

Are Lean, World Class Manufacturing and Industry 4.0 are related?

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Purpose: The purpose of this research is to present the relationships between the Lean Manufacturing methodology, the World-Class Manufacturing method and the practices of industry 4.0, showing how these actors have been discussed in literature, mainly in terms of gains and improvements for organizations.

Design/methodology/approach: The search strategy was extracting data from Web of Science and Scopus databases using the following keywords: “lean”, “lean production”, “lean manufacturing”, “WCM”, “world-class manufacturing”, “world class business” and “industry 4.0”. No restrictions of subject area were defined. For data analysis, bibliometric analysis was carried out using VOSviewer (version 1.6.9) and NetDraw (version 2.158) software.

Findings: This review reveals that studies related to Industry 4.0, World-Class Manufacturing, lean and Industry 4.0 and structured processes have the highest number of publications. Papers that bring the link between Lean and World-Class Manufacturing, and World-Class Manufacturing and Industry 4.0, are few, and 92% of them were published from 2018 onwards. There are no publications carried out on the three proposed topics as a set: Lean, World-Class Manufacturing and Industry practices 4.0. In the network analyses, three keyword clusters was found: technology, manufacturing and strategy.

Originality: There is no significant evidence in the literature that proves that the intense use of technologies associated with World-Class Manufacturing is related to greater efficiency in processes.

Keywords: Bibliometric analysis, World-Class Manufacturing, Industry 4.0 practices, Operations management.

Paper type: Literature Review

INTRODUCTION

Faced with the fierce competition in the business, organizations - whether manufacturing and/or service - seek alternatives that help them overcome difficulties and continually improve the performance and quality of their processes. Production methods such as World-Class manufacturing, digital transformation based on industry 4.0 practices and the avant-garde Lean methodology production model, that when combined would promote positive results for organizations.

Implementing Lean manufacturing methodologies supports to improve the processes by eliminating non-value-added activities across supply chain and then attaining operational efficiency (Bajad, 2022). On the other hand, the World-Class Manufacturing surged as alternative to Lean and this approach focused mostly on cost and quality, it aims attention at zero-waste and continuous improvement of processes by engaging all employees. So, this helps organizations to achieve a global manufacturing performance, and consequently, remaining competitive (Chiarini and Vagnoni, 2015; Terra, Berssaneti and Quintanilha, 2021). Also, Industry 4.0 allows creating a “interconnected environment” where organizations can answer quickly, in real time and in a more effective way to changes using digital technologies (D’Orazio, Messina and Schiraldi, 2020). Therefore, extracting the best of each practice will help organizations to enable a sustainable manufacturing in order of operational and financial success.

This study aims to explore the relationships between the Lean Manufacturing, the World-Class Manufacturing and industry 4.0 in current literature, by showing how these actors have been discussed in literature, mainly in terms of gains and improvements for organizations. Therefore, the question to be answered by this paper is “are Lean Manufacturing, the World-Class Manufacturing and Industry 4.0 related to each other? What are major achievements from this synergy? And what are strategies to accomplish better results from each themes?”.

To answer the proposed question, this paper conducted a review search, which is structured in four sections. Section 1 briefly introduces the subject that will be discussed. Section 2 describes the research methodology used in this study. Section 3 presents the main findings covered throughout paper analysis. Lastly, Section 4 summarises the discussions and shows limitation of study.

RESEARCH METODOLOGY

This study is a bibliometric review in which has done a quantitative and qualitative analysis of papers. This type of analysis allows the evolution of the theme over the years, as well as highlighting the most cited publications and the main authors. Araújo, 2006 states that the bibliometrics analysis focus on usage of quantitative methods, performing objective estimates about scientific production.

The Scopus database was used as a reference for the collection of bibliometric information, due to the academic relevance that this database has. All papers that proved to be relevant and were found in the Web of Science database were also searched in the Scopus database and inserted in the bibliometric database.

To survey the database, searches were performed using the following search strings: “Lean”, “Lean production”, “Lean manufacturing”, “WCM”, “World-Class manufacturing”, “World Class Business” and “Industry 4.0”. These included terms were searched individually, and combining in pairs and trios, connected by the Boolean connector AND, which resulted in 42 combinations of searches. Only papers published in journals or conference proceedings until February 2022 were considered. No other filters were defined to extract papers. These articles were scanned by titles and abstracts and a final sample of 167 papers were assigned as relevant for the subsequent analyses. The sampling papers were analysed individually, allowing for a more in-depth study on the topic.

The first analyses realized throughout sampling articles were based on Bradford's 1934 dispersion law – which purpose to organize a set of documents in a descending manner, according to the number of citations (Araújo, 2006). It shows that only 29 papers, which have 100 or more citations, represent 90% of the total citations related to sample. These articles are displayed in Table 1. However, it is noteworthy that the analysis of the networks considered the complete sample, that is, 167 papers.

Table 1 – Most sampling articles cited

Paper	Authors	Year	Citation	Source
Dynamic capabilities and strategic management	David J. Teece; Gary Pisano; Amy Shuen	1997	15912	Strategic Management Journal
Dynamic capabilities: What are they?	Kathleen M. Eisenhardt and Jeffrey A. Martin	2000	7881	Strategic Management Journal
Opportunities of Sustainable Manufacturing in Industry 4.0	T. Stock and G. Seliger	2016	865	Procedia CIRP
Generalization in quantitative and qualitative research: Myths and strategies	Denise F. Polit and Cheryl Tatano Beck	2010	554	International Journal of Nursing Studies
Contingency research in operations management practices	Rui Sousa and Christopher A. Voss	2008	554	Journal of Operations Management
The expected contribution of Industry 4.0 technologies for industrial performance	Lucas Santos Dalenogarea, Guilherme Brittes Benitez, Néstor Fabián Ayala and Alejandro Germán Franka	2018	497	International Journal of Production Economics
Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives	Sachin S. Kamble, Angappa Gunasekaran and Shradha A. Gawankara	2018	431	Process Safety and Environmental Protection

The future of manufacturing industry: a strategic roadmap toward Industry 4.0	Morteza Ghobakhloo	2018	422	Journal of Manufacturing Technology Management
Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing	Adam Sanders, Chola Elangeswaran and Jens Wulfsberg	2016	381	Journal of Industrial Engineering and Management
Human resource management and employee well-being: towards a new analytic framework	David E. Guest	2017	348	Human Resource Management Journal
Successful lean implementation: Organizational culture and soft lean practices	Thomas Bortolotti, Stefania Boscari and Pamela Danese	2015	323	International Journal of Production Economics
When titans meet – Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors	Ana Beatriz Lopes de Sousa Jabboura, Charbel Jose Chiappetta Jabboura, Cyril Foropona and Moacir Godinho Filho	2018	313	Technological Forecasting and Social Change
Holistic Approach for Human Resource Management in Industry 4.0	Fabian Hecklaua, Mila Galeitzkea, Sebastian Flachsa and Holger Kohl	2016	295	Procedia CIRP
Ways of constructing research questions: Gap-spotting or problematization?	Jörgen Sandberg and Mats Alvesson	2011	288	Organization
Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production	Selim Erola, Andreas Jägera, Philipp Holda, Karl Otta and Wilfried Sihna	2016	271	Procedia CIRP
Combining qualitative and quantitative research within mixed method research designs: A methodological review	Ulrika O"stlund, Lisa Kidd, Yvonne Wengstro"mc and Neneh Rowