efficiency:** Optimization of production processes, reducing operation time and costs [6, 9, 16, 23, 35]. • **Data Integration:** Consolidation of information into a single system, facilitating data management and process visibility [7, 14, 17, 21]. • **Cost and Time Reduction:** Minimizing waste and increasing task execution speed, while improving ergonomics and safety [26, 33]. • **Supply Chain Visibility:** Continuous monitoring of inventory and demand forecasting to prevent stockouts and excess inventory [10, 25, 28]. • **Decision Support:** Access to updated and accurate data to support strategic and operational decisions, reducing errors and rework [16, 20, 27, 30, 32].
Issues	• **Resistance to Change:** Challenges in employee acceptance and adaptation to new ERP systems and technologies [6, 14, 17, 35]. • **Implementation Complexity:** The process involves multiple stages, from customization to data integration, requiring significant time and resources [7, 21, 23]. • **Steep Learning Curve:** The complexity of ERP systems necessitates continuous employee training to fully utilize all functionalities [1, 9, 32]. • **Data Quality and Updates:** Outdated or low-quality data impact decision-making accuracy and operational efficiency [1]. • **Integration with Physical Systems:** Challenges in communication between ERP systems and production equipment, especially in complex industrial environments [5, 8, 20]. • **High Implementation and Maintenance Costs:** Substantial initial and ongoing investments, which can significantly impact ROI and company budgets [17, 21, 35].
Opportunities	• **Integration with AI and IoT:** Adoption of Artificial Intelligence and the Internet of Things in ERP systems for enhanced predictive analysis and real-time process monitoring [1, 3, 14, 35]. • **Expansion to Digital Twins:** Utilization of digital twins to simulate operations and predict failures, enabling proactive adjustments in production control [1, 20]. • **Continuous Adaptation and Customization:** Development of customizable ERPs tailored to specific needs, broadening applicability across different industries and company sizes [6, 22, 34]. • **Automation and Resource Optimization:** Implementation of algorithms and process automation to optimize human and material resources, reducing waste and maximizing productivity [24, 32]. • **Real-Time Decision Support Capabilities:** Tools for rapid and precise analysis, allowing immediate decision-making responsive to market dynamics [1, 3, 21]. • **Sustainability and Environmental Management:** Integration of sustainable practices and reduction of environmental impact through optimized resource and process management [17, 24, 32].

However, ERP implementation poses challenges that can impact simulation efforts. Employee resistance to new systems may limit the quality and completeness of data input, accuracy and reliability of simulation models [6, 22]. Training and stakeholder engagement are crucial to ensure reliable data entry and system usage [17]. Additionally, the complexity of ERP implementation, often involving process reengineering, can delay or hinder the development of simulation-ready environments [5]. The learning curve associated with ERP functionality may also affect the system's contribution to timely and accurate modelling [9].

Looking ahead, integrating ERP with emerging technologies significantly enhances simulation capabilities. Automation and AI allow for real-time data analysis and predictive modelling, more sophisticated scenario modelling and optimization techniques [3]. The incorporation of digital twin, virtual replicas of physical processes, supports detailed and dynamic simulations, enabling the testing of alternative planning and control strategies before implementation [20]. These tools also introduce new Key Performance Indicators (KPIs) related to energy efficiency, waste reduction, and resource utilization, which can be monitored and optimized through simulation.

According to [6] and [16], the continuous adaptation of ERP systems to emerging technologies is vital to maintaining their relevance and utility in dynamic environments. As ERP systems evolve into intelligent, interconnected platforms, their value as simulation enablers grows, supporting organizations in validating decisions, forecasting outcomes, and improving systemic performance. In conclusion, ERP systems not only enhance production planning and control but also provide a solid foundation for organizational simulation by offering integrated, real-time data and interoperability with advanced technologies.

4. CONCLUSION AND FUTURE DIRECTIONS

The adoption of ERP systems has significantly transformed the way companies manage Production Planning and Control (PPC), promoting integration, strategic decision-making, and operational optimization. This Systematic Literature Review (SLR), based on 32 peer-reviewed articles, examined ERP's role in the context of Digital Transformation, addressing key questions about application sectors, objectives, tools, benefits, challenges, and future directions. Findings show that ERP-supported PPC is a growing field, with research intensifying since 2017, especially in Europe and Asia. Countries like Germany, India, China, and Brazil stand out due to industrial maturity, infrastructure, and policy support. The manufacturing sector leads ERP applications, followed by logistics, services, semiconductors, and aerospace.

The review highlights ERP's contribution to efficiency, responsiveness, transparency, and cost control, despite barriers such as high implementation costs and integration complexity. ERP systems also align with sustainability efforts by promoting energy efficiency and environmental performance. A key contribution of ERP systems is enabling simulation-based decision-making. Through real-time data integration, automation, and predictive analytics, ERP provides the foundation for building models like discrete-event simulation (DES) and digital twins. These tools allow organizations to simulate scenarios, test strategies, and assess performance, improving risk management and strategic agility. ERP-supported simulation not only enhances PPC decisions but also fosters organizational learning, innovation, and resilience. Sector-specific solutions, such as cyber-physical systems and energy management tools, emphasize the need for tailored ERP-simulation strategies.

Future research should explore deeper integration between ERP and simulation platforms, real-time capabilities, and simulation-based KPIs. It should also investigate organizational readiness, training needs, and the broader impact on performance and sustainability. Ultimately, ERP systems serve as critical infrastructure for advanced simulations, shaping the future of smart, adaptive, and data-driven manufacturing.

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