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Advancing Intelligent Supply Chain Management in the Industry 4.0 Era: A Meta-Synthesis Analysis

Rohollah Ghasemi ✉ [1], **Ali Mohaghar** [2], **and Mohammad Mehdi Dehghanian**[3]

1. Corresponding author, Assistant Prof., Faculty of Industrial Management & Technology, College of Management, University of Tehran, Tehran, Iran. E-mail: ghasemir@ut.ac.ir
2. Prof., Faculty of Industrial Management & Technology, College of Management, University of Tehran, Tehran, Iran. E-mail: amohaghar@ut.ac.ir
3. Ph.D. Candidate, College of Kish, University of Tehran, Tehran, Iran. E-mail: dehghanian@ut.ac.ir

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ABSTRACT

Objective: In the Fourth Industrial Revolution, advanced technologies are revolutionizing supply chains by enhancing data collection, processing, and analysis across material, financial, and information flows. This shift enables businesses to adopt intelligent supply chain processes with unprecedented efficiency. The integration of intelligent strategies and process-oriented approaches, supported by tools like Intelligent Business Process Management Systems (iBPMS), holds transformative potential for supply chain management, paving the way for Intelligent Supply Chain Management (iSCM) models. This study aims to identify the key dimensions and sub-dimensions of intelligent supply chain processes within the context of Industry 4.0 technologies.

Methods: The research employs a meta-synthesis methodology, systematically reviewing peer-reviewed literature and international publications from 2016 to 2025. Following strict meta-synthesis protocols, the study involved keyword screening, thematic evaluation, and iterative refinement, resulting in a curated selection of 62 high-impact journal articles and 4 seminal books. These sources underwent rigorous validation to ensure scholarly relevance before analysis.

Results: The findings identified 117 open codes related to intelligent supply chain processes, which were consolidated into 18 core codes and further classified into five key dimensions: (1) Intelligent Supply Chain Management (covering SCM and intelligent procurement); (2) Process Intelligent Automation (including automation approaches, intelligent processes, and equipment); (3) Process Management (focused on process-oriented approaches, systems, and modeling); (4) Technological Infrastructure (encompassing emerging technologies, ICT infrastructure, software maturity, and robotics); and (5) Macro & Structural Dimensions (addressing managerial, industrial, e-business, market, and organizational factors).

Conclusion: The study concludes that Industry 4.0 technologies—such as IoT, AI, blockchain, robotics, and big data analytics—facilitate advanced data-driven supply chain management. When integrated with iBPMS, these innovations enhance efficiency, agility, and end-to-end visibility, establishing a foundation for next-generation intelligent supply chains.

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Introduction

Over the past two decades, the advent of the Fourth Industrial Revolution (Industry 4.0) has driven factories and production and service companies to widely adopt cutting-edge, transformative technologies. This shift has given rise to a new generation of intelligent manufacturing and operations, factories, and supply chains, enabling the seamless integration of the physical, digital, and cyber worlds. As a result, businesses have increasingly steered their activities and processes toward intelligence and autonomy.

However, despite these advancements, the intelligent transformation of processes remains in its infancy across many technological applications within supply chains. In most cases, these innovations are implemented in isolated pockets within pioneering companies or exist merely as conceptual frameworks explored in academic institutions, research centers, startups, and incubators. Thus, many companies still require a deeper understanding of *Intelligent Supply Chain Management (iSCM)* to optimize financial, informational, and material flows. Only then can they fully leverage these advancements as a reliable achievement of Industry 4.0 (Govindan et al., 2022).

Regarding Industry 4.0 literature, employing emerging technologies in factories and intelligent logistics has delivered significant industrial benefits. Proper implementation of these innovations has been shown to enhance supply chain performance, driving the maturity of models and frameworks while enabling the evaluation of adoption readiness. Key success factors—such as technological integration, operational efficiency, and strategic alignment—have been identified as critical to Industry 4.0 success (Mayr, 2022). The role of these technologies is now well understood, particularly in the evolution of Logistics 4.0 (Pozzo et al., 2022). The hardware and software technologies adopted in industrialized and advanced economies—and subsequently in developing nations—hold immense potential to mature supply chain management practices and boost overall productivity.

Besides, all levels of the supply chain must operate as an integrated and coordinated system to achieve sustainability in industry and supply chains. This requires leveraging tools such as automation across socio-economic dimensions to drive environmental benefits (Haghighi et al., 2016; Yang et al., 2022; Sheikhi-Zadeh et al., 2024). Besides, the adoption of transformative Industry 4.0 technologies can enhance productivity and enable more customized product offerings for consumers (Billiardi et al., 2024). It would facilitate the introduction of novel products (Jafari-Nejad et al., 2010), contributing to the resolution of sustainability challenges at an industrial scale (Zarei et al., 2016). Ultimately, Industry 4.0 promises a digitally transformed paradigm (Addo-Manu et al., 2022), reshaping production, logistics, and consumption in alignment with the Sustainable Development Goals. The synergy between circular supply chains and the Fourth Industrial Revolution enables transformative business process redesign. Statistical studies reveal key interactive drivers that facilitate this evolution (Dávid et al., 2023).

Furthermore, rapid and unpredictable shifts in global economic and regulatory conditions have compelled organizations to adopt agile structures and intelligent tools to enhance adaptability. For instance, the COVID-19 pandemic underscored the critical role of iSCM in meeting dynamic market demands. However, despite the advancements of Industry 4.0, warehouse planning and logistics optimization still require significant refinement (Hernández et al., 2023).

A proposed framework offers guidance for evaluating supply chain operations and developing a digital maturity roadmap, helping organizations bridge gaps in technological integration (García Reyes et al., 2022). Embedding advanced technologies into supply chains enhances system interoperability, driving greater productivity and sustainability through data-driven analytics. Yet, the potential of Intelligent Business Process Management Systems (iBPMS)—powered by Internet of Things (IoT) and other emerging technologies—remains underexplored in supply chain Automation. This study aims to design and validate a comprehensive framework for advancing intelligent supply chain processes, leveraging IoT-enabled iBPMS to enhance responsiveness, efficiency, and sustainability.

A thorough examination of existing literature indicates that while previous studies have investigated "intelligent supply chains" in general terms, no comprehensive or definitive model has been established specifically for the intelligent transformation of supply chain processes. Although research precedents exist in the broader field of "supply chain automation," systematic bibliometric analyses and extensive searches across academic databases yielded no results regarding "iSCM" implemented through " iBPMS ". To address this critical gap in the literature, this study aims to develop an innovative model that will enable supply chains, particularly in industrial manufacturing sectors, to achieve intelligent system status by leveraging cutting-edge technologies, with special emphasis on iBPMS capabilities.

This study attempts to address the following main research question:

What conceptual model best captures the intelligent transformation of supply chain processes through Fourth Industrial Revolution technologies, and what are its essential structural dimensions and operational categories?

This research adopts a systematic research architecture beginning with a comprehensive literature review that examines transformative Industry 4.0 technologies, including an in-depth analysis of ten selected disruptive innovations, followed by theoretical foundations of iBPMS and iSCM. The methodology section elaborates on the meta-synthesis approach, detailing its seven-stage implementation process and selection criteria. Subsequent analysis applies rigorous meta-synthesis protocols to derive thematic insights and categorical frameworks. The study then presents and validates an original conceptual model through robust reliability and validity testing, while positioning findings against existing theoretical frameworks. The conclusion synthesizes key contributions, outlines practical applications for industry practitioners, acknowledges research limitations, and proposes meaningful directions for future scholarship in intelligent supply chain systems.

