Lean supply chain management and Industry 4.0: a systematic literature review

Matteo Rossini
Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Daryl John Powell
Norwegian University of Science and Technology, Trondheim, Norway, and

Kaustav Kundu
Department of Industrial Systems Engineering and Management, National University of Singapore, Singapore, Singapore

Received 12 May 2021
Revised 10 November 2021
Accepted 6 May 2022

Abstract

Purpose – Even though the integration of Lean Supply Chain Management (LSCM) and Industry 4.0 (I4.0) technologies is relatively recent, it has been receiving a lot of attention. Partly because it is a recent field of practise and research and partly because the number of works developed in this field has grown rapidly, it is important to frequently update the perspectives on this field of investigation. Thus, this study aims to review the integration between LSCM and I4.0 analysing relationship at operative, tactical and strategic levels.

Design/methodology/approach – Systematic literature review was conducted to identify and explain the integration of LSCM and I4.0 from scientific sources that were published before March 2021.

Findings – The analysis of the literature revealed the level of integration of LSCM and I4.0 is present at different managerial levels. Moreover, when the integration is detailed at different managerial levels, it appears that LSCM paves the way for the adoption of I4.0 at a strategic level, while I4.0 technologies promise to enhance LSCM practices at the operational level.

Research limitations/implications – The main contribution of this study is the framework which shows that LSCM paves the way for the adoption of I4.0 at a strategic level, while I4.0 technologies promise to enhance LSCM practices at the operational level.

Originality/value – This study develops a new perspective of the articles published under the thematic of LSCM and I4.0. Additionally, it proposes a framework of analysis that can be used by future researchers. Finally, it shows the most recent implementations of LSCM and I4.0, exposing the current trends, improvements and also the main gaps.

Keywords Supply chain management, Lean production, Industry 4.0, Digitalization, Lean supply chain

Paper type Literature review

International Journal of Lean Six Sigma
Vol. 14 No. 2, 2023
pp. 253-276
Emerald Publishing Limited
2040-4166
DOI 10.1108/IJLSS-05-2021-0092

1. Introduction

Since the past decades, the Lean Supply Chain Management (LSCM) practices and principles have been successfully adopted across different sectors (Chakrabarty and Wang, 2020). Such increasing interest is because LSCM implementation can bring several benefits in the form of cost reduction, throughput time shortening, quality and other aspects (Moyano-Fuentes *et al.*, 2020; Vanichchinchai, 2019).

The advent of Industry 4.0 (I4.0) has re-opened the debate of the introduction of novel technologies in already established managerial system led by human-centred philosophy such as lean management (Ghadge *et al.*, 2020). The modern information and communication technologies (ICT) of I4.0 make it possible to establish connection among the products, machines and processes. In this sense, many authors have spotlighted the potential benefits of integrating technologies such as Big Data analytics, Internet of Things and Cloud Computing in lean systems, generating great expectations and enthusiasm (Buer *et al.*, 2020; Tortorella *et al.*, 2019a, 2019b).

Literature presents papers discussing interplay between LSCM and I4.0, but the topic is still in the novelty phase (Núñez-Merino *et al.*, 2020).

Moreover, the literature is presenting different perspective of analysis, which does not support the structure of such relationship, thereby creating chaos on the value of the interplay.

This paper wants to fill that gap in the literature, presenting the state of the art of interplay between LSCM and I4.0, defining a framework to outline the interplay and, therefore, paving the base for future studies in this field of research. Therefore, we come up with the following research question:

RQ1. Is there any interrelationship between Lean Supply Chain Management and Industry 4.0?

To answer the research question, this study provides a systematic literature review (SLR).

The article is structured as follows: Section 2 introduces and defines the domain of LSCM and I4.0, while Section 3 describes the applied methodology for the SLR. Section 4 outlines the findings of the study and presents the conceptual framework of the interplay between LSCM and I4.0. Section 5 concludes the article, indicating its limitations and future research opportunities.

2. Theoretical background

2.1 Lean supply chain management

Given the current situation where there is high turbulence in the customer demand and the competitive landscape is rapidly changing, firms grapple with the challenge of satisfying the desired needs of the customers (Vanpoucke *et al.*, 2014).

According to Krajewski *et al.* (2015), the most successful companies are those that take into consideration the external customers and suppliers into their internal improvement processes. Thus, integration with suppliers and customers acts as an external aid to improve competitiveness and efficiency (Flynn *et al.*, 2010). One approach that can help supply chains to reduce waste and achieve sustainability is Lean Production (LP), based on the Toyota Production System (Rossini *et al.*, 2019). As such, in an environment where the companies are competing for shorter lead times and better quality with cost reduction, LP practices can be implemented in the spirit of a supply chain integrative approach (Guilherme Luz Tortorella *et al.*, 2017).

LSCM is the management of different organizations integrating both upstream and downstream flows of different entities that can increase value and reduce cost and waste by responding promptly to satisfy the demand of each customer (Anand and Kodali, 2008;

Saxby *et al.*, 2020). Thus, the aim of LSCM is to ensure that value is created and transferred efficiently to the downstream. The concept of LSCM is not only confined in automotive, construction or manufacturing companies but also extended to service firms such as hospitality, health care and retail (Borges *et al.*, 2019). However, several studies on the topic have focused only on individual aspects of LSCM. In particular, many studies have concentrated only on analysing "upstream" lean practices, while scarcely any attention has been given on their application in the "downstream" (Reichhart and Holweg, 2007; Reitsma *et al.*, 2020). The gradual adoption of LP practices "downstream" in the flow could be justified by the production levelling (heijunka) concept, as there is a requirement of production to cope up with fluctuations with high market demand variability (Mason-Jones *et al.*, 2000). Nevertheless, it is found out that it is not possible to achieve complete sustainable results by applying LP principles only at upstream actors in the supply chain.

Hines *et al.* (2004) indicated that the evolution of LP principles and practices over the years from the shop floor to every actor across the supply chain. They can be applied, from developing products and services, through placing orders with suppliers, to transporting the products to the customers (Bittencourt *et al.*, 2021). Its aim is to continuously improve all the activities which will be beneficial for the customers. In this sense, LSCM highlights the importance of using LP practices effectively to create an efficient production and logistics system that meets the customers' expectations (Chu *et al.*, 2021).

As stated by Agarwal *et al.* (2006), LSCM requires a different business model, which should consider a strategic relationship with different supply chain actors and eliminate waste through cooperative and systematic approach. In this sense, the advent of new technologies opens many new options for LSCM, facilitating coordination and collaboration among supply chain partners and fostering integration to more competitive levels (Tortorella G., Miorando R., 2019).

2.2 Industry 4.0

The term I4.0 was first coined out in 2011 by the German Industry–Science Research Alliance (Buhr, 2017). Nowadays, I4.0 or simply the *digital transformation* creates many challenges for manufacturing companies from different points of view. The I4.0 can be seen as an expansion of ICT horizontally (Lee *et al.*, 2018). In fact, ICT is now used more extensively across all spheres, including business, government and everyday life. The digitalization of I4.0 helps to connect different entities across the whole supply chain through real time information (Chiarini *et al.*, 2020). Because of this interconnection, different entities will be able to cope with the fluctuations in the environmental factors thanks to artificial intelligence (Hecklau *et al.*, 2016). Mario *et al.* (2017) described I4.0 as "[. . .] a collective term for technologies and concepts of value chain organization".

