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Industry 4.0 Implementation in Lean Supply Chain Management: a Systematic Literature Review

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Abstract The major aspects and impacts of the interrelationships between Industry 4.0 (I4.0) technology and Lean Supply Chain Management are discussed in this article (LSCM). Many practical LSCM systems based on I4.0 have lately appeared [1]. Despite this, there has been little research into the use of I4.0 technologies within LSCM. Machine learning, smart factories, blockchain, and the internet of services (IoS) are all possible LSCM revolution enablers. The goal of this research is to find out more about present and potential I4.0 technologies that can improve LSCM research and application in order to fill a gap in the current literature. A Systematic Literature Review (SLR) technique was used for the collection, selection, and evaluation of published literature. We looked at 79 studies published between 2010 and 2021 that were found in the Scopus database.

Keywords Lean Supply Chain Management, Industry 4.0, Systematic Literature Review.

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1. Introduction

Supply Chain Management (SCM) has been used to manage and coordinate physical and inbound and outbound logistics processes and data flows, and procedures with other businesses [2], [3]. SCM aims to reduce all sorts of waste by minimizing internal and external sources of variation [3].

Lean is a philosophy of management that has grown since its inception as a collection of tools for manufacturing (for instance, Just in Time - JIT) into a human-centered global view that can be applied to any business and in any context (for example, Lean Management - LM) [3]. Lean Supply Chain Management (LSCM) is the deployment of Lean Manufacturing (LM) throughout the supply chain (SC) to drastically improve all operations, pertinent information, processes, and equity markets from the perspective of the end consumer.

Industry 4.0 technologies assist businesses in improving their business sectors in order to maintain competitiveness and competition in order to deliver high-quality products to the correct customer in the quickest time feasible while satisfying client needs [4]. Thus, the goal of this research is to maximize the value of research by locating and evaluating works on this topic, as well as their interactions and classification, to aid in their study and the recognition of research gaps, in order to gain important insights into any assessment criteria lines that need to be examined or extended. The current study's research questions are as follows:

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- (RQ_1) Which I4.0 technologies are most frequently used in LSCM research?
- (RQ_2) What are the potential I4.0 technologies that can be employed in LSCM studies?

In terms of the structure of this article, the following is a breakdown of the study's structure. The research's methodology, as well as the facts around how the review was carried out, is detailed in the next section. After then, the analysis and synthesis section deconstructs each study into its component elements. Finally, the outcomes are assessed. The report's concluding part summarizes the findings and provides some conclusions [5].

2. Methodology

To examine the state of research into the LSCM-I4.0 technologies interaction, the SLR approach was chosen [5], [6]. The main advantages of this method are that it ensures a systematic, repeatable, and rigorous workflow for thoroughly and objectively integrating current data [5]. The chosen method is made up of five phases that were suggested by [6]. This approach [7] and the Supply Chain Management field [8] have been updated to include the criteria developed to construct a thorough SLR in the area of Operations Management (OM), as well as to ensure the correctness and efficiency of the outcomes. The five stages are summarized here (see Figure 1).

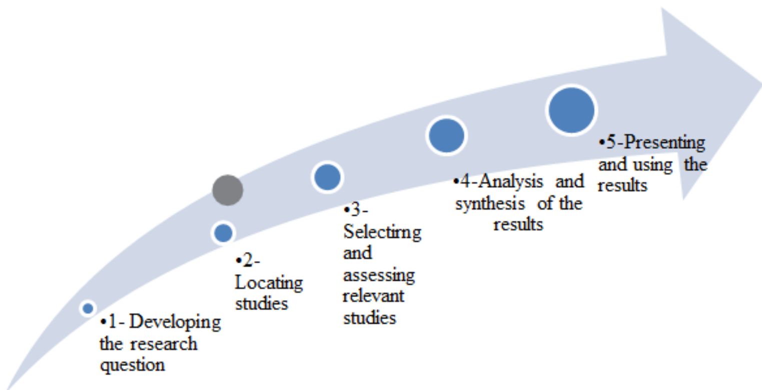

Figure 1. Steps of Systematic Literature Review. Source: Adapted from [5].

2.1. Locating and assessing relevant studies

The purpose of the third stage is to get rid of any papers that aren't relevant. This is performed by determining which publications should be included in the review (inclusion criteria) and which should be discarded without further inquiry (exclusion criteria) [5], [6]. This approach is depicted in Table 1.

2.2. Analyzing and using the results

Based on the selected papers, Figure 2 depicts the evolution of the interactions between LSCM and Industry4.0 from 2010 to 2021. Figure 3 shows how the material for this study was gathered from 26 publications between 2010 and 2021. Table 2 shows a list of the most important periodicals' contributions.

Table 1. Stages involved in the selection of articles for this Study.

	Details	Number of records
Stage 1: Keywords search	• Keywords: (lean, just in time}, supply chains, logistics, Industry 4.0, information systems, information technology, information and communication technology, technological innovation, internet of things, cloud computing, software, artificial intelligence, cyber security technology, augmented reality • Search Databases : SCOPUS, • Field : Title, Abstract, Keywords, • Article type: Academic/scholarly and peer-reviewed journals, • Time range: Published from 2010 to June 2021.	622
Stage 2: Select and sort	• Inclusion criteria: Articles addressing issues in Industry 4.0 technologies of whole or part of LSCM. • Exclusion criteria: Working papers, Conference papers/proceedings, Company/Industry reports, Market reports, Editorials and News reports. Articles written in any language other than English.	254
Stage 3: Refined select and sort	• Inclusion criteria: Article should be published in ABDC/ABS ranking OR published in journals dedicated for LSCM and Industry 4.0 technologies • For other journals: Articles must have standards of perceived quality of relevance, rigor, and readability (H index and SCImago ranking was considered)	79

3. I4.0 Technologies

Another factor on which the studied material is based is the I4.0 technologies that have been implemented or discussed. Industry 4.0 is defined as a systematic adoption of high-tech innovations [7], and any information technologies used in industry to improve efficiency and effectiveness while complying with Internet connectivity are termed I4.0 technologies [8], [9]. Table 3 displays the overall count of I4.0 tools found throughout the literature. the total count of I4.0 tools, however, exceeds the total number of articles because the majority of articles employed numerous I4.0 technologies.

First and foremost, we must examine the Internet of Things (IoT) as the most pervasive I4.0 technology, which is regarded as a key technology of Industry 4.0 since it allows for real-time evaluation of the entire system [[10], [11], [12], [13]]. Big data and artificial intelligence come in second and third, respectively, with 19 mentions each, probably due to the breadth of their applications. IT (six times), Augmented Reality, Virtual Reality, Autonomous vehicles, and 3D printing (four times each), ERP, Additive manufacturing, Advanced Manufacturing technologies, and Internet of Services are the next most prevalent technologies (15 times each), followed by cloud computing (15 times), CPS, robotics, and RFID (10 times each) (two

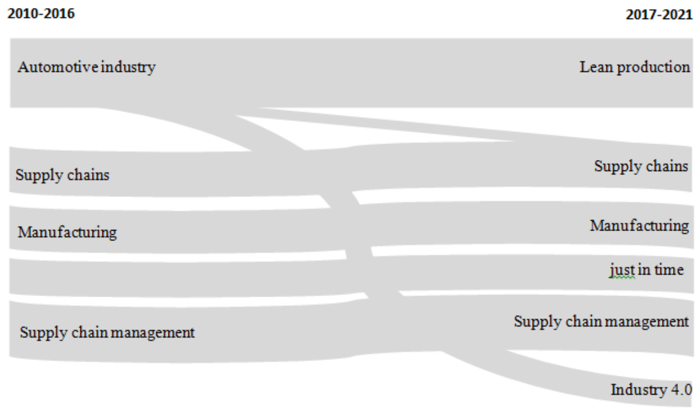

Figure 2. The Thematic Evolution.

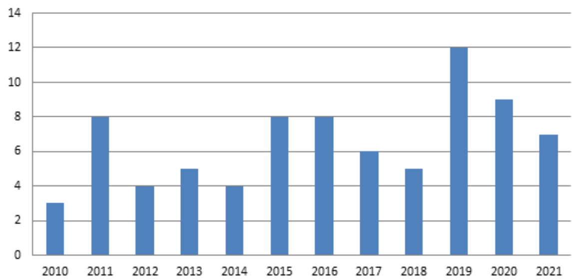

Figure 3. Time distribution.

times each). Barcode systems and electronic data interchange are the only remaining technologies that are used once.

4. Discussion

Although there are various I4.0 technologies that can be employed in LSCM, our data show that some are used more frequently than others. The Internet of Things (IoT) is the most widely used and well-known, consisting of a network of interconnected, internet-connected devices that allows users to control data through a wireless grid utilizing an integrated architecture[11], [12]. Inventory management, manufacturing systems, and production planning are all examples of LSCM applications, as are supplier selection, lean operations, process planning, and demand forecasting. IoT is becoming more relevant in today's commercial industries, according to [13].

The second technology is AI, which refers to machines' ability to communicate with and emulate human capacities [14]. LSCM has been identified as one of the most AI-capable companies in the industry. Despite widespread interest among practitioners and academics (as indicated by the large number of AI-related articles, such as this one) [15], [16].

Big-data, a mix of structured, semistructured, and unstructured data accumulated by organizations and mined for information [17], is another technology mentioned in the LSCM literature. In terms of LSCM, BD has been employed in a number of studies and for a variety of objectives, including calculating the quantity of materials deliveries [18], estimating the procurement process accurately [19], selecting suppliers [20], and supplying a decision-making support system [21].

Table 2. Classification by journals.

Journal	Articles	% of Total
INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	16	20%
PRODUCTION PLANNING AND CONTROL	7	9%
INTERNATIONAL JOURNAL OF SUPPLY CHAIN MANAGEMENT	6	8%
JOURNAL OF MANUFACTURING TECHNOLOGY MANAGEMENT	5	6%
INTERNATIONAL JOURNAL OF LEAN SIX SIGMA	4	5%
PROCEDIA MANUFACTURING	4	5%
SUPPLY CHAIN MANAGEMENT	4	5%
EXPERT SYSTEMS WITH APPLICATIONS	3	4%
IEEE ENGINEERING MANAGEMENT REVIEW	3	4%
INTERNATIONAL JOURNAL OF BUSINESS PERFORMANCE AND SUPPLY CHAIN MODELLING	2	3%
INTERNATIONAL JOURNAL OF INFORMATION SYSTEMS AND SUPPLY CHAIN MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF INTEGRATED SUPPLY MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF LOGISTICS SYSTEMS AND MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF OPERATIONS AND PRODUCTION MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF PRODUCTIVITY AND PERFORMANCE MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF QUALITY AND RELIABILITY MANAGEMENT	2	3%
INTERNATIONAL JOURNAL OF VALUE CHAIN MANAGEMENT	2	3%
JOURNAL OF BUSINESS LOGISTICS	2	3%
LOGISTICS JOURNAL	2	3%
IEEE SOFTWARE	1	1%
IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT	1	1%
INTERNATIONAL JOURNAL OF APPLIED MANAGEMENT SCIENCE	1	1%
INTERNATIONAL JOURNAL OF AUTOMOTIVE TECHNOLOGY AND MANAGEMENT	1	1%
INTERNATIONAL JOURNAL OF BUSINESS SCIENCE AND APPLIED MANAGEMENT	1	1%
INTERNATIONAL JOURNAL OF INDUSTRIAL ENGINEERING: THEORY APPLICATIONS AND PRACTICE	1	1%
INTERNATIONAL JOURNAL OF LOGISTICS RESEARCH AND APPLICATIONS	1	1%
Total	79	100%

Many research take advantage of cloud computing, a paradigm for providing omnipresent, efficient, on-demand network connectivity to a pool of configurable computer resources that can be quickly provided and released with minimal operational labor or service provider involvement [18].