Literature Background

In the global competition landscape, enterprises worldwide require robust technological infrastructure and digital readiness to transition from efficiency-driven to innovation-driven economic models (Razavi et al., 2011; Ghasemi et al., 2018). This transformation is predicated on fundamental technological capabilities (Jafari-Nejad et al., 2013; Rastegar et al., 2012; Jafari-Nejad et al., 2011; Ghasemi et al., 2013) and continuous performance enhancement (Safari et al., 2012). Emerging disruptive technologies now offer unprecedented opportunities for operational excellence across manufacturing and service sectors, particularly in supply chain ecosystems (Quey et al., 2022; Ghasemi et al., 2016). Modern supply chains increasingly demand innovative approaches to integrate not only physical product flows but also complex financial and information streams (Mohaghar et al., 2024a, b).

Digital Supply Chain Management (DSCM) encompasses intelligent business processes, transactions, and smart contracts that optimize operational workflows and enable effective implementation of financial innovations (Korpisawehalki, 2022). This paradigm directly addresses our core research question regarding the identification of critical components for intelligent supply chain processes within Industry 4.0 frameworks. The convergence of these technological, operational, and financial dimensions creates a transformative pathway for supply chain intelligence, where digital integration becomes the cornerstone of competitive advantage in the fourth industrial revolution.

Conventional supply chains face significant challenges, including uncertainty, high operational costs, systemic complexity, and vulnerability to disruptions. To overcome these drawbacks, modern supply chains must embrace intelligent digital transformation. Large-scale intelligent infrastructure development for seamless integration of data, information, physical objects, and end-to-end supply chain processes now increasingly relies on IoT technologies. These enable the creation of intelligent, secure supply chain ecosystems (Abdulbasit & Wanogran, 2018; Mohaghar et al., 2023a). Furthermore, Artificial Intelligence (AI) has evolved from an emerging technology to an operational necessity, transforming all aspects from product design and manufacturing processes to comprehensive supply chain management (Kaiouf et al., 2022). This technological integration represents a paradigm shift from reactive to predictive and adaptive supply chain models, fundamentally altering how modern enterprises achieve resilience and competitive advantage.

In Industry 4.0, intelligent companies are revolutionizing production by delivering highly personalized and efficient manufacturing, powered by automated processes and industrial IoT-connected systems (Grambo & Heber, 2021; Moqarr et al., 2023b). These factories integrate a diverse array of advanced technologies, including industrial IoT, AI, machine learning, automation, robotics, data analytics, and cloud computing. However, a research gap persists in understanding the complexities of intelligent process management and automation.

Cutting-edge Technologies in Industry 4.0. Emerging information and communication technologies associated with Industry 4.0 play a vital role in enhancing supply chain performance (Zhang et al., 2022). In the wake of the COVID-19 pandemic, sustainability has become a key priority in supply chain management. The introduction of emerging digital technologies has been instrumental in driving the intelligent transformation of supply chain processes (Khan et al., 2022). Nine cutting-edge technologies have been identified as key indicators of digital integration in the Industry 4.0 adoption ranking for EU companies (Yang et al., 2022). Table 1 outlines the innovative tools shaping the Industry 4.0 supply chain.

Table 1. A list of Cutting-edge technologies in the Industry 4.0 era

Technology	Definition and Applications	Sources
Cyber-Physical Systems	Systems that integrate the physical world with computational and virtual space	Akanmu & Anumba (2015)
IoT	Connecting small computing devices embedded in products and objects to the internet, enabling data reception and transmission	Feldmann et al. (2010); Zhou et al. (2015)
Automation and Robotics	Automated technology is capable of designing, building, and operating without human intervention throughout the process	Tjahjono et al. (2017)
Additive Manufacturing/3D-Printing	The industry standard for using 3D printing to create industrial parts in production	Tjahjono et al. (2017); Ghadge et al. (2018)
Cloud Computing	A network of remote servers that enables data storage, processing, and management with a local server.	Hofmann & Rüsch (2017)
Big Data Analytics	The process of examining large and diverse datasets to discover useful information and patterns that may help organizations make decisions	Farahani et al. (2017); Zhong et al. (2016)
Miniaturization of Electronics	The process of manufacturing smaller electrical, optical, and mechanical devices with different capabilities than before	Feldmann et al. (2010)
Blockchain	A widespread digital technology that ensures transparency, traceability, and security in cyber data and information	Saberi et al. (2019)
AI	The application of artificial intelligence, from the design process and production stages to the supply chain and its management, is becoming an essential topic	Kähkönen (2022)
Intelligent business process management systems	Intelligent Business Process Management is an advanced version of Business Process Management supported by artificial intelligence. Compared to traditional BPM tools, it enables companies to perform more advanced analysis, better integration with big data, and complex event processing	Ilmiz (2024); Szlązak-Łopatka & Brniak-Woźny (2024)

The intelligent supply chain is a dynamic and rapidly evolving field in both research and implementation, with its concepts, standards, and theories continuously advancing. Some of the most transformative emerging technologies shaping this domain include the IoT, cyber-physical systems, automation and robotics, additive manufacturing (3D printing), cloud computing, big data analytics, electronics miniaturization, blockchain, AI, and machine learning. As innovation accelerates, this list continues to expand, introducing new advancements that further optimize supply chain intelligence and efficiency.

Intelligent Business Process Management Systems (iBPMS). iBPMS integrate emerging technologies and modern scientific advancements—such as AI, system dynamics, cloud computing, and blockchain—to develop sophisticated decision-support frameworks. These systems play a pivotal role in enabling real-time decision-making, offering fresh insights into iSCM, and seamlessly integrating with IoT platforms (Lasi et al., 2014; Horshad et al., 2023). Within the landscape of Industry 4.0, smart companies are transforming manufacturing by delivering highly customized and efficient production through advanced automation and industrial IoT-connected devices. However, despite the critical role of industrial IoT in facilitating essential operational workflows, its integration into existing process models remains a challenge (Grambo & Heber, 2021). As industries navigate current technological trends, hardware and software platforms are profoundly shaping businesses, enabling the structured adoption of iBPMS powered by AI. This transformation fosters greater efficiency and connectivity, accelerating the transition toward iSCM and redefining operational excellence in modern enterprises.

Industries across various sectors are increasingly adopting intelligent technologies to enhance efficiency. In the logistics sector, one of the greatest advantages is its rapid technological evolution, driven by the growing demand for speed, responsiveness, and the ability to comprehend systemic dynamics with agility. To stay competitive, companies are leveraging AI to boost operational adaptability (Boanba et al., 2022). To underscore the industrial significance of AI, particularly its role in combating the COVID-19 pandemic, intelligent manufacturing systems have been introduced (Mezgbe et al., 2023). These advancements not only contribute to pandemic response efforts but also extend their impact to optimizing organizational processes, fostering a more intelligent and efficient operational landscape.

