Empowering Industry 5.0 Supply Chain: Insights from a Systematic Literature Review of Digital Maturity Models

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Abstract
The supply chain has been revolutionized and transformed into a way business that operates within the integration of advanced technologies. These emerging technologies have been instrumental in streamlining processes, improving efficiency, and offering increased transparency throughout the supply chain. Our research conducts a comprehensive review of studies on digital maturity models across different fields, with a particular focus on supply chain applications. In addition, it explores the digital transformation of supply chains as they evolve from Industry 4.0 to Industry 5.0. By employing a five step methodology of systematic literature review, 63 articles were identified. The results underline the importance of implementing comprehensive digital maturity models to successfully navigate supply chains through the ever-changing technological, thereby promoting improved efficiency, resilience, and sustainability. Our study concludes by proposing future prospects and necessary advancements in the development of digital maturity models within the framework of supply chains.

Keywords: Systematic Literature Review, Industry 4.0, Supply Chain, Industry 5.0, Digital Maturity Model.

1 Introduction

The digital revolution has filled all industries, especially reshaping business operations. In particular, the integration of Industry 4.0 principles has undergone a considerable transformation within the context of supply chain (SC) [1]. Additionally, Industry 4.0 has enabled greater automation and improved decision-making processes throughout the entire SC [2]. Currently, machines have become capable of surpassing human performance in certain conceptual tasks, potentially bringing about significant social changes [3]. Industry 5.0 focuses on human-machine collaboration, leveraging technology to enhance human abilities and foster a more cooperative working environment [4]. In this context, digital maturity models (DMMs) emerge as critical

tools to guide and navigate this transformative journey. These offer a systematic approach to evaluate an organization's existing digital competencies within the SC and identify areas that need enhancement. Additionally, these models provide a structured framework to assess the current level of digital capability, identify strengths and areas for improvement across key dimensions. Ultimately, studying these models allows companies to benchmark their progress, set realistic transformation goals, and develop targeted strategies. Hence, this article presents insights derived from a systematic literature review (SLR) of DMMs in the framework of SC transformation within the evolution from Industry 4.0 to Industry 5.0. By combining findings from current literature, this paper provides a comprehensive review of the DMM landscape and its impact on facilitating successful SC transformation efforts. This manuscript is organized as follows. The first section presents the methodology for conducting the SLR. The next part will discuss the main findings and analysis obtained from the literature review, highlighting common dimensions, and challenges in DMM for SC transformation within Industry 5.0. Hence, practical implications and recommendations are presented in the last section along with recommendations for future studies.

2 Methodology

In order to present a comprehensive analysis and precise examination of DMMs a SLR was conducted. This methodology affords a well-organized and replicable procedure for identifying and synthesizing relevant academic literature [5]. The research methodology employed in our paper and based on [6], is depicted in fig 1.

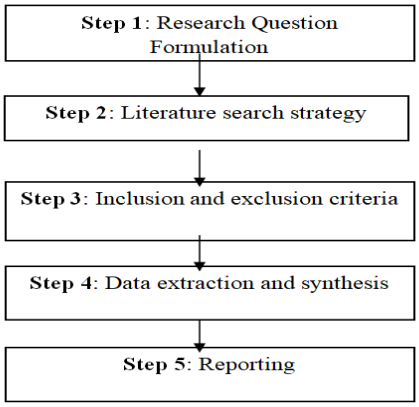

Fig.1. Research Methodology

2.1 Research Question Formulation

The first step of our methodology is essential to develop well-defined and concentrated research questions (RQs) that will guide the SLR. By formulating good and pertinent RQs, we can guarantee that our literature review stands concentrated, and facilitates the extraction of valuable insights and the deduction of conclusions from the literature assessed. The specific research questions are as follows: What insights can be found from the existing literature review regarding the effectiveness of the DMMs in the framework of SC transformation? What are the main challenges of SC transformation in the evolution from Industry 4.0 to Industry 5.0?

2.2 Literature search strategy

Search Keywords

Keywords are essential in identifying relevant articles because they act as the primary means of search databases to recover information that matches with the topic. The terms used are DMMs, SC, industry 5.0, and industry 4.0. The search query was constructed by utilizing Boolean operators. "OR" was employed to include various spellings, while "AND" was used to connect the keywords [6]. The resulting search string was created by combining these terms and operators:

(a) “digital maturity models” AND “Industry 4.0” OR “ Industry 5.0”
(b) “digital maturity models” AND “supply chain”
(c) “digital maturity models” AND “Industry 5.0”

Period of review

In our review, we selected the period between 2015 and 2024. Although the term Industry 5.0 coexisted in Germany at the CeBIT 2017 trade fair in Hannover [7], we opted to commence the period from 2015 because this concept is a continuation of Industry 4.0, and also to comprehend the evolution and the distinction between them. Hence, Fig. 2 presents the number of studies published per year. The graph shows that there were 15 papers published on this topic in 2023, which suggests that there is a growing interest and focus on this subject.