Table 3. Total frequency of I4.0 technologies used.

I4.0 Technologies	Amount
IoT	23
artificial intelligence	19
Big data	19
Cloud computing	15
RFID	10
Cyber physical systems	10
Robotics	10
Information technology	6
Autonomous vehicles	4
3D printing	4
Virtual Reality	4
Augmented Reality	4
Internet of Services	2
Enterprise resource planning	2
Advanced Manufacturing technologies	2
Additive manufacturing	2
Barcode Systems	1
Electronic data interchange	1

LSCM research has used cloud computing in a variety of methods, including supply chain risk management [19], leagile SCM [20], supply chain negotiations [21], and real-time workflow management with information available to all stakeholders.

RFID is another I4.0 technology that is regularly utilized in LSCM experiments. RFID (radio frequency identification) is a technique that employs radio transmission information from an electronic chip, known as an RFID tag, affixed to a system, to identify and track a thing across a reader [22]. In LSCM and other sectors, RFID has been widely employed to address a range of difficulties. Inventory tracking and management [23], supply chain automation [24], supply chain communication and collaboration [25], and superior quality service and cost reduction in general [26] are some examples of uses.

CPS, which may be conceived of as a platform that link together the factual and virtual worlds [27], is one of the most relevant I4.0 technologies in the LSCM literature, according to the findings. CPS has become a powerful technique in many LSCM investigations due to its vast variety of applications, including supplier selection flexibility [23], cross-company information collection and transmission [24], supply chain network architectural and engineering optimization [25], and the configuration of agile supply chain networks[28].

Robotics, a combination of science, engineering, and computer that builds devices known as robots [28], is another technology used in the I4.0-LSCM literature. LSCM has been used in a range of studies and for a variety of reasons, including synchronizing end-to-end supply chain processes [29], reducing inventory check frequency [29], optimizing picking, sorting, and storing times [30], and minimizing warehousing expenses [31].

Information technology, Augmented Reality, Virtual Reality, Autonomous vehicles, Advanced Manufacturing technologies, Internet of Services, 3D printing, Barcode systems, and Additive manufacturing are among the technologies used in LSCM studies, in addition to the most significant I4.0 technologies discussed thus far.

5. Conclusion

This paper's goal was to find, evaluate, and assess literature on LSCM and I4.0 technologies interrelationships. Over the course of five steps, we looked at 79 articles that were chosen. This study provides a framework for scholars and practitioners to use in their research. For scholars interested in this area, our investigation and identification of the issue handled in the interrelationships among LSCM and I4.0 technologies is relevant. Previous literature research on this topic has disregarded the interrelationships between LSCM and I4.0 technologies; As a result, this work covers an important gap in the literature.

Despite this, further research on the application of new I4.0 technologies in LSCM contexts is required, since they demand more attention from academics due to their growing potential and capacity to meet LSCM objectives. There are also upcoming I4.0 technologies, such as Blockchain, smart factories, and advanced manufacturing technologies, whose impact on the LSCM environment has yet to be investigated.

Finally, given to the obvious SLR methodology employed, this strategy has significant limitations. On the one hand, we only looked at press pieces and articles written in English that met our quality and theme requirements (for instance, use of the Scopus database or keywords). As a result, it's possible that some lean and supply chain papers were overlooked (publication bias). Given that our SLR spans a time when Industry 4.0 ideas were still in their infancy, i.e. the researchers' own standards. These constraints, on the other hand, are inextricably linked to the SLR approach, as adequate limitations must be established in order for the review to be practical.