Intelligent Supply Chain Management (iSCM). Modern businesses and organizations require real-time data collection and analysis systems, intelligent decision-making tools powered by AI, and the ability to swiftly adapt processes to environmental changes. Strategic plans must align seamlessly with operational programs to keep pace with evolving demands. However, implementing these transformations within organizational structures and business workflows presents considerable complexity, operational challenges, and planning difficulties. To address these issues, emerging technologies in intelligent supply chains and Industry 4.0 have been developed (Mayar, 2022).

A secure and iSCM system, accessible via a web platform for suppliers and managers, offers a viable solution (Abdulbaset & Manogaran, 2018). Among the most promising applications of the IoT is its role in smart cities and the food industry, where IoT-based systems facilitate food monitoring, analysis, and management. A study introduces a dynamic IoT-driven food supply chain tailored for smart cities. This framework employs IoT-enabled smart sensors to optimize data collection, enhance supply chain efficiency, and improve network accuracy by minimizing dataset size and utilizing vehicle routing algorithms. Additionally, it enables real-time tracking of food perishability and contamination in markets, ensuring quality and safety (Nagarajan et al., 2022).

Numerous studies have explored iSCM, process automation, the adoption of Industry 4.0 technologies, and process-driven supply chain strategies, each examined individually. Table 2 highlights some of the most significant research conducted in these areas.

Table 2. A summary of literature background

Authors (Year)	**Intelligent Supply Chain**	**Process Intelligent Automation**	**Application of Industry 4.0 Technologies**	**Process Orientation in Supply Chain**
Abdulbasit & Manogran (2018)	*			*
Grambow & Hyber (2021)		*	*	*
Susilawati & Basanta (2024)	*		*	*
Abuzeid et al. (2022)	*		*	*
Asim et al. (2025)	*		*	
Basu et al. (2025)		*	*	
Current Research	*	*	*	*

However, there remains a gap in studies addressing the intelligent transformation of supply chain processes within the framework of Industry 4.0 technologies. This research aims to bridge that gap by providing a comprehensive examination of this emerging field.

Materials and Methods

This study employs a qualitative approach, grounded in interpretive-critical paradigms, to explore the less-visible dimensions of the phenomenon under investigation. From a research perspective, it is descriptive-applied in its aim and relies on qualitative raw and secondary data. In the initial phase of the study, since no prior research was found on defining the dimensions of the intelligent process model in supply chains, a detailed examination of these relationships was conducted to address this gap.

The meta-synthesis method was employed to identify key factors influencing intelligent process automation. Firstly, a strategic search approach was developed to select the relevant literature. Next, academic articles published between 2016 and 2025 were retrieved from reputable scientific databases. After filtering the collected materials, content analysis was performed on 62 research articles and four international books (in English), using the meta-synthesis approach to extract meaningful insights.

This method provides researchers with a systematic perspective, integrating diverse qualitative studies to uncover fundamental themes and metaphors. This approach enhances the depth and comprehensiveness of qualitative findings, offering a broader and more insightful understanding across various disciplines (Filfgeld-Kuonet, 2018; Moqarr et al., 2013). Seven steps of the meta-synthesis method are illustrated in Figure 1.

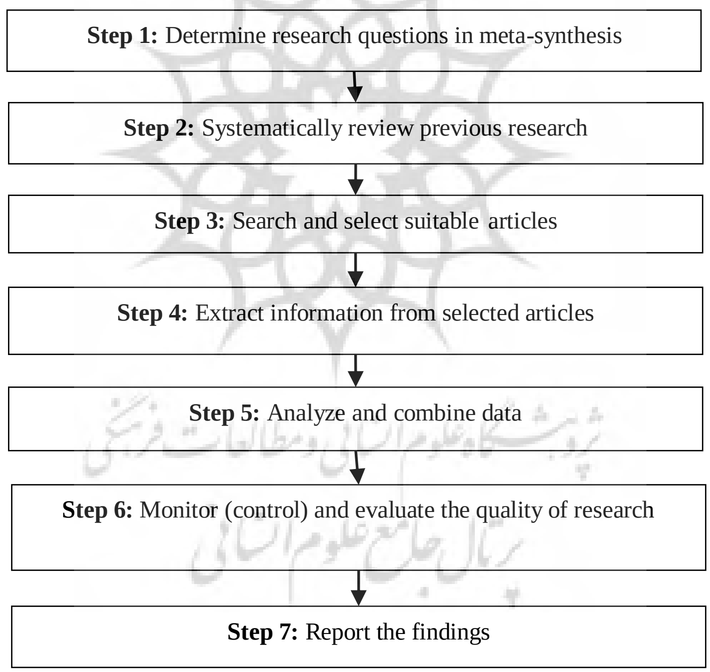

Figure 1. Seven steps of the meta-synthesis method (Sadlowski & Barroso, 2007)

By synthesizing research findings, meta-synthesis creates a cohesive framework that adds greater value beyond individual results, generating new insights previously unobserved in prior studies (Crow et al., 2017). Its main objective is to examine, evaluate, and integrate research to develop innovative models and frameworks (Hall, Leach, Brosnan & Collins, 2017). Meta-synthesis encompasses a range of existing and emerging methodologies, systematically integrating multiple studies into a broader conceptual framework aimed at creating findings that directly inform practice (Peterson et al., 2009).

Results

Based on seven steps of the meta-synthesis method (Figure 1), the research findings are reported as follows:

First Step: Determining Research Questions in Meta-Synthesis. In the first step, foundational research questions are formulated to define the scope of the study and eliminate ambiguity in subsequent research phases (Adler & Lalonde, 2020). Every research initiative must begin with a clear question or objective, which requires specifying what, who, when, and how (Shoelevar et al., 2019). The meta-synthesis research questions focus on the nature of the study, the target population, and the time frame (Farid, 2019). Accordingly, the main research question guiding this meta-synthesis is: *"What are the key factors influencing the automation of intelligent supply chain processes as identified in scholarly research published in reputable academic journals and international scientific databases (in English) between 2016 and 2025? And how can they be categorized?"*

To frame the research questions, four key dimensions are outlined:

I. "What?" – Focuses on identifying, categorizing, and classifying the strategic dimensions and components of intelligent process automation in supply chains.

II. "Who?" – Refers to the target population, encompassing studies on intelligent industrial supply chain processes, emphasizing applicability and resource extraction from scientific databases.

III. "When?" – Specifies the time frame, covering studies published between 2016 and 2025, including online articles published in 2015.

IV. "How?" – Defines the research methodology, primarily relying on previous research articles as methodological references and treating prior data as secondary sources for analysis.

Second Step: *Systematically reviewing previous research.* In this step, data were examined using the outlined strategic approaches, as presented in Table 3. The research incorporates reputable university books, publications from distinguished publishers, peer-reviewed journal articles, and scientific database sources, ensuring a comprehensive and credible analysis.

Table 3. Systematic search results of books and articles related to research strategies

Criterion	Acceptance condition
Study Time period	September 2023 to August 2024
Source Search Timeframe	From 2016 to 2025 AD (last 10 years)
Research Language	English
Article Type	Articles published in reputable scientific journals and at reputable international conferences
Book Type	Reputable academic books, generally from the University of Tehran Press
Study Method	Qualitative data collection and analysis methods, and review of quantitative results
Geographical Scope	Domestic and international research
Studied Topics	Smartization, process smartization, business process management systems, smart business process management systems, supply chain management, smart supply chain management, emerging tools in the smart supply chain, and the Internet of Things
Statistical Population	Scientific data databases: Scopus and Web of Science
Studied Statistical Population	Supply chain, and specifically the supply chain of semi-prepared food industries

Therefore, the criteria in Table 3 for organizing the review of books and articles, based on the keywords in Table 4, were searched using the "And" operator simultaneously with the terms "supply chain," "Intelligentization" and "process".