Digitization is affecting all sectors, either replacing traditional products with digital counterparts or enhancing those products with new digital features (Prem, 2015). However, the digital transformation that results from a shift towards I4.0 goes beyond the improvement at the product and process levels. Though it has created revolution in production and business models, it left the companies with challenges (Bleicher and Stanley, 2018). In particular, the ultimate goal of digitalization of manufacturing is to establish connection among all the actors in manufacturing value chains. In other words, digitalization enhances not only the physical products but also the business and the overall strategy of the organizational structure (Matt *et al.*, 2015). According to Meier (2016), for the full digital transformation, the companies should first analyse and identify what customers want; then, they should perform the changes within the organization according to the customer needs. But the challenge for business remains on the speed and depth that the companies can adopt digital transformation (Rossini *et al.*, 2021).

It has been proved a strict link between the implementation of I4.0 technologies and lean systems (G.L. Tortorella *et al.*, 2019b), but the research is focused on the single plant implementation and still misses a broader perspective of relationship outside the walls of the single plant, looking at the supply chain.

Given that LSCM and I4.0 represent two relevant opportunities for business but their relationship is still unstructured, this paper aims to explore and discuss the potential synergy for firms adopting both approaches.

3. Methodology

To explore the landscape of combining LSCM with I4.0, we adopted SLR. According to Fink (2005), a SLR is:

> [. . .] a systematic, explicit, comprehensive and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners.

In this section, the methodology adopted to conduct the literature review is described. According to the authors, it can be said to be systematic to a fair degree, considering the strict procedure that has been used.

Following the guidance of Xiao and Watson (2017), for a review to be successful, it should involve three phases: Planning, Conducting and Reporting.

Figure 1 shows the reviews in eight different steps.

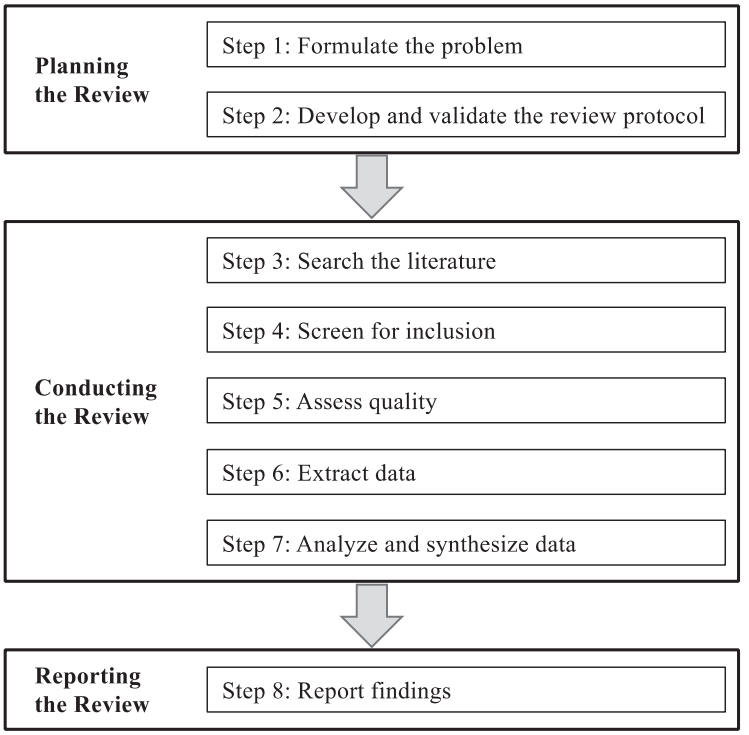

Figure 1.
Literature review methodology

In the following paragraphs, all the steps are detailly discussed and an explanation of how they have been put in practice is provided.

Step 1: Formulating the problem

The starting point for conducting a SLR is the formulation of the problem. The driving forces of the SLR process are the research questions (Kitchenham and Charters, 2007), which are the aim of the formulation of the problem.

A too broad research question could invalidate the SLR because of a huge amount of identified data to work with (Cronin *et al.*, 2008). For this reason, the adequate research question could be identified with an iterative process.

The foundation of the SLR is the relationship between the environment of lean supply chain and the one of I4.0. Therefore, the starting aim was to study how the two paradigms interact with each other. Gradually, conducting the initial research, a more structured and refined question has been necessary. Indeed, different relationships between lean supply chain and I4.0 could be identified in relation with different business sectors. Moreover, these relationships may have already been thoroughly studied in some sectors, while in other sectors, this research has just begun. This iterative process has been instrumental in identifying the boundaries of the research question of the SLR.

Step 2: Developing and validating the review protocol

The review protocol is "a preset plan that specifies the methods utilized in conducting the review" (Xiao and Watson, 2017), and it is absolutely crucial for rigorous systematic reviews. It should significantly reduce the bias during the analysis of the selected data (Kitchenham and Charters 2007).

Step 3: Searching the literature

The systematic search follows five steps. First, the channels for the literature search must be defined by researchers. As there are infinitely many channels available, researchers should choose a subgroup of channels. Second, the research question must be translated in keywords that could be used for the research. Third, researchers should identify the sampling strategy. According to the review requirement, the research can be either exhaustive or selective (Suri and Clarke, 2009; Bayliss and Beyer, 2015). Fourth, researchers should refine results with additional restrictions because there could be further practical criteria to exclude some papers from the SRL. Finally, it is important to identify a stopping rule that helps researcher to understand when the studies could be considered finished.

Regarding the channels for literature review, among the countless available sources, *Scopus* has been chosen as the only database for this SLR. This choice is because this electronic storage delivers "a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, and arts and humanities".

The following step is the identification of the keyword used for the search. For what concerns this study, as the aim is to study the relationship between LSCM and I4.0, the first keywords are "Lean", "Supply Chain" and "Industry 4.0". Given the need to have a comprehensive research environment, the search must be extended using synonymous, alternative spellings, abbreviations and related terms. Specifically, one synonymous of "Lean" is "JIT", while the synonymous of "Industry 4.0" are "Digital" and "Smart". Moreover, there is also an abbreviation for "Industry 4.0" that is "I4.0" and the alternative German spelling of "Industry 4.0" that is "Industrie 4.0". To create the search strings, "AND" is used to join the main terms, while "OR" is used to include synonymous and abbreviations. Therefore, the final search string was {[("JIT" OR "Lean") AND ("Supply Chain")] AND ("Industry 4.0" OR "I 4.0" OR "Digital" OR "Smart" OR "Industrie 4.0")}. Table 1 synthesizes the final set of keywords, divided into the two themes addressed by this literature review.

For what concerns the sampling strategy, the search can be either exhaustive or selected (Suri and Clarke, 2009; Bayliss and Beyer, 2015). This SLR is more selected and representative. For this reason, "grey literature", such as conferences, was not included in the search papers. This decision stems from the fact that grey literature is considered of lower quality than peer-reviewed papers (Xiao and Watson, 2017). Moreover, "grey literature" could be affected by more biases than peer-reviewed papers.

To further refine the results, additional restrictions have been applied including date range of publication and publication language. For what concerns the time horizon, documents published before 2011 were excluded from the research, as the term "Industry 4.0" came up for the first time during the Hannover Fair of that year. On the other side, the ending date of the research horizon corresponds to the end of 2020. As regards the publication language, the research has been confined to English language.

Finally, according to Levy and Ellis (2006), a rule of thumb is to stop the search in case of obtaining the same references with no new results. In this case, the stopping rule has been applied to the research keywords. In particular, it has been tested that adding the new keywords "I4.0" and "Industrie 4.0" to identify I4.0 leads to the same results. For this reason, no other keywords besides those presented in Table 1 were included.