REFERENCES

1. A. Haddud, and A. Khare, Digitalizing supply chains potential benefits and impact on lean operations, Int. J. Lean Six Sigma, vol. 11, no 4, p. 731-765, 2020, doi: 10.1108/IJLSS-03-2019-0026.
2. N. V. K. Jasti, and R. Kodali, critical review of lean supply chain management frameworks: proposed framework, Production Planning & Control, vol. 26, no 13, p. 1051-1068, oct. 2015, doi: 10.1080/09537287.2015.1004563.
3. M. Alefari, K. Salonitis, and Y. Xu, he Role of Leadership in Implementing Lean Manufacturing, Procedia CIRP, vol. 63, p. 756-761, janv. 2017, doi: 10.1016/j.procir.2017.03.169.
4. C. S. Tang, and L. P. Veelenturf, The strategic role of logistics in the industry 4.0 era, Transportation Research Part E: Logistics and Transportation Review, vol. 129, p. 1-11, sept. 2019, doi: 10.1016/j.tre.2019.06.004.
5. D. Denyer, and D. Tranfield,, Producing a systematic review, in The Sage handbook of organizational research methods, Thousand Oaks, CA: Sage Publications Ltd, 2009, p. 671-689.
6. C. Okoli and K. Schabram, A Guide to Conducting a Systematic Literature Review of Information Systems Research, Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1954824, mai 2010. doi: 10.2139/ssrn.1954824.
7. A. G. Frank, L. S. Dalenogare, and N. F. Ayala, ndustry 4.0 technologies: Implementation patterns in manufacturing companies, International Journal of Production Economics, vol. 210, p. 15-26, avr. 2019, doi: 10.1016/j.ijpe.2019.01.004.
8. R. Drath and A. Horch, ndustrie 4.0: Hit or Hype? [Industry Forum], EEE Ind. Electron. Mag., vol. 8, no 2, p.56-58, juin 2014, doi: 10.1109/MIE.2014.2312079.
9. M. Ghobakhloo, Industry 4.0, Digitization, and Opportunities for Sustainability, Journal of Cleaner Production, vol. 252, p. 119869, déc. 2019, doi: 10.1016/j.jclepro.2019.119869.
10. R. Kirk, Cars of the future: the Internet of Things in the automotive industry, Network Security, vol. 2015, no 9, p. 16-18, sept. 2015, doi: 10.1016/S1353-4858(15)30081-7.
11. J. Arif, Y. Mouzouna, and F. Jawab The Use of Internet of Things (IoT) Applications in the Logistics Outsourcing: Smart RFID Tag as an Example. 2019.
12. J. Gubbi, R. Buyya, S. Marusic, et M. Palaniswami, Internet of Things (IoT): A vision, architectural elements, and future directions , Future Generation Computer Systems, vol. 29, no 7, p. 1645-1660, sept. 2013, doi: 10.1016/j.future.2013.01.010.
13. L. Atzori, A. Iera, et G. Morabito,, he Internet of Things: A survey, Computer Networks, vol. 54, no 15, p.2787-2805, oct. 2010, doi: 10.1016/j.comnet.2010.05.010.
14. D. Schutzer, Business expert systems: The competitive edge, Expert Systems with Applications, vol. 1, no 1, p. 17-21, janv. 1990, doi: 10.1016/0957-4174(90)90065-3.
15. R. Toorajipour, V. Sohrabpour, A. Nazarpour, P. Oghazi, and M. Fischl, Artificial intelligence in supply chain management: A systematic literature review, Journal of Business Research, vol. 122, p. 502-517, janv. 2021, doi: 10.1016/j.jbusres.2020.09.009.
16. M. Sangeetha, A. Hoti, R. Bansal, M. Faez Hasan, K. Gajjar, and K. Srivastava Facilitating artificial intelligence supply chain analytics through finance management during the pandemic crises, Materials Today: Proceedings, déc. 2021, doi: 10.1016/j.matpr.2021.11.418.