Table 4. Search Keywords

Keywords
Intelligence
Intelligentization of processes
Business Process Management Systems (BPMS)
iBPMS: Intelligent Business Process Management Systems (iBPMS)
Internet of Things (IoT)
intelligent supply chain management (iSCM)
Emerging tools in the smart supply chain

Third Step: Searching and Selecting Relevant Articles. At this stage, articles deemed unreliable by the researcher were excluded based on title, inclusion criteria, exclusion criteria, and abstract, ensuring they were not considered in the meta-synthesis process. Once the selected articles reached the final review stage, involving a comprehensive content evaluation, the researcher applied critical appraisal skills to assess the quality of the remaining studies, ultimately filtering out irrelevant materials to refine the final selection (Chen et al., 2020). Using predefined keywords and applying the AND operator between terms such as "supply chain," " Intelligentization," and "process," the search yielded 218 research articles and 12 academic books. These sources were systematically reviewed based on content relevance, research methodology, and presented findings, ensuring the exclusion of non-aligned topics. Figure 2 presents a summary of this process, detailing the number of articles and books retained at each stage. Firstly, articles were initially screened based on their titles, eliminating those that did not align with the study's scope. Secondly, articles and books were further reviewed based on their abstracts, leading to the removal of irrelevant sources. Next, A content evaluation was conducted to assess relevance to the primary research question, resulting in the exclusion of materials that lacked conceptual alignment. Finally, the remaining articles and books that matched the research methodology and contained relevant intelligent supply chain indicators were identified and retained for analysis.

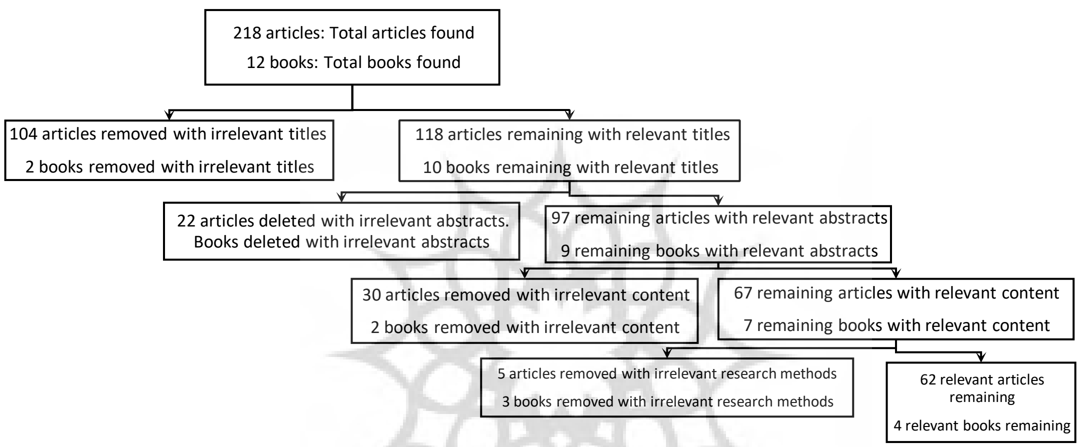

Figure 2. Summary of the books' and articles' search and selection process (Meta-Synthesis Diagram)

Afterward, the Critical Appraisal Skills Program (CASP) method was applied to assess the quality of the selected articles. This approach evaluates research across 10 key qualitative criteria, allowing for a comprehensive assessment of accuracy, credibility, and relevance to the study's objectives. Each article was rated on a scale of 1 to 5, and according to Table 5, only articles that achieved a minimum score of 30 were retained, while those scoring below this threshold were excluded (Moqarr et al., 2022). The CASP evaluation criteria in this study include:

- *Alignment of the article's objectives* with the research goals
- *Up-to-date methodology*, study design, and sampling approach
- *Quality and reliability* of data collection techniques
- *Generalizability of findings*, assessing whether results can be applied beyond the study context

- *Ethical considerations*, ensuring compliance with research integrity standards
- *Precision in data analysis*, confirming methodological rigor.
- *Clear presentation of results*, offering well-articulated and transparent findings
- *Overall significance of the article*, determining its contribution to the broader research framework (Moqarr et al., 2022; Shoelevar et al., 2019)

Table 5. Article Scoring (Scores Obtained)

Article Classification		Very Weak	Weak	Medium	Good	Very Good
Range of Classes	From	0	11	21	31	41
	To	10	20	30	40	50

Following the scoring process, articles were categorized based on their total scores across these 10 dimensions, as shown in Table 6. During the assessment, each criterion was assigned a numerical score between 1 and 5 by the research team, with the total score calculated out of 50. Articles that received less than 30 points were excluded, while those meeting the quality threshold proceeded to the final analysis (Daneshjooash, Jafari & Khamseh, 2020).

Table 6. Scores of 48 valid articles out of 62 reviewed articles using CASP

Authors (Year)	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Article Score
Asim et al. (2025)	4	5	5	5	3	4	3	5	4	3	41
Basu et al. (2025)	5	5	5	3	4	3	5	5	3	5	43
Heguy et al. (2024)	5	5	5	3	5	3	5	4	3	5	43
Susyitra & Basanta (2024)	5	5	3	4	5	3	4	5	3	5	42
Yousefi et al. (2024)	5	4	3	5	4	5	3	5	4	5	43
Farshidi et al. (2024)	4	5	5	4	5	4	5	3	5	5	45
Mezgebe et al. (2023)	5	5	5	4	5	5	5	4	3	5	46
Hernández et al. (2023)	5	3	3	4	4	3	5	5	4	3	39
Pavlicek et al. (2023)	5	4	5	3	4	5	3	4	3	5	41
Hao (2023)	5	4	3	5	4	4	3	5	4	5	42
Abouzeid et al. (2022)	5	5	4	5	5	4	3	5	5	5	46
Waldram et al. (2022)	4	4	3	5	3	4	5	4	5	5	42
Nagarajan et al. (2022)	5	5	4	5	3	4	3	5	3	5	42
Lin et al. (2022)	5	5	4	5	5	4	5	5	4	5	47
Kumi et al. (2022)	5	5	5	5	5	3	5	3	3	5	44
Kheyf et al. (2022)	5	4	5	5	3	5	3	5	5	4	44
Khan et al. (2022)	5	3	5	4	5	5	5	4	5	3	44
Kim & Jeong (2022)	5	4	5	5	3	5	3	5	3	4	42
Dwivedi et al. (2022)	4	3	3	5	4	5	5	3	5	5	42
Mayr (2022)	4	5	3	4	5	5	3	5	3	5	42
Zhang et al. (2022)	5	4	3	3	3	3	4	4	5	5	39
Shin et al. (2022)	4	5	3	4	3	5	5	3	5	3	40
Korpysa & Halik (2022)	4	3	5	4	4	3	3	5	3	5	39
Zavanella et al. (2022)	5	5	4	3	5	5	4	3	5	5	44
Boanba et al. (2022)	5	3	5	3	4	3	4	3	5	5	40
Najim et al. (2022)	5	5	4	5	4	5	4	3	5	5	45