Step 4: Screen for inclusion

Once the search of articles has come to the end, a list of paper has been generated in the channel selected for literature search. From this list, researchers have to screen each article to identify the possibility of including it for data extraction and analysis. Starting from the articles list generated in previous steps, the authors should screen this list by reading the abstract of each article according to inclusion and exclusion criteria. This procedure should be done by each researcher to select the studies based on the inclusion and exclusion criteria (Gomersall *et al.*, 2015). These criteria, that are based on the research question, should match with the practical situations and appropriate enough to classify the research. Moreover, they can be trustworthy and should result in a manageable source of literature (Xiao and Watson, 2017). Only when the screen of articles is completed by each researcher, they should compare the two respective outputs of this procedure. In the case of conflicting opinions, the paper should be included.

The list of the exclusion criteria applied by the authors in this literature review is described below:

- *Not peer-reviewed* (*NR*): Articles found with the keywords previously described and that are not-peer-review should be discarded. Specifically, conferences articles are considered "grey literature". For this reason, according to the sampling strategy adopted, these papers should be rejected, while only article and review types should be considered by researchers;
- *Completely unrelated* (*CU*): Papers which are not related to the relationship between lean supply chain and I4.0 should not be included in the literature review. Indeed, because of some keywords used, such as "Smart" and "Digital", articles that have in

Table 1.
Research keywords used

Lean supply chain	Industry 4.0
JIT supply chain	Industry 4.0
Lean supply chain	Industrie 4.0
	I4.0
	Digital
	Smart

their abstract these terms have appeared in the search list. However, these articles sometimes are not related to the relationship between lean supply chain and I4.0, and for this reason, it should be rejected.

- *Vaguely related* (*VR*): Articles which are related only to lean supply chain or I4.0 but not to the relationship between these two should be excluded. Moreover, papers that are just focused on one of these two areas and just briefly mention the other ones were discarded from the literature review.
- *Duplicates* (*D*): As it has been decided for the literature to use only one database, *Scopus*, there are no overlapping results that could be obtained by using different databases. By the way, in the same database, there could be duplicates that must be deducted from the total number of articles reviewed.
- *No access* (*NA*): It is possible that in the list of the literature review, there are some papers that could be accessed in terms of title and abstract, but that do not allow to access to the full text. For this reason, these papers should be rejected from the final list of papers.

Furthermore, to have a complete and comprehensive insight on the relationship between lean supply chain and I4.0, the authors have decided to use also the inclusion criteria presented below:

- *Backward related* (*BR*): Some articles that are cited in the articles reviewed should be included in the literature review to deepen the knowledge about the two paradigms under analysis.
- *Forward related* (*FR*): Researchers should include publications by the key authors of the two paradigms analysed using the same database, Scopus.

All of these inclusion and exclusion criteria described above have been implemented by researchers only after the other exclusion and inclusion criteria described in Step 3 were applied. Indeed, the step of refining results with additional restrictions made researchers able to delineate the boundary of the literature review. More specifically, the rejection conditions used have been:

- *Outdated* (*O*): Articles published before 2011 should be excluded from the literature review because the paradigm of "Industry 4.0" came up the first time during the Hannover Fair of 2011.
- *Language* (*L*): Papers written in a language that differs from English must be discarded for the literature review.

A summary of the exclusion and inclusion process with the related numbers is provided in Figure 2.

After the application of the inclusion and exclusion criteria presented above, a final list of papers for the literature review could be identified, first by each researcher independently, before all researchers were able to discuss the list and reach consensus for inclusion in the study. We ensured that researchers had a balance of expertise, for example, one of us has expertise in lean, another in I4.0 and the other in both lean and I4.0. To guarantee future readers to be able to replicate the same search, a record of excluded papers has been kept for their reference (Kitchenham and Charters, 2007).

Step 5: Assessing quality

According to Whittemore and Knafl (2005), quality standards will differ from one review to another. On one hand, quality assessment is of vital importance for testing reviews,

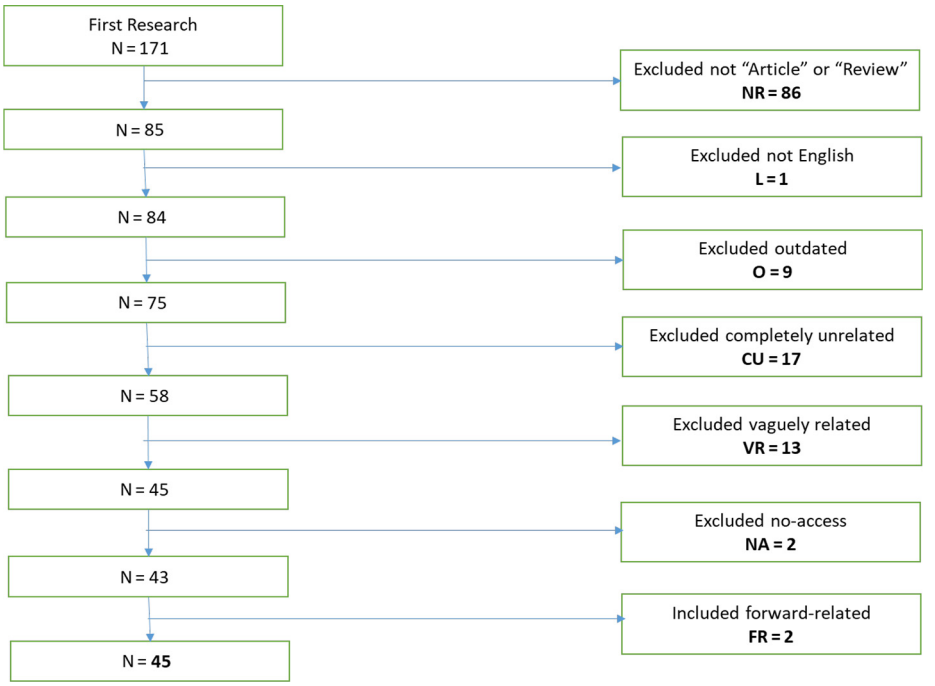

Figure 2.
Literature review process

whose aim is generalization. On the other hand, this phase is not important for certain reviews such as scoping reviews, whose objective is to discover the breadth of studies, not the quality. Similar to the inclusion screening process, the authors have performed the quality assessment parallelly, as recommended by Noordzij *et al.* (2009). Any disagreement has been resolved through discussion and consultation.

As it has already been discussed that this literature review can be classified as a scoping review, the type of quality assessment applied has not excluded papers from the pool. This decision is aligned with both the desire to have as much input as possible and the novelty of the topic.

Therefore, quality assessment has been an important means for learning the overall quality and distribution of the selected studies.

The specifications objects of this assessment are the methodology used to conduct the study and the ranking of the publishing journal. The list of 45 papers including their title, authors, publication year, journal name, ranking and methodology is reported in Table 2.

From Figure 3, it is possible to notice an increasing trend in the interest for this topic. In particular, it is worth to point out that the majority of papers has been published during past three years, 2018–2020.

Looking at the methodologies used for the research (Figure 4), it is immediately clear that 31% of studies have used case study, typically applying this methodology to specific fields.

For instance, Ramirez-Peña *et al.* (2020) focused on shipbuilding, a complex manufacturing industry that needs 4.0 guidelines to improve supply chain efficiency, while Ge and Jackson (2014) investigated usability of Big Data technologies as tools for Six Sigma process to achieve cost reduction in automotive industry.