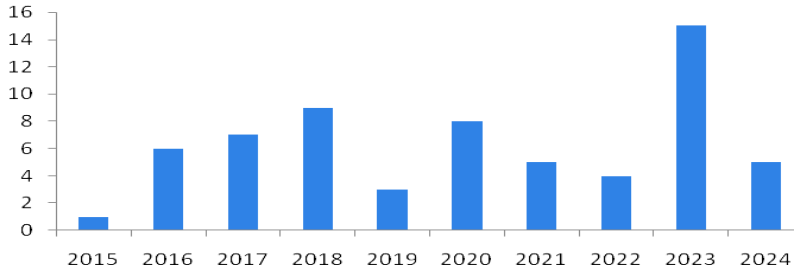

Fig.2. Number of studies published per year

Scientific Databases

In this study, we utilized six databases to select three categories of publications: conference papers, book chapters, and journal articles. Fig. 3 illustrates the classification of studies across the selected databases.

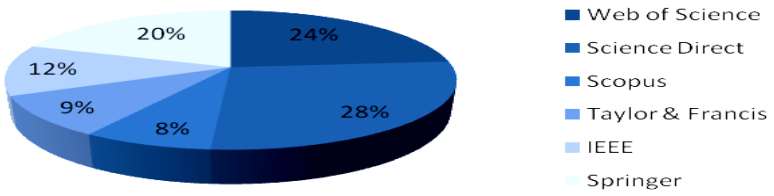

Fig.3. Classification of publications across Databases

Identification of publications

Based on[6]**,** to select the studies, we followed four stages: recognition, screening, qualification and insertion. The first one was to pinpoint all pertinent studies in the databases. Fig. 4 illustrates in the entire process.

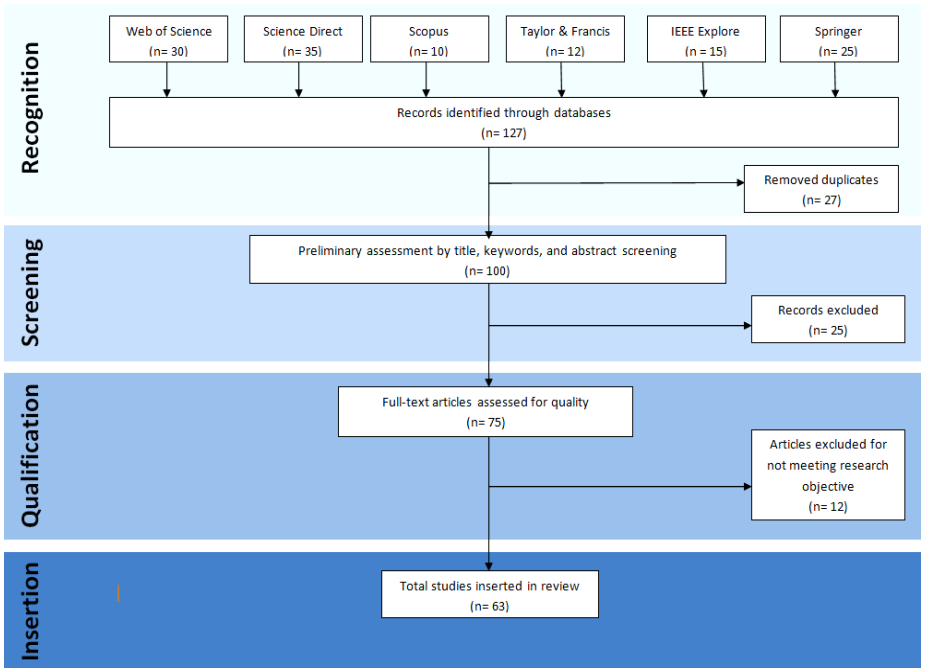

Fig.4. Process of identifying article

The preliminary assessment was based on the title, keywords, and abstracts. First, we excluded 25 studies. For the eligibility step, we excluded studies that did not include a model. Hence, 63 articles were inserted in this review. Fig. 5 presents the distribution of publications based on article type.