Authors (Year)	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9	Criterion 10	Article Score
Karimi et al. (2022)	5	5	3	5	5	3	4	5	3	5	43
Nasrollahi et al. (2022)	4	5	5	3	4	5	3	5	3	5	42
Ahmed et al. (2022)	5	4	5	3	5	4	3	5	4	5	43
Rezaeifard et al. (2022)	5	5	4	3	5	5	3	5	3	5	43
Mohaghar et al. (2021)	5	3	5	5	3	5	4	5	3	5	43
Grambow et al. (2021)	5	3	5	3	5	5	5	3	5	4	43
De-Vos et al. (2021)	5	4	4	4	3	5	3	4	5	3	40
Karanam et al. (2021)	5	3	5	4	3	5	5	5	3	3	41
Koksic et al. (2020)	5	5	3	4	3	5	3	5	4	4	41
Mladenova (2020)	5	3	5	4	3	5	5	3	4	5	42
García-García et al.(2020)	4	5	4	3	5	4	3	4	5	5	42
Ben Daya et al. (2019)	5	4	5	5	3	4	5	5	3	5	44
Liao (2019)	5	4	3	4	3	5	3	5	4	4	40
Zad Tootaghaj et al.(2019)	5	4	4	3	5	5	3	3	4	5	41
Abdulbasit & Manogran(2018)	5	5	3	4	5	3	5	3	5	4	42
Zamani et al. (2018)	5	5	4	3	5	5	3	5	3	5	43
Mohammadzadeh et al.(2018)	4	5	3	5	5	3	4	3	5	5	42
Jamalian et al. (2018)	5	3	4	5	3	5	4	3	5	5	42
Wang et al. (2017)	5	4	5	4	3	5	5	5	4	3	43
Zarei et al. (2017)	4	5	3	4	3	5	5	3	5	5	42
Domingues & Martins (2017)	5	5	4	3	5	5	3	4	5	5	44
Lao et al. (2016)	4	5	4	5	5	3	4	5	3	5	43

Table above presents the scores of 48 initially selected articles, evaluated using CASP. Out of the 62 assessed articles, 14 received scores below 30 and were subsequently excluded from the study. The remaining 48 articles, deemed valid, were approved for data analysis.

Fourth Step: Extracting Information from Selected Articles. At this stage, the findings from the selected articles were extracted through multiple rounds of review. A standardized monitoring checklist was utilized to ensure systematic extraction of insights. This checklist included essential details such as author names, year of publication, journal title, and key findings (Zhang & Zhou, 2020). The final selection of articles underwent a detailed review process. The criteria for extracting codes were based on addressing the research questions formulated during the initial stages. Articles were systematically coded using the monitoring checklist, which incorporated dimensions such as the article code, year of publication, author names, and main findings related to the intelligentization of supply chain processes, as identified directly from the articles.

In the fourth stage, 117 open (secondary) codes were identified along with their corresponding sources. These codes are detailed in columns (3) and (4) of Table 7. It is important to note that the findings from both the fourth and fifth stages have been summarized and presented collectively in Table 7.

Fifth Step: Data Analysis and Synthesis. The main objective of meta-synthesis is to create an integrated, comprehensive, and innovative perspective on the findings, which is achieved at this stage. During the fifth step of the meta-synthesis process, the researcher categorizes, codes, and synthesizes the findings from the selected articles to provide the most accurate and thorough explanation of the core research topic (Alzazzara, Timms & Degennaro, 2020; Daneshjooash, Jafari & Khamseh, 2020). At this stage, open codes (secondary codes) with similar meanings are merged. The final secondary codes, which share conceptual and practical similarities, are grouped. This process leads to the extraction of axial codes (themes), representing the shared characteristics of the secondary codes. These themes and commonalities are displayed in Table 7.

As stated, the findings from both the fourth and fifth steps have been summarized in Table 7. In the fourth step, a total of 117 open codes were identified along with their corresponding sources, detailed in columns (3) and (4) of Table 7. Column (1) presents the classification of open codes, while Column (2) highlights the shared characteristics of these codes, which served as the basis for their categorization. These columns collectively represent the output from the fourth step.

Table 7. Coding results

Axial code	Commonality of Open Codes	Open code	Source
Supply Chain Management	Considering supply chain management, components, types of intelligentizing approaches for supply chain processes, actors, and the role of intelligentizing, and its impact on functional components and actors to achieve sustainability and an intelligent supply chain	Supply Chain	Lin et al. (2022); Ben Daya et al. (2019); De-Vos et al. (2021); Sadeghi Moghadam et al. (2017); Razavi et al. (2016); Mohaghar et al. (2011a); Mohaghar et al. (2011b); Mohaghar & Ghasemi (2011)
		Supply Chain Sustainability	Khan et al. (2022); Jamalian et al. (2018)
		Supply Chain in Industry 4.0	Hernandez et al. (2023); Zhang et al. (2022); Mayar (2022); Duvidienko et al. (2022); Kumi et al. (2022); Grambow et al. (2021)
		Knowledge Management in Supply Chain	Jafarnejad et al. (2014); Jamalian et al. (2018)
		Performance, Agility, and Efficiency of Supply Chain	Zhang et al. (2022); Hernandez et al. (2023)
		Green Supply Chain	Mayar (2022)
		Supply Chain Processes	Ben Daya et al. (2019)
		Investors and Stakeholders	Najim et al. (2022)
		Monitoring Perishable Materials of the Supply Chain	Nagarajan et al. (2022)
Intelligent Sourcing	Emphasizing the capabilities of the "Intelligent supply chain" by using emerging tools for supply chain management, product tracking, and process management, and	Intelligent Sourcing	Asim et al. (2025); Valdres et al. (2022); Khayuf et al. (2022); Karimi et al. (2022); Zhang et al. (2022)
		Intelligent Supply Chain Management	Lin et al. (2022); AbouZied et al. (2022); Zhang et al. (2022); Duvidienko et al. (2022); De-Vos et al. (2021)