17. K. Moharm, State of the art in big data applications in microgrid: A review , Advanced Engineering Informatics, vol. 42, p. 100945, oct. 2019, doi: 10.1016/j.aei.2019.100945.
18. W. Zhao, Y. Peng, F. Xie, and Z. Dai, Modeling and simulation of cloud computing: A review, in 2012 IEEE Asia Pacific Cloud Computing Congress (APCloudCC), Shenzhen, China, nov. 2012, p. 20-24. doi: 10.1109/APCloudCC.2012.6486505.
19. A. Jede and F. Teuteberg, ntegrating cloud computing in supply chain processes: A comprehensive literature review, Journal of Enterprise Information Management, vol. 28, no 6, p. 872-904, janv. 2015, doi: 10.1108/JEIM- 08-2014-0085.
20. R. mason-jones and D. TOWILLz, Lean, Agile or Leagile? Matching Your Supply Chain to the Marketplace , International Journal of Production Research, vol. 38, nov. 2010, doi: 10.1080/00207540050204920.
21. L. Xu, C. Wang, and J. Zhao, , ecision and coordination in the dual-channel supply chain considering cap-and-trade regulation, Journal of Cleaner Production, vol. 197, p. 551-561, oct. 2018, doi: 10.1016/j.jclepro.2018.06.209.
22. Y. Wu, D. C. Ranasinghe, Q. Z. Sheng, S. Zeadally, and J. Yu, FID enabled traceability networks: a survey, Distrib Parallel Databases, vol. 29, no 5, p. 397-443, oct. 2011, doi: 10.1007/s10619-011-7084-9.
23. F. Altiparmak, M. Gen, L. Lin, et T. Paksoy„ genetic algorithm approach for multi-objective optimization of supply chain networks , Computers & Industrial Engineering, vol. 51, no 1, p. 196-215, sept. 2006, doi: 10.1016/j.cie.2006.07.011.
24. A. Akanmu et C. J. Anumba, Cyber-physical systems integration of building information models and the physical construction, Engineering, Construction and Architectural Management, vol. 22, no 5, p. 516-535, janv. 2015, doi: 10.1108/ECAM-07-2014-0097.
25. J. Lee, B. Bagheri, et H.-A. Kao, , Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems, Manufacturing Letters, vol. 3, p. 18-23, janv. 2015, doi: 10.1016/j.mfglet.2014.12.001.
26. J. Lee, B. Bagheri, et H.-A. Kao, Recent Advances and Trends of Cyber-Physical Systems and Big Data Analytics in Industrial Informatics, 2014. doi: 10.13140/2.1.1464.1920.
27. X. Yuan, C. Anumba, and M. Parfitt, Review of the Potential for a Cyber-Physical System Approach to Temporary Structures Monitoring , International Journal of Architectural Research: ArchNet-IJAR, vol. 9, p. 26-44, nov. 2015, doi: 10.26687/archnet-ijar.v9i3.841.
28. D. Szafir, B. Mutlu, and T. Fong„ Designing planning and control interfaces to support user collaboration with flying robots, The International Journal of Robotics Research, vol. 36, no 5-7, p. 514-542, juin 2017, doi: 10.1177/0278364916688256.
29. J. Vogt Duberg, G. Johansson, E. Sundin, and O. Tang, Economic evaluation of potential locations for remanufacturing in an extended supply chain – a case study on robotic lawn mowers, Procedia CIRP, vol. 90, p. 14-18, janv. 2020, doi: 10.1016/j.procir.2020.01.087.
30. C. Flechsig, F. Anslinger, and R. Lasch„ obotic Process Automation in purchasing and supply management: A multiple case study on potentials, barriers, and implementation, Journal of Purchasing and Supply Management, p. 100718, août 2021, doi: 10.1016/j.pursup.2021.100718.
31. S. Subbiah, C. Schoppmeyer, J. M. D. L. F. Valdès, C. Sonntag, et S. Engell, Optimal Management of Shuttle Robots in a High-Rise Warehouse Using Timed Automata Models, IFAC Proceedings Volumes, vol. 46, no 9, p. 1358-1363, janv. 2013, doi: 10.3182/20130619-3-RU-3018.00192.