No.	Authors	Year	Journal	Methodology
1	Homer, G. and Thompson, D.	2001	*International Journal of Automotive Technology and Management*	Case study
2	White, R.E. and Pearson, J.N.	2001	*International Journal of Physical Distribution and Logistics Management*	Framework
3	Heikkila, J.	2002	*Journal of Operations Management*	Case study
4	Tan, K.C., Lyman, S.B. and Wisner, J.D.	2002	*International Journal of Operations and Production Management*	Survey
5	Berkhout and Hertin	2004	*Futures*	Framework
6	Bruun, P. and Mefford, R.N.	2004	*International Journal of Production Economics*	Framework
7	Ward, P. and Zhou, H.	2006	*Decision Sciences*	Survey
8	Adamides, E.D., Karacapilidis, N., Pylarinou, H. and Koumanakos, D.	2008	*Production Planning and Control*	Case study
9	Hong, P.C., Dobrzykowski, D.D. and Vonderembse, M.A.	2010	*Benchmarking: An International Journal*	Survey
10	Ge X. and Jackson J.	2014	*SAE International Journal of Commercial Vehicles*	Case study
11	Lasi, H., Kemper, H.G., Fettke, P., Feld, T. and Hoffmann, M.	2014	*BISE*	Framework
12	Digiesi, S., Facchini, F., Mossa, G., Mummolo, G. and Verriello, R.	2015	*IFAC-PapersOnLine*	Case study
13	Haq, A.N. and Boddu, V.	2015	*Int. J. Business Performance and Supply Chain Modelling*	Case study
14	Jasti, N.V.K. and Kodali, R.	2015	*Production Planning and Control*	Framework
15	Hermann, M., Pentek, T. and Otto, B.	2016	*49th Hawaii International Conference on System Sciences*	Case study
16	Sanders, A., Elangeswaran, C. and Wulfsberg, J.	2016	*Journal of Industrial Engineering and Management*	Literature review
17	Davies, R., Coole, T. and Smith, A.	2017	*Procedia Manufacturing*	Case study
18	Lu	2017	*Journal of Industrial Information Integration*	Survey
19	Mrugalska, B., Wyrwicka, M.K.	2017	*Procedia Engineering*	Framework
20	Pinho, C. and Mendes, L.	2017	*International Journal of Production Research*	Literature review
21	Vazquez-Martinez, G.A., Gonzalez-Compean, J.L., Sosa-Sosa, V.J., Morales-Sandoval, M. and Perez, J.C.	2018	*International Journal of Information Management*	Simulation
22	Perboli, G., Musso, S. and Rosano, M.	2018	*IEEE Access*	Case study
23	Ante, G., Facchini, F., Mossa, G. and Digiesi, S.	2018	*IFAC-PapersOnLine*	Framework
24	Tortorella, G. L. and Fettermann, D.	2018	*International Journal of Production Research*	Survey
25	Horváth, D. and Szabó, R.Z.	2019	*Technological Forecasting and Social Change*	Interview

(*continued*)

Table 2.
Selected papers for systematic literature review

No.	Authors	Year	Journal	Methodology
26	Rossini, M., Costa, F., Tortorella, G.L. and Portioli-Staudacher, A.	2019	*The International Journal of Advanced Manufacturing Technology*	Survey
27	Haddud, A. and Khare, A.	2019	*International Journal of Lean Six Sigma*	Survey
28	Bittencourt, V.L., Alves, A.C. and Leão, C.P.	2019	*IFAC-PapersOnLine*	Literature review
29	Bevilacqua, M., Ciarapica, F.E. and Antomarioni, S.	2019	*Management and Production Engineering Review*	Framework
30	Ashrafian, A., Powell, D.J., Ingvaldsen, J.A., Dreyer, H.C., Holtskog, H., Schütz, P., Holmen, E., Pedersen, A. and Lodgaard, E.	2019	*International federation for information processing*	Literature review
31	Roy, M. and Roy, A.	2019	*IEEE Engineering Management Review*	Case study
32	De Giovanni, P. and Cariola, A.	2020	*Research in Transportation Economics*	Survey
33	Núñez-Merino, M., Maqueira-Marín, J.M., Moyano-Fuentes, J. and Martínez-Jurado, P.J.	2020	*International Journal of Production Research*	Literature review
34	Chiarini, A., Belvedere, V. and Grando, A.	2020	*Production Planning and Control*	Survey
35	Pekarcikova, M., Trebuna, P., Kliment, M. and Rosocha, L.	2020	*International Journal of Simulation Modelling*	Simulation
36	Saxby, R., Cano-Kourouklis, M. and Viza, E.	2020	*The TQM Journal*	Interview
37	Alieva, J. and von Haartman, R.	2020	*Operations and Supply Chain Management*	Interview
38	Frontoni, E., Rosetti, R., Paolanti, M. and Alves, A.C.	2020	*Manufacturing Letters*	Case study
39	Ramirez-Peña, M., Sánchez Sotano, A.J., Pérez-Fernandez, V., Abad, F.J. and Batista, M.	2020	*Journal of Cleaner Production*	Case study
40	Buer, S. V., Semini, M., Strandhagen, J. O. and Sgarbossa, F.	2020	*International Journal of Production Research*	Survey
41	Nunez-Merino, M., Maqueira-Marin, J.M., Moyano-Fuentes, J. and Martinez-Jurado, P.J.	2020	*International Journal of Production Research*	Literature review
42	Bittencourt, V.L., Alves, A.C. and Leao, C.P.	2021	*International Journal of Production Research*	Literature review
43	Ciano, M.P., Dallasega, P., Orzes, G. and Rossi, T.	2021	*International Journal of Production Research*	Case study
44	Raji, I.O., Shevtshenko, E., Rossi, T. and Strozzi, F.	2021	*The International Journal of Logistics Management*	Framework
45	Spenhoff, P., Wortmann, J.C.H. and Semini, M.	2021	*Production Planning and Control*	Case study

Table 2.

Second, significant number of studies developed a framework connecting the two paradigms of lean supply chain and I4.0. As an example, Bevilacqua *et al.* (2019) formulated a procedure based on lean principles to minimize the number as well as the duration of picking processes in a warehouse equipped with an automated storage and retrieval system.

Then, three studies of the sample used interviews as a way to gather non-structured information to derive insightful findings.

Third, 4% of studies exploited the power of simulation to conduct some what-if analysis. Through this technique, Vazquez-Martinez *et al.* (2018) developed a model that is able to connect different customers, partners and organizations and perform the stages of digital product lifecycle across them.