Axial code	Commonality of Open Codes	Open code	Source
	achieving macro goals and information and data requirements for intelligent decision-making	Integrated Intelligent Logistics Management	Boanba et al. (2022); Ben Daya et al. (2019); Mayar (2022); Karimi et al. (2022)
		Tracking Intelligent Supply Chain Network	Nagarajan et al. (2022)
		Circular Supply Chain	Duvidienko et al. (2022)
		Common Platforms for Supply Chain Intelligentizing	Wang et al. (2017)
Intelligentization Approach	Expressing the concepts of intelligence as a general concept in systems management and its impact on decisions, prioritization, and execution using the capabilities created in carrying out transactions, contracts, and communications, and the application of modern intelligence tools	Intelligent Technology and Tools	Dwivedi et al. (2022); Zhang et al. (2022)
		Intelligent Systems	Zavantis et al. (2022); Davidi et al. (2022); Shin et al. (2022); Abdulbassit and Manogran (2018); Ahmed et al. (2022)
		Intelligent Transactions, Contracts, and Communications	Korpisa and Haliki (2022)
		Intelligent Systems Security	Korpisa and Haliki (2022)
		Intelligent Business Decisions	Abouzeid et al. (2022)
		Intelligent Prioritization	Nasrollahi et al. (2022); Mohqer et al. (2021); Zadtot-Aghaj et al. (2019)
		Business Intelligence	Hao (2023)
Process-Oriented Approach	Emphasis on process orientation and intelligence as system-improving complements in a supply chain for systematization, monitoring, measurement, and system improvement and auditing in an integrated manner	Business Process Management	Grambo et al. (2021)
		Process Agility	Pavlichek et al. (2023)
		Intelligent Supply Chain Business Processes	Abouzid et al. (2022); Abdelbassit and Manogran (2018); Valdras et al. (2022)
		Digital Processes	Khan et al. (2022)
		Process Quality Measurement	Hegoy et al. (2024)
		Intelligent Monitoring and Execution Systems	Zavantis et al. (2022); Bouanba et al. (2022)
		Intelligent Manufacturing and Business Processes	Khayov et al. (2022); Komi et al. (2022)
		Business Process Automation	Abouzid et al. (2022)
		Enhanced Business Processes	Valdras et al. (2022)
		Business Process Integration	Lin et al. (2022); Korpisza and Haliki (2022)
Intelligent Processes	Respecting process intelligence to gain the benefits of this tool in the industry and supply chain, and expressing the algorithm introduced with the emerging tools of Industry 4.0 Emphasis on intelligence equipment in the implementation of the "intelligent supply chain"	Process Intelligence	Abu Zaid et al. (2022); Abdul Basit and Manogran (2018(
		Intelligent Business Process Management Systems	Abdulbassit and Manogran (2018); Comey et al. (2022)
		Business Process Management Systems	Wang et al. (2017)
Intelligent Equipment	Expressing the importance of managing processes in a digital system and process platforms with "business process management" and "intelligence" tools	Intelligent Devices and Technology	De-Vos et al. (2021); Hernandez et al. (2023); Mezgebe et al. (2023)

Axial code	Commonality of Open Codes	Open code	Source
Process Systems	Regarding process intelligence to gain the benefits of this tool in the industry and supply chain, and expressing the algorithm introduced with the emerging tools of Industry 4.0	Business Process Management Systems	Pavlicek et al. (2023); Basu et al. (2025); Jin and Samantha (2025)
		Process Intelligence Methodology	Morgner and Berger (2024)
		Digital Business Process Management	Kurpisza and Haliki (2022)
		Business Process Management Tools	Farshidi et al. (2024)
Process Modeling	Emphasis on intelligence equipment in the implementation of the "intelligent supply chain"	Process Modeling Standards	Hao (2023)
		Business Process Management Modeling	Valderas et al. (2022); Grambo et al. (2021); Abuzaid et al. (2022)
		Modeling "Business Process Model[1] and Markup"	Domingos and Martinez (2017); Abuzaid et al. (2022); Waldras et al. (2022)
		Relativistic Intelligence Process Modeling Language	Farshidi et al. (2024)
		Manufacturing Processes	Khayov et al. (2022)
Emerging tools	Expressing the undeniable role of emerging tools, along with software platforms and management information systems, in achieving the intelligence of data-driven supply chain processes	IoT Technology	Abuzeid et al. (2022); Nagarajan et al. (2022); Ben Daya et al. (2019); Zarei et al. (2017); Zadtot-Aghaj et al. (2019); Asim et al. (2025); Mohammadzadeh et al. (2018); Karimi et al. (2022); Nasrollahi et al. (2022); Yousefi et al. (2024)
		Industrial IoT Processes	Grambo et al. (2021)
		Connecting IoT to Digital Processes and the Network of Things	Abuzeid et al. (2022)
		IoT Sensors and Tools	Mohgher et al. (2021); Karimi et al. (2022)
		Intelligence of Things	Asim et al. (2025); Ben Daya et al. (2019); Karimi et al. (2022)
		AI	Najim et al. (2022); Bouanba et al. (2022); Wang et al. (2017); Lin et al. (2022); Kahayov et al. (2022)
		Modern AI Tools	Lin et al. (2022); Kahayov et al. (2022)
		Connected Devices	Mohghar et al. (2021); Ghasemi et al. (2016)
		Blockchain	Kim and Jung (2022); Kim and Jung (2022)
		Cyber-Physical Systems	Shin et al. (2022); De-Vos et al. (2021)
		Machine Learning	Lin et al. (2022)
		Cloud Computing and Data Management	Comi et al. (2022)
		Big Data Analytics and Integration	Liao (2019)
Information and Communication Technology Infrastructure and Data Management	Emphasis on data-driven models, methods, and tools based on IT engineering as the basis and feeder through data	Transactional data	Domingos and Martinez (2017)
		Reducing transactions, reducing unnecessary traffic	Domingos and Martinez (2017)
		Sharing, monitoring, and accessing data	Comi et al. (2022)

[1] Business Process Model and Notation (BPMN)

Axial code	Commonality of Open Codes	Open code	Source
	and information management and their transformation into knowledge (intangible assets) for product tracking and management, and executive system management	Information and communication technology	Zhang et al. (2022)
		Radio frequency identification technology	Abdulbassit and Manogran (2018)
		Automatic identification, collection, and tracking of elements	Jin and Samantha (2025)
		Real-time information management	Kim and Jung (2022)
		Information integration	Nagarajan et al. (2022); Kim and Jung (2022)
		Data-driven models and applications	Khan et al. (2022); Shin et al. (2022)
		Real-time information and data	Mayar (2022)
Software Maturity and Capabilities	Considering the positive and negative (inhibitory) dimensions of software systems for implementing intelligent systems with a perceived impact on the implementation of supply chain intelligence	Intelligent Internet Web 2.0 and the connected Internet	Asim et al. (2025)
		Business process automation	Valdras et al. (2022)
		Systems and weaknesses of "Enterprise Resource Planning"	Mladenova (2020)
		Non-theoretical weaknesses of "Business process management systems"	Pavlicek et al. (2023)
		Application software and intelligent automation	Lin et al. (2022); Khan et al. (2022)
		Open source (open source)	Mladenova (2020)
		Digital library	Garcia-Garcia et al. (2020)
Management Dimensions	Emphasis on the two-way interaction of management dimensions and intelligence in achieving productivity and management decisions commensurate with the status of the supply chain, and achieving modern management components resulting from this interaction	Waste and Loss Management	Suchitra and Vasanta (2024)
		Systems Approach (Deep Systems Analysis)	Mezgbe et al. (2023)
		Startup and Agile Innovation	Korpisza and Haliki (2022); Bouanba et al. (2022)
		Supply Chain and Project Management	Korpisza and Haliki (2022); Hernandez et al. (2023); Mahkhar et al. (2022:b)
		Sustainable Development and Change Management	Dovidi et al. (2022)
		Real-Time Coordination and Instant Decision Making	Nagarajan et al. (2022)
		Intelligent Repair and Maintenance	Coxi et al. (2020)
		Decision Support Systems	Coxi et al. (2020)
		Improving Productivity and Reducing Material Consumption	Hernandez et al. (2023)
		Intelligent Business Decisions (Conscious)	Valdras et al. (2022)
		Material Procurement and Supply Management	Khayov et al. (2022)
		Executive Works	Suchitra and Vasanta (2024)
Structure Industry and Production	Emphasis on the importance of the structure and macro dimensions of the industry with intelligent approaches, with unique characteristics to respond to market needs and manage data, information, and process knowledge	Intelligent Factory	Grambo et al. (2021); Mayar (2022); Kim and Jung (2022); Khan et al. (2022)
		Intelligent Manufacturing Systems and Technologies	Mezgbe et al. (2023) Hernandez et al. (2023)
		Flexibility of Customization Unique Manufacturing (Unique)	Grambo et al. (2021); Domingos and Martinez (2017); Kahayov et al. (2022)
		Intelligent Manufacturing Processes	Kahayov et al. (2022); Zavantis et al. (2022); Kim and Jung (2022)
		Intelligent Manufacturing Ecosystem	Mezgbe et al. (2023); Mayar