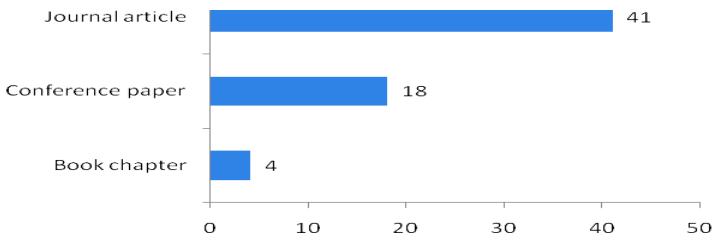

Fig.5. Distribution of publications based on article types

2.3 Inclusion and Exclusion standards

The process identified before depend on pre-established criteria, which are illustrated in Table 1.

Table1. Standards of inclusion and exclusion of publications

Inclusion Standards		**Exclusion Standards**	
Id	Description	Id	Description
IC 1	Publications that specifically answer the research questions	EC 1	Non published articles
IC 2	Studies written in English	EC 2	Duplicate articles
IC 3	Studies published between 2015 & 2024	EC 3	Papers published in other languages
IC 4	Journal articles, Conference papers, book chapter	EC 4	Papers that are not related with the topic
IC 5	Papers that clearly state the digital maturity model		

2.4 Data extraction and Synthesis

The primary objective of the fourth step in our methodology is to collect and integrate data from the 63 relevant articles. The extracted items are described in Table 2.

Table 2. Extracted data from studies

Data extraction	Description
Author(s)	The authors' names
Year of publication	The article's publication year
Title	Research title
Type of publication	Book chapter, Journal article, Conference paper
Domains	Application domains used
Dimensions	Dimensions used in the model proposed in the paper
Future research	Future research suggested by the paper

2.5 Reporting

The concluding part of our methodology presents the outcomes of the SLR. We devolve the pertinent implications of our research and contribute to the progression of knowledge within the domain of SC transformation and DMMs. Therefore, it will be discussed in the final part of the paper.

3 Results

3.1 Research questions results

What insights can be found from the existing literature review regarding the effectiveness of the DMMs in the framework of SC transformation?

In recent years, the digital transformation of SCs has emerged as a major area of research and practical application, driven largely by advancements in Industry 4.0 technologies and the transition to Industry 5.0. Fig.6 presents the application sectors detected in the selected articles. These sectors are SC with the entire processes, healthcare, airline, telecommunication and others such as defense Industry, education, etc. As for Fig.7, it illustrates the processes of supply chain applied in the articles.

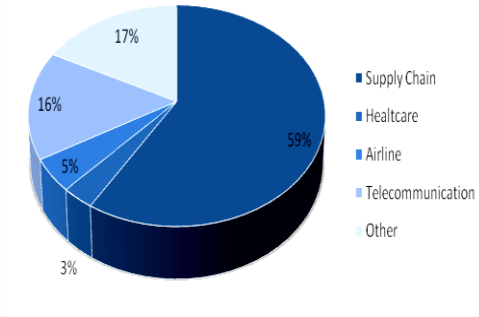

Fig.6. Distribution of application sectors

Fig.7. Processes of supply chain

The SC involves several processes essential to its management. A key process is planning, which includes demand forecasting, inventory management, and coordinating production schedules **[8, 9]**. Another process in the SC is procurement, which is essential for ensuring that the necessary materials are available for manufacturing, as evidenced by the eight articles that apply the model to this process **[10]**. Manufacturing is another crucial process in the SC, which involves converting raw materials into finished goods. Several articles apply the model to this process, indicating its significance **[11]**. Transportation and logistics are also vital processes, involving the movement and storage of goods from suppliers to manufacturing facilities and ultimately to end customers **[12, 13]**. Finally, the customer process involves order fulfillment, customer service, and feedback, as demonstrated by the six articles that apply the maturity model to this process **[14, 15]**. It is worth noting that only four articles integrate the entire process of the SC in the maturity model, highlighting the importance of considering the entire SC in maturity model applications **[16]**.

DMMs are crucial for assessing and guiding the digital transformation of SCs, especially as they progress from Industry 4.0 to Industry 5.0.These models assess several essential dimensions that are critical for enhancing digital capabilities within an organization. The dimensions per articles in selected studies are depicted in Fig. 8.