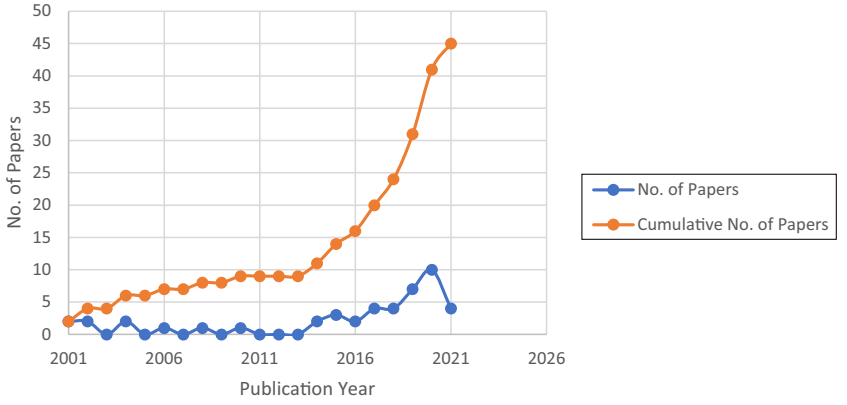

Figure 3.
Yearly distribution of the papers considered

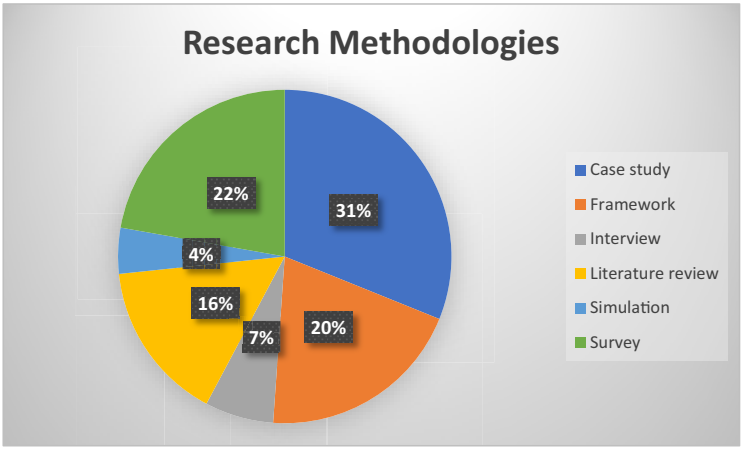

Figure 4.
Methodology distribution of the papers considered

Next, 16% of studies have used the literature review methodology with the aim to describe the state of the art of the literature regarding the interaction and concurrent application of lean supply chain and I4.0. In particular, the purpose of De Giovanni and Cariola (2020) is to investigate how a process innovation strategy that firms implement through I4.0 technologies affect the performance of lean practices and green supply chains.

Finally, the survey methodology has been applied by Rossini *et al.* (2019) among others (22%) to evaluate how the adoption of I4.0 technologies along with LP practices impact the operational performance of European manufacturers.

Step 6: Extracting data

Generally, the data extraction process often involves coding. As recommended by Gomersall *et al.* (2015), the researchers have coded the studies independently by reviewing the entire papers, not simply relying on the main interpretation. In this way, it is possible to avoid the distortion of the original paper. The articles were coded to identify the characteristics of each study (e.g. research method) and variables that might be used to explain emergent themes or differences in the works (e.g. interplay between both lean and I4.0 approaches).

Step 7: Analysing and synthesizing data

Once the data extraction process is completed, the reviewers have to sort out the data according to the previously defined review type (Xiao and Watson, 2017). Each qualitative and quantitative literature identified with the search set through the above steps was again analysed by each researcher independently. Subsequently, reviewers discussed together to translate the quantitative results proposed in the papers to a qualitative output. The approach adopted is the integrated design which analyses and synthesizes quantitative and qualitative research together. Results were synthesized into three emergent groups (again by reaching consensus on the emergent similarities and differences from the literature) – lean favouring I4.0, mutual support of lean and I4.0 and I4.0 supporting lean (see analysis of literature in the following section).

Step 8: Report findings

In the end, the findings from literature search should be reported after screening and quality assessment in a visual diagram. New insights should be highlighted. In addition, report findings should include also opportunities and direction for future research (Okoli and Schabram, 2010).

4. Results and discussion

In this section, the literature on the interplay between I4.0 and LSCM is analysed. Through literature analysis, 45 articles were identified that directly and indirectly satisfied our criteria and helped us to establish the interrelationships between I4.0 and LSCM. First, an analysis of the literature is presented showing the trend of articles. Then the findings in each of the identified lines are presented followed by discussion.

4.1 Analysis of literature

We can divide the papers into three main categories: Lean favouring I4.0; Mutual support of lean and I4.0; and I4.0 supporting lean. Table 3 shows the papers based on these categories.

Because of the low number of articles and the novelty of the topic, authors defined two research lines that clearly define different approaches to this field of research: strategic and operative levels.

The former research line includes all the articles that investigate interplay of the two paradigms focusing on a system perspective, looking at a path of implementation, with long-term period perspective. The latter research line includes all articles that analyse the interplay of the two paradigms at operative level, with a single implementation point of view and short-term perspective linked with the specific practice/technology implementation in a specific context.

The details are discussed in the next sections.

4.2 Strategic level

With the automation provided by I4.0, questions have risen about the interoperability with the lean approach. Lean environment creates a culture more receptive to new technologies, especially the ones that reduce waste (Bittencourt *et al.*, 2019, Torri *et al.*, 2021). In this sense, LSCM and I4.0, despite different perspectives, should be considered together, as they have the same goal of reducing the costs and increasing the productivity for companies. The authors conducted reviewed this interaction, focusing on the role that lean could play in the ongoing fourth Industrial Revolution. They derived that lean could facilitate to implement I4.0 in the companies, which is also mentioned by Kolberg and Zühlke (2015). Therefore, the maturity level of lean within a system is an important metric which determines the association with I4.0 (Saxby *et al.*, 2020). However, the authors stressed the

Lean favouring Industry 4.0	Mutual support of lean and Industry 4.0	Industry 4.0 supporting lean
Berkhout and Hertin (2004)	Ge and Jackson (2014)	Homer and Thompson (2001)
Vazquez-Martinez *et al.* (2018)	Digiesi *et al.* (2015)	White and Pearson (2001)
Bittencourt *et al.* (2019)	Davies *et al.* (2017)	Heikkila (2002)
Ramirez-Pena *et al.* (2019)	Lu (2017)	Tan *et al.* (2002)
Rossini *et al.* (2019)	Mrugalska and Wyrwicka (2017)	Bruun and Mefford (2004)
Alieva and von Haartman (2020)	Ante *et al.* (2018)	Ward and Zhou (2006)
Saxby *et al.* (2020)	Tortorella and Fettermann (2018)	Adamides *et al.* (2008)
Bittencourt *et al.* (2021)	Buer *et al.* (2020)	Hong *et al.* (2010)
	Nunez-Merino (2020)	Lasi *et al.* (2014)
	Ciano *et al.* (2021)	Haq and Boddu (2015)
	Raji *et al.* (2021)	Jasti and Kodali (2015)
	Spenhoff *et al.* (2021)	Hermann *et al.* (2016)
		Sanders *et al.* (2016)
		Pinho and Mendes (2017)
		Perboli *et al.* (2018)
		Ashrafian *et al.* (2019)
		Bevilacqua *et al.* (2019)
		Haddud and Khare (2019)
		Horváth and Szabó (2019)
		Roy and Roy (2019)
		Chiarini *et al.* (2020)
		Frontoni *et al.* (2020)
		Giovanni and Cariola (2020)
		Pekarcikova *et al.* (2020)

Table 3.
Literature details

importance of understanding which LSCM elements provide more support to I4.0 introduction. This is necessary to avoid huge investments, both in terms of money and time, for re-inventing operations systems, while a simply update of some element effectively supports I4.0 technologies implementations (Saxby *et al.*, 2020).

The linkage between ICT and LSCM has been confirmed also by Jasti and Kodali (2015) who included Information Technology Management among the pillars of their LSCM framework already presented in the literature review on lean supply chain. Moreover, according to Tan *et al.* (2002), the information technology is monitoring the information flow within the supply chain, and it is also crucial to maintain and control the multi-organization networks in the present scenario (White and Pearson, 2001). Adamides *et al.* (2008) highlighted the relevance of ICTs as facilitator for LSCM development if greater integration with customers and suppliers is allowed.

Many studies presented I4.0 and LSCM as mutually supportive, where LSCM items are believed to be drivers of I4.0, and I4.0 is thought to strengthen lean (Uriarte *et al.*, 2018). This insight is also confirmed by Tortorella and Fettermann (2018) that presented a survey study demonstrating that companies who implemented both lean and I4.0 had achieved higher levels of performance improvement than other companies.

Chiarini *et al.* (2020) in their exploratory research on I4.0 technological developments have highlighted the support that I4.0 can provide to LSCM, confirming the results of previous scholars (Kolberg and Zühle, 2015). In particular, they highlight the impact of I4.0 on quality management practices – particularly the emergence of Quality 4.0 concept. However, they also showed some concern about the implementation of I4.0 technologies in an agile and fast-changing lean environment. They suggested that LSCM should be used to remove the waste, which will be a pre-requisite for I4.0 technologies and thereby prevent the automation of waste.

The issue of waste is addressed also by Alieva and von Haartman (2020) who focused on the negative impact of inefficient usage of data in the decision-making process on manufacturing performance. In fact, these authors claimed that technological solutions created to gain advantages through data analytics also produce a new form of waste, the digital waste. According to them, digital waste should be considered as a new type of Muda and should encourage to give extra attention to data analytics.

According to Ashrafian *et al.* (2019), digital lean manufacturing means the application of digital technology in the forms of e-Kanbans or kaizen in digital collaborative environments in an environment where lean is already implemented. It can enhance the lean principles in the form of digitalization that creates less waste.

In addition, digitalization in communication is very important for all the partners in the supply chain (Ashrafian *et al.*, 2019). In fact, strategic supplier development is trying to encourage and enable the suppliers to develop their lean capabilities. It will help them to improve their performance using lean practices (Sako, 2004). Furthermore, the challenges of competitive rivalry have been considered in the development of lean supplier networks.

The merits of digital technologies for transforming performance are now widely recognized, and a few contributions can also be seen for connection of digital transformation with LSCM principles (Pinho and Mendes, 2017). However, how digitalization can facilitate or hinder the way in which manufacturing firms use and encourage the development of lean practices with their suppliers is still challenging.

Although, despite being complementary initiatives in concept, information technology of I4.0 and LM are not always compatible, companies should try to adopt both in such a way so that sustainable competitiveness can be achieved. The work of Powell (2013) presented ways in which ERP could be used to support LP and pull production, particularly in small- and medium-sized enterprises. In similar fashion, Spenhoff *et al.* (2021) present challenges and opportunities for lean and I4.0 integration from a technical perspective. As such, we suggest that IT should be adopted to solve real, organizational problems – rather than blindly adopting "sexy" new tech. If firms begin by finding and framing problems, then the solution space for lean techniques, and indeed, digital technologies can be much better explored. In this way, the firms can strengthen the benefits obtained with LM and become more digital and sustainable over time (Mo, 2009).

Kolberg and Zühlke (2015) discussed a potential contradiction between lean approach and I4.0 paradigm. The latter stressed the contradiction between lean's focus on people and I4.0's focus on the machine technologies. Also, Ruttimann and Stockli (2016) investigated the different role of employee for the two approaches: while lean has historically valued the human resources for their knowledge, I4.0 considers them as a source of variability and potential trouble-shooters in their work interaction with the work carried out by machines. Instead, few authors emphasized total different perspectives and highlighted the potential job enrichment which I4.0 could lead employees, removing physical activities monotony and more intellectual stimulation (Lagorio *et al.*, 2021).

Many authors stressed the relevance of ICTs as necessary elements for managing LSCM operations by not only simply exchanging information with different actors of the supply chain but also establishing an integration with the external partners (Martínez-Jurado and José Moyano-Fuentes, 2014), such as the identification and optimization of value flows.

However, Ward and Zhou (2006) found that the information technology implementations used for lean functioning along the supply chains resulted in failures because of the poor infrastructure and communication. Also, different types of information technology have different impact on the lean supply chain. Therefore, Hong *et al.* (2010) pointed out the importance of categorization of information technology for the supply chain performance.

Based on the assumption that the existence of companies totally depends on the long-term competitiveness, Ante *et al.* (2018) highlighted the relevance of a robust performance indicators system to obtain excellent results. In this context, I4.0 represents a major opportunity, as on one hand it makes easier to analyse machine data, thereby enhancing quality; on the other hand, it helps to avoid faults in the production process. However, the digital revolution has lot of disadvantages for different industries. In fact, I4.0 requires a high level of system control to provide greater flexibility and competitiveness (Digiesi *et al.*, 2015; Lu, 2017). Then, Ante *et al.* (2018) designed a key performance indicators tree to connect the key performance indicators with the improvement measures in an efficient manner. The KPI tree is divided in a five-level hierarchical structure: the Value Contribution, the Key Performance Result (KPR), the Value stream KPRs, the Monitoring KPRs and the Improvement KPRs. These structures help to monitor I4.0 projects as well as to drive the lean continuous improvement process.

4.3 Operative level

In a different branch of literature about interplay of LSCM and I4.0, authors have focused on specific I4.0 technologies and applications and their links with specific LSCM items.

According to the study of Ramirez-Peña *et al.* (2020), to properly implement I4.0, the supply chain must be lean. In fact, I4.0 technologies can play an important role for different actors of the supply chain.

Simulation is one of them, as highlighted by Rossini and Staudacher (2016) that conducted a study through simulation to understand how lean techniques can improve the performance of supply chain planning. Artificial intelligence has proven to be connected to lean supply chain by Haq and Boddu (2015), who presented a fuzzy logic model incrementing significantly the efficiency of the system.

According to Ahmed *et al.* (2018), Big Data impacts the supply chain management from the environmental point of view. Ramirez-Peña *et al.* (2020) investigated and found out that Autonomous Robots, Additive Manufacturing, Cybersecurity, Cloud Computing and Augmented Reality are the most relevant to improve Green LSCM items.

With a similar perspective, De Giovanni and Cariola (2020) investigated the impact of I4.0 technologies implementation on lean and green practices in supply chains. The authors stated that process innovation via I4.0 technologies does not lead to relevant effect on green performances, while it makes lean practices more effective for improving operational and economic performance.

Roy and Roy (2019) previously described in the literature review on I4.0 about developing their Smart Management System (SMgS). The new technology-based SMgS will help the industries to become more efficient, sustainable, lean, safer and cost effective. In particular, "Lean and Efficient" shows up between the benefits of the system, meaning that SMgS can be used faster with less difficulty compared to lean philosophy but leads to the same results. In fact, the system integration will make the operation lean and efficient by removing wastes (Heikkilä, 2002).

Instead, recently, few authors investigated the evolution of a traditional LSCM elements, such as Kanban, with the introduction of I4.0 technology. In particular, they focused on the implementation of a CPS and on the consequent benefits on the Kanban aiming to automate with limited or no human interaction. The "e-Kanban" is based on a virtual system; the traditional card is evolved in a digital card and is transmitted electronically. The e-Kanban replaces traditional Kanban cards with barcodes; it exploits the technology to improve the movement of material. The e-Kanban reduces human effort for managing the card, and it

provides real-time availability of all relevant Kanban information, directly linked online with the Cloud.

Bevilacqua *et al.* (2019) stated that, with the current manufacturing environment moving towards a 4.0 perspective, there is a growing focus on Big Data Analytics techniques. Indeed, data understanding represents a key aspect for extracting useful knowledge and new information with the aim of taking advantage from them. These authors claimed that like lean manufacturing, manufacturing automation also has the goal of satisfying the customers at the possible minimum cost. Manufacturing automation addresses the removal of nonvalue-added activities and produces predictable quality to achieve these goals. In this scenario, Big Data Analytics methods help to communicate between automation and LP approaches (Bevilacqua *et al.*, 2019).

Vazquez-Martinez *et al.* (2018) presented a new distribution model with the name CloudChain, inspired by LSCM principles and useful for digital products supply chain. In the model, I4.0 technologies create secured containers and operations network configuration that supports transportation activities.

Managers can configure CloudChain as a traditional packing and logistic service but exploiting I4.0 potentials. This distribution model aligns applications of multiple partners involved in the supply chain, both upstream and downstream, and supports the design of value chains with continuous information flows through different cloud storage resources (Vazquez-Martinez *et al.*, 2018).

Earlier Blockchain, the leading technology layer, is used only for financial applications. But since the past few years, the research trend for Blockchain technologies is shifting to other domains; in particular, Perboli *et al.* (2018) have investigated the application of Blockchain in supply chain and logistics.

Ensuring data immutability and public accessibility of data streams make the Blockchain a disruptive innovation. Moreover, the decentralization structure of the Blockchain overcomes the issues that occurred in the centralization structure, including trust issues. However, since its inception, Blockchain has some inherent defects, which need to be addressed before its deployment to other sectors.

Anyhow, the adoption of the Blockchain technology can represent the backbone of a new digital supply chain. Together with the other technological aspects, such as Business Analytics and artificial intelligence, it has contributed to the rapid evolution of logistics in the past decade. Blockchain can be used to overcome the security challenges in Internet of Things. As, as highlighted, Blockchain can break down some barriers of I4.0 technologies along the supply chain, it can favour the integration of the lean philosophy and the I4.0 in the supply chain.

Ge and Jackson (2014) focused on the newest adoption of Big Data to minimize cost in the automotive sector. Authors identified Big Data application beneficial proactively minimizing cost and reactiveness. Moreover, Big Data technologies can enable automotive companies to develop circular economy. Some of the benefits provided by Big Data are also supportive of other existing methodologies used in the automotive engineering domain such as Continuous Product Improvement methodologies. Based on Plan-do-check-act, DMAIC is one such Continuous Product Improvement methodology. The successful usage of Big Data technologies for the DMAIC process suggests that they might work more efficiently in aggregating data, in performing preliminary analysis and increasing the support that DMAIC methodology could give high-level decisions. Therefore, there is room for the complementary usage of lean techniques and Big Data in terms of both cost reduction and optimization of high-level strategies.

Frontoni *et al.* (2019) presented a project related to high-end fashion products company and its international shipment company, a 3PL provider with the aim of satisfying new requirements of higher sales volume and digital channels. In this context, they recognized that having a truly lean enterprise with Just-In-Time (JIT) production along the value stream requires a synchronization of materials and information flows between suppliers, manufacturing and distributors that is hard to find. To achieve this, new emergent I4.0 technologies can help when integrated in a lean environment (Kagermann *et al.*, 2013) because they will enable:

- thorough understanding of the customer demand;
- rapid exchange of the demand data throughout the complex supply chain;
- faster smart factories production with less waste;
- much quicker one-piece flow of customized products;
- potential to radically reduce inventories throughout the supply chain;
- real-time information sharing through coordination in the entire supply chain; and
- radically improvement form of instant just-in-time pull production reducing/eliminating overproduction (Netland, 2015).

Rossini *et al.* (2019) examined the impact of the association between lean adoption and I4.0. Authors highlighted that, of the 16 main I4.0 technologies found in the literature, "big data" and "augmented reality" were the most common. On the other hand, "Collaboration with suppliers/customers through real-time data sharing" seems to be scarcely investigated in the I4.0 literature. This justifies the fact that a lower emphasis is given on the studies related to I4.0 for customers/suppliers relationships (Rossini *et al.*, 2019).

This insight is notably important for the purpose of this analysis. In fact, this study provides some answers to the interrelationships between I4.0 and lean at the operation level of supply chain context.

Haddud and Khare (2019) investigated the impact of digitalization in supply chains and suggest that they may provide benefits in a lean environment. More specifically, the study examined the potential impacts of seven enabling digital technologies (Meier, 2016) on five selected lean operations practices that are JIT, Visual Management, Total Productive Maintenance, Continuous Improvement and Autonomation (failure prevention) and Poka-Yoke (mistake-proofing). The digitalization in supply chains was shown to have an enormous impact on all the five lean operations practices mentioned above.

4.4 Discussion

The SLR clearly shows that LSCM and I4.0 support each other in a synergistical perspective. As I4.0 technologies enhance LSCM practices with the digitalization of traditional LSCM items, LSCM practices work as enablers for the introduction of I4.0 technologies in the supply chain system. This mutual support is perfectly aligned with the most part of recent research about interplay between lean system and I4.0 (Buer *et al.*, 2018; Núñez-Merino *et al.*, 2020).

However, some more insights clearly emerge. In fact, if it is out of discussion that LSCM and I4.0 mutually support each other, then this slightly changes while we split analysis from strategical and operative level.

The operative stream of research mainly focuses on presenting the positive impact of LSCM practices digitalization, or the support that the introduction of I4.0 technologies gives to traditional, and sometime old, LSCM practices. On the other face of the coin, the strategic

stream of research mainly focuses on proposing LSCM paradigm as necessary base for the introduction of I4.0 technologies, because of the goodness of the operations supply chain system and the guideline principles for the correct choice of investments.

With these perspectives, there is a clear trend of what supports and what is supported, as shown in the framework presented Figure 5: at strategic level, LSCM supports I4.0 because it drives I4.0 introduction, but at operative level, I4.0 supports LSCM because it enhances LSCM practices.

This framework adds a piece of knowledge of the literature of the interplay between LSCM and I4.0, but at the same time, it could support in understanding more in general the interplay between lean and I4.0. It is coherent with all the research works that presented a positive correlation between lean and I4.0 (Rossini *et al.*, 2019; Tortorella *et al.*, 2021). It supports the literature of synergic perspective of the two paradigms (Buer *et al.*, 2020), given a clearer positioning of the role of the paradigms. This fact is also supported by the recent literature where specific I4.0 technologies are adapted with lean techniques from the simple 5S to the more sophisticated SPC and Total Productive Maintenance systems (Chiarini and Kumar, 2020; Bittencourt *et al.*, 2021; Ciano *et al.*, 2021; Raji *et al.*, 2021; Spenhoff *et al.*, 2021).

At strategic level, lean supply chain is driving I4.0 by streamlining different entities of supply chain to reduce waste. This is particularly true with regard to the greater horizontal and vertical integration enabled by ICT in I4.0, for example, the Industrial Internet of Things, Digital Twin and advanced IT infrastructures which build on more traditional ERP systems. According to lean, once the value is defined for the customers, the situation is mapped within and across organizations, to find the nonvalue-adding activities that have to be eliminated. The value stream mapping is also supported by I4.0, but importance will be given to digital environment rather than the physical environment.

At the operational level, continuous flow is one of the key lean elements. The production process must maintain the takt time agreed with the customers. Instead of physical entities, I4.0 aims to make the data stream flow according to the real time. Again, we see that digital technologies such as Big Data Analytics and digital twins, as well as tools that support the worker such as augmented reality, virtual reality and smart wearables, will in fact contribute to enhanced lean practices.

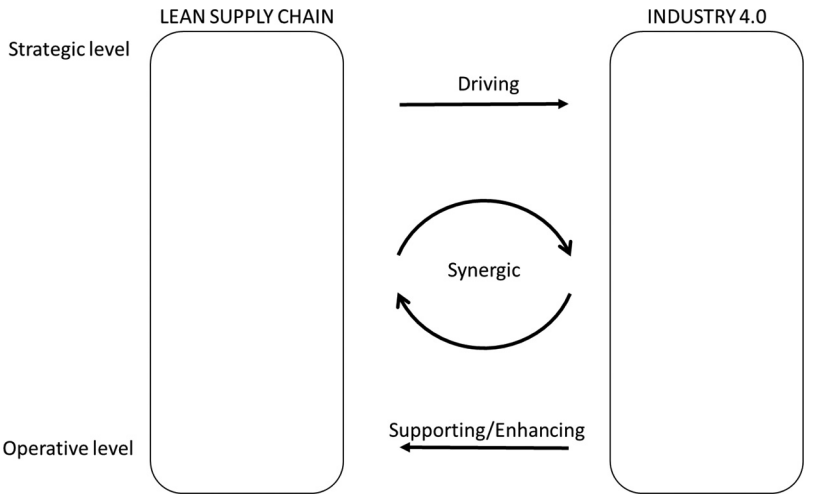

Figure 5.
Relationship between lean supply chain management and Industry 4.0

The final objective of lean is to produce only according to the time and specifications provided by the customers. In addition to the products, I4.0 makes the customers to pull the essential services related to the product. This will help to improve the customer satisfaction. Therefore, the smartification of products using Radio Frequency Identification will provide an evolutionary impact of I4.0 in favour of lean principles.

In the following paragraphs, the theoretical and practical implications of the study are going to be discussed.

4.5 Theoretical implications

To the best of our knowledge, this paper represents the first structured analysis regarding the interrelation between LSCM and I4.0 in the literature. Indeed, currently, in literature, there are several papers focused on this argument, but they are not totally comprehensive. Therefore, this study represents the fundamental starting point for those academicians that want to develop further advanced researches in the field of LSCM and I4.0 environments.

The outcomes achieved through the analysis developed in this paper confirm the role of I4.0 practices in a LSCM environment. At the strategic level, LSCM influences I4.0, whereas I4.0 in the LSCM enhances integration and information flow with customers and suppliers, especially horizontal and vertical integration, CloudChain, Big Data, etc. Additionally, this paper attaches an active role of I4.0 regarding continuous improvement, which is a salient feature of lean. Thus, this confirms the knowledge direction supported by the previous studies by Ward and Zhou (2006) and Adamides *et al.* (2008). Hence, in this paper, the academicians can find the reasoning behind the school of thought in the literature that sustain the existence of a mutual beneficial partnership between LSCM and I4.0. Moreover, each relationship that exists between these two paradigms and the detailed explanation of these connections can by analysed by academicians.

4.6 Practical implications

From a managerial point of view, this study investigates the interactions between LSCM and I4.0 providing a twofold and complete point of view. On one hand, it offers suggestions on the action plan to follow if a firm is already implementing the lean paradigm along the supply chain and wants to begin a new project involving the I4.0; on the other hand, it represents a guideline for companies already adopting I4.0 and seeking to begin to implement also some lean concepts.

The understanding of the implications of I4.0 and its expansion to the supply chain level will help companies to properly adopt the LSCM and the I4.0 paradigms concurrently. The lack of knowledge about the potential benefits or uncertain outcomes of investments has many times prevented many companies to implement both LSCM and I4.0. But the findings from this research are suggesting to concentrate more to develop LSCM given its high importance in driving the improvement in I4.0 paradigm, not only fostering the adoption of other practices but also reducing the barriers of I4.0. Moreover, the framework can act as a decision-making tool for the companies to obtain maximum benefits while implementing LSCM and I4.0 together.

Another practical implication that is worth to point out regards the I4.0 practices and in particular the characteristics of the most relevant practices according to the influence that they can exert on other practices or on the barriers.

Finally, to make I4.0 a success in LSCM internally and externally, the government or the public sector should come forward and take into consideration the findings of this research as a reference to promote a roadmap transition towards the adoption of I4.0 and LSCM.

5. Conclusion

For many years, the philosophy of lean thinking and its principles offered a way for practitioners to build an efficient and competitive production system. Success by success, lean management is slowly becoming relevant for improvement in supply chain, that is, LSCM. On the other hand, I4.0 appeared more recently as a revolution, offering potentials of improvement in quality, flexibility and productivity exploiting the digital technologies. Thus, it comes into doubt about the relationship between the two paradigms, whether they are coherent or they are opposite, they are alternative or complementary. In this context, we provide a framework which suggests the interrelationship and interplay between the two paradigms.

The starting point of the research has been to collect the information about the two paradigms under analysis, LSCM and I4.0 that were available in the current literature. Then, the authors have investigated through a SLR the relationships between the two paradigms.

It is observed from the literature that there is an increasing trend in papers which are discussing about both importance of lean and I4.0. From the literature analysis, it is possible to categorize the interrelationship between LSCM and I4.0 in two directions: strategic and operative levels. At the strategic level, LSCM is driving I4.0 to build sustainability and diverse demand of the customers is thriving for Digital LSCM. At the operative level, I4.0 is supporting LSCM in terms of advanced tools and techniques, like Big Data, Augmented reality, Digital products, CloudChain, Blockchain and additive manufacturing.

The main contributions of this paper are the identification of the research lines developed from the literature analysis; an understanding of the interrelationship between LSCM and I4.0 and an exploration of the most relevant areas where the greatest effort has to be made.

An overview of the limitations of the research and some suggestions about the direction of further studies are presented below.

5.1 Limitations

Considering the interrelations between LSCM and I4.0, the discussed results have contributed to enhance the knowledge in this field both in terms of theoretical and practical implications, as mentioned above. Nevertheless, this paper is not exempt from limitations, as any other research paper.

Starting from the SLR performed, the authors have included only one database, Scopus. According to this, there might be additional knowledge about the relationship between lean supply chain and I4.0. Therefore, considering different databases, such as Google Scholar and Web of Science, or a combination of more than a single database could bring different information.

Furthermore, it has been difficult to detect practitioners that are applying the two industrial paradigms in the boundaries of their firms or, at least, that are experts of both LSCM and I4.0. This aspect demonstrates the novelty of the argument covered with this paper.

5.2 Future scope

Given the novelty of the paper, it could be considered as a preliminary analysis for further advanced researches regarding the relationships between LSCM and I4.0, as highlighted in the theoretical implications. Therefore, the authors have identified several further improvements for future possible complementary studies.

To increase the knowledge in the literature, relevant results could be obtained considering only firms that are currently applying LSCM and want to start the journey with I4.0 or vice versa. In this scenario, a case study could be developed to understand the practical implications of the simultaneous application of both paradigms and to validate the theoretical results obtained.

A possible future step can involve the application of the framework of analysis developed in this paper on specific situations, that is, considering a specific industry, company size or geographical location. Indeed, considering a small- and medium-sized enterprise or a large enterprise could bring different outcomes in the simultaneous adoption of LSCM and I4.0.

Finally, because of the novelty of the argument and the significant importance that this argument is achieving nowadays, these types of analysis would need to be replicated after few years.

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Corresponding author
Matteo Rossini can be contacted at: matteo.rossini@polimi.it