Axial code	Commonality of Open Codes	Open code	Source
		and Products	(2022)
Process Robots	Emphasis on professional and modern technology of software and intelligent robots in the evolution of process intelligence	Intelligent Software Robot	Cooksey et al. (2020)
		Autonomy	Ben Daya et al. (2019)
		Intelligent Automated Processes	Grambo et al. (2021)
E-Business and Digital Infrastructure	Respecting the dimensions of electronic and digital business, along with the centrality of process and process orientation, and its application in factory and industry intelligence	Digital Business	De-Vos et al. (2021)
		Real-time Business Operations	Wang et al. (2017)
		Secure and Efficient Systems	Abdulbassit and Manogran (2018)
		Digital Hubs and Techniques	Najim et al. (2022)
		Business Platform Trends	Wang et al. (2017)
		Intelligent Warehouse	Hernandez et al. (2023)
Market and Demand	Emphasis on the dimensions of the market and its interaction with intelligent systems and process intelligence	Marketing Opportunity	Mazgebe et al. (2023)
		Financial Market Management	Wang et al. (2017)
		Customer Relationship System	Lao et al. (2016)
		Bullwhip Effect and Demand Forecasting	Rezaifard et al. (2022)
		Recovery and Growth Opportunity	Mazgebe et al. (2023)
National and International Macro Dimensions	Expression of international and national dimensions (macro dimensions) and macro theories effective in launching and applying intelligent systems in the supply chain	Emerging Economies	Mezgebe et al. (2023)
		Developing Countries	Mezgebe et al. (2023)
		Challenges and Constraints of the COVID-19 Pandemic	Hernandez et al. (2023); Mezgebe et al. (2023)
		Circular Economy	Dovidi et al. (2022)
Organizational Structures and Dimensions	Expression of increasing the unique capabilities of the structure and organizational dimensions in intelligence and two-way interaction, integration of structures, and the process approach of intelligence	Deep Organizational Integration of the Supply Chain	De-Vos et al. (2021); Khan et al. (2022)
		Strategy Development	Zhang et al. (2022)
		Corporate R&D Growth	Mezgbe et al. (2023); Bouanba et al. (2022)
		Production Growth after the COVID-19 Pandemic	Mezgbe et al. (2023)
		Intelligent Sustainability	Bouanba et al. (2022)
		Digital Finance	Najm et al. (2022)
		Financial Data Integration	Karanam et al. (2021)

Sixth Step: Monitoring and Evaluating Research Quality. In the context of meta-synthesis, external validity is not applicable since the findings are not intended for generalization to a broader population or community. Instead, the emphasis lies solely on internal validity, which involves verifying the research objectives and framework to ensure the accuracy and reliability of the results (Horton, 2020; Cheng & Bai, 2022). CASP was used to conduct a qualitative evaluation of the study content. Additionally, the inter-coder agreement method was employed to enhance the reliability of the model.

To assess reliability, the Kappa coefficient was applied. From the coded studies, 62 articles were randomly selected and reviewed by an expert in the field of process smartization. A total of 44 codes were identified by two researchers through the study's findings. The Kappa coefficient, which measures agreement between researchers, was calculated at 77.27%, indicating an acceptable level of consistency between coders. This assessment demonstrates that the extracted concepts are of satisfactory quality. The efforts undertaken during this stage aimed to ensure the quality and precision of the research process, effectively identify concepts relevant to the study, and conduct continuous reviews and refinements to uphold the integrity of the findings.

Seventh Step: Prporting the Findings. At this stage, the results from the previous steps were systematically followed and organized into a model. The framework was presented in Table 8 and visually depicted in Figure 3. To ensure validity, the findings were reviewed and approved by three field experts who participated in a survey, confirming the overall structure and key elements of the proposed model.

Table 8. Classification results

Main Category (Component)	Axial Code	Number of Open Codes (Subcategories)
Intelligent Supply Chain	Supply Chain Management	9
	Intelligent Procurement	6
Intelligentization of Processes	Intelligentization Approach	7
	Intelligent Processes	3
	Intelligent Equipment	1
Process Management	Process-Oriented Approach	10
	Process Systems	4
	Process Modeling	5
Technology Infrastructure	Emerging Tools	13
	Information Technology and Communication Infrastructure and Data Management	10
	Software Maturity and Capabilities	7
	Process Robots	3
Environmental and Structural Components of the Organization	Managerial Dimensions	12
	Industry and Production Structure	5
	E-commerce and Digital Business Infrastructure	6
	Macro National and International Dimensions	4
	Market and Demand	5
	Organizational Structures and Dimensions	7

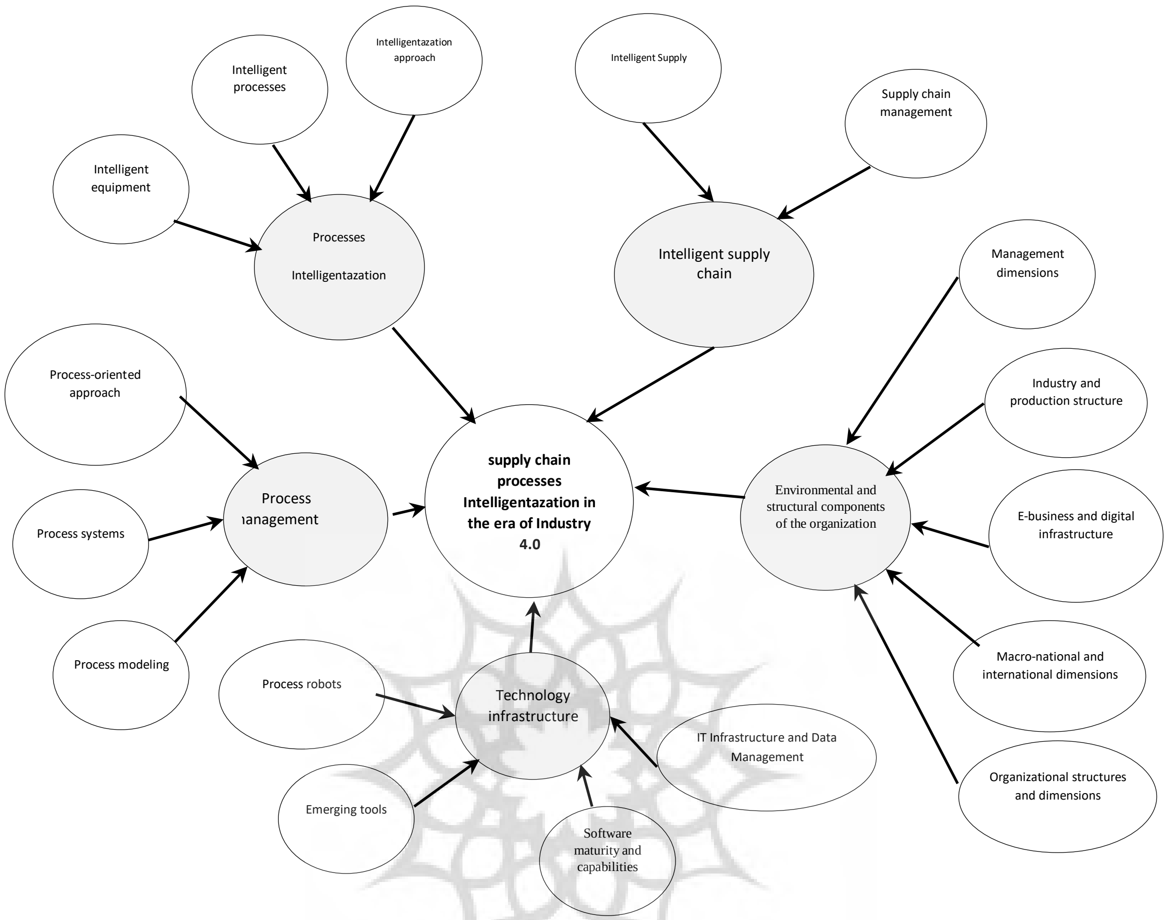

Figure 3. Components and Categories of Smartization of Supply Chain Processes in the Industry 4.0 Era Based on...

Based on the findings in Figure 3, 18 axial codes were organized into five core components: 1) Supply Chain Management and Intelligent Supply Chains, 2) Process Intelligentization, 3) Process Management, 4) Technological Infrastructure, and 5) Macrostructural Dimensions. The above diagram illustrates the inductive progression of the components driving the smartization of supply chain processes in the Industry 4.0 era.

Discussion

In the final step of the meta-synthesis process, the extracted codes were categorized into five core components essential for the Intelligentization of supply chain processes: 1) Intelligent Supply Chains, 2) Process Intelligentization, 3) Process Management, 4) Technological Infrastructure, and 5) Environmental and Organizational Structural Components.

The final model was developed to establish mechanisms and infrastructures for data management and information analysis, enabling highly efficient decision-making. A key outcome of this research is the creation of a process information system for the supply chain, leveraging modern tools such as AI, and the advancement of a process Intelligentization model.

Based on the findings:

- Intelligent Supply Chains: This category includes 15 open codes, organized into two axial codes: Supply Chain Management and Intelligent Supply.
- Process Intelligentization: This category consists of 11 open codes, classified into three axial codes: Intelligentization Approach, Intelligentization Processes, and Intelligentization Equipment.
- Process Management: This category includes 19 open codes, grouped into three axial codes: Process-Oriented Approach, Process Systems, and Process Modeling.
- Technological Infrastructure: Comprising 33 open codes, this category is categorized into four axial codes: Emerging Tools, INFORMATION AND COMMUNICATION TECHNOLOGY and Data Management Infrastructure, Software Maturity and Capabilities, and Process Robots.

Environmental and Organizational Structural Components: This category contains 39 open codes, grouped into six axial codes: Managerial Dimensions, Industry and Production Structure, E-Business and Digital Infrastructure, Macro-Level National and International Dimensions, Market and Demand, and Organizational Structure and Dimensions.

Conclusion

In today's business landscape, competition has shifted from being company-centric to supply chain-centric (Ghasemi et al., 2018). Organizations and their supply chains navigate a complex network of processes, continually encountering challenges, threats, opportunities, and avenues for growth driven by legal, environmental, organizational, and global dynamics. To thrive, optimizing and modernizing these processes through iBPMSs has become indispensable. Achieving iSCM hinges on leveraging strategic initiatives and advanced technologies.

At the national level, intelligentizing supply chain processes can improve supplier quality and quantity, forming a cornerstone for business development (Bazargan et al., 2017; Pourazat et al., 2022) and enhancing global competitiveness (Razavi et al., 2015; Mehregan et al., 2016). While previous studies have explored aspects of supply chain intelligence, there is a lack of comprehensive research into the core components influencing intelligent processes. This gap led to the present meta-synthesis study, aimed at developing a unified model for intelligentizing supply chain processes.

In the first step, key concepts such as process intelligence in supply chains were identified to build a clear understanding of the model and its elements. A base model was selected for the development of an intelligent supply chain framework, focusing on key supply chain features and their role in intelligentization. The interplay between productivity and intelligentization emphasized the importance of addressing organizational structures and processes relevant to automation.

To guide this research, the following question was posed:*"What are the key factors influencing the intelligentization of supply chain processes, as identified in studies published in reputable scientific journals and databases between 2016 and 2025?"*

Using bibliometric tools, 48 articles were selected from an initial pool of 62 for final analysis. The findings from these studies yielded 117 open codes, which were systematically merged based on similar meanings, resulting in 18 axial codes.

The purpose of this study was to develop a comprehensive model to serve as a guide for business leaders and policymakers in the Fourth Industrial Revolution. The model focuses on five primary areas: 1) Intelligent Supply Chains, 2) Process Intelligentization, 3) Process Management, 4) Technological Infrastructure, and 5) Environmental and Organizational Structural Components. The model is designed to establish mechanisms and infrastructures for data management and information analysis, enabling decision-making with maximum efficiency.

According to the findings, technologies like the IoT, autonomous machines, and robots generate data at the organizational level. Digital security technologies play a vital role in ensuring privacy and safeguarding this data. Meanwhile, big data technologies, characterized by their real-time, ubiquitous, and comprehensive capabilities, shape data related to the flow of materials, information, and finances among supply chain actors. These data streams, which contribute to value creation across various processes, can be further utilized through machine learning and artificial intelligence to inspect and benchmark processes for better outcomes.

The research also recommends developing a process-oriented supply chain information system using advanced AI tools, as well as designing a model for the intelligentization of processes. Additionally, process results could be visualized through digital twins, providing a dynamic representation of their outcomes. These suggestions are part of the practical and managerial insights derived from the study. Adopting this process-centric perspective enables the creation of a value chain spanning the entire supply chain. It shifts focus away from non-value-adding activities and waste, instead prioritizing essential, value-adding actions that drive efficiency and growth.

The final model proposed in this study distinguishes itself from previous research by simultaneously addressing numerous factors involved in the smartization of supply chain processes. By effectively categorizing these factors, it provides senior organizational managers with a practical roadmap to navigate and select suitable methods for process smartization.

The dynamic, interrelated nature of the model's components, along with its unique and adaptable features, allows it to analyze external data based on incoming information and system requirements. This adaptability ultimately enhances the model's robustness and stability.

Future advancements in hardware and software technologies are expected to significantly improve the model's efficiency and broaden its applicability. However, the study's limitations include its reliance on the perspectives and beliefs of article authors, challenges in generalizing findings, and the restricted use of research tools.

Data Availability Statement

Data available on request from the authors.

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Ethical considerations

The ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work.

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