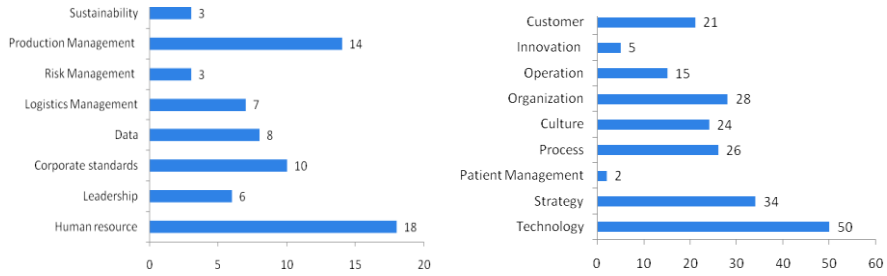

Fig.8. Dimensions per articles in selected studies

The dimensions depicted in Fig.8 are common in all the selected articles, with the entirety of the dimensions amounting to approximately 123 dimensions across the 63 selected articles. A considerable number of the selected studies highlight the dimension of technology due to its significance. [16] incorporates technology as a dimension with nine items, such as cloud technology, additive manufacturing and other emerging technologies. Digital transformation and the application of AI methods must be approached more holistically within the framework of Industry 5.0, taking into account all impacted layers and focusing on human-centered strategies that incorporate participatory elements [17]. Consequently, it is essential to incorporate a human-centered focus into current and future maturity models.

What are the main challenges of SC transformation in the evolution from Industry 4.0, to Industry 5.0?

The evolution from Industry 4.0 to Industry 5.0 in SC transformation presents numerous challenges. As indicated in [18, 19], whereas Industry 4.0 emphasizes the use of disruptive technologies, Industry 5.0 seeks to establish a Society 5.0 by leveraging the technologies developed during Industry 4.0. It focuses on incorporating social and human elements to foster a sustainable environment within this technological landscape. DMMs need to evolve to reflect the integration of advanced technologies, which requires substantial investment and technical expertise. Furthermore, DMMs must incorporate sustainability as a core dimension, ensuring that the environmental impact is minimized across all processes. Another critical challenge is the adaptation of the workforce, necessitating continuous training and cultural shifts towards embracing new technologies. In addition, managing vast amounts of data securely, achieving system interoperability, and meeting personalized customer demands complicate this transition [20]. DMMs must also address the complexities of evolving regulatory standards and risk management strategies to ensure resilient and compliant SC, balancing high initial costs with long-term efficiencies and benefits. Lastly, Industry 5.0 remains a forward-looking concept aimed at integrating human, social, and sustainability factors into the highly technology-driven focus of Industry 4.0 [21].

3.2 Research gaps

Through a systematic review of 63 articles, we have determined that there are several significant gaps in the current literature on DMMs for Industry 5.0 supply chains:

Gap 1: The dimension of Sustainability: In the existing literature, it is evident that certain articles emphasize the integration of sustainability, with a percentage of 4%. It is crucial to incorporate sustainability into digital transformation initiatives as it not only improves operational efficiency and resilience, but also satisfies the growing needs of consumers and regulators for environmentally practices.

Gap 2: Processes of SC: The present review highlights various studies that incorporate diverse SC processes within the DMM; however, only a limited number of studies, amounting to four out of the sixty-three identified articles, integrate the entirety of the SC processes.

Gap 3: Evolution from Industry 4.0 to Industry 5.0: In our review, we depicted two articles that incorporate this transition into their DMMs. It is crucial to take into account this evolution when examining DMMs for the successful digital transformation of SCs.
Gap 4: The dimension of Risk Management: Although current maturity models take into account emerging technologies, few studies have explored the dimension of risk management. Incorporating risk management into the DMM is vital for evaluating digital transformation in SC.

4 Conclusion

Our study examined the role of DMMs in strengthening Industry 5.0 supply chains through a comprehensive literature review. From the initial selection of 63 articles, we extracted key insights and pointed out several important research gaps. Significantly, few models integrate sustainability, take into account the entire SC processes, facilitate the shift from Industry 4.0 to Industry 5.0, or incorporate risk management. Closing these gaps is crucial for creating all-inclusive DMMs that can effectively support SCs. In conclusion, DMMs are essential tools for empowering Industry 5.0 SCs. They provide a structured guide for organizations to successfully navigate the challenges of digital transformation, ensuring they can utilize the potential of human and technological intelligence. By systematically evaluating and improving their digital maturity, SCs can achieve a level of efficiency, adaptability, and robustness that meets the demands of the future industrial environment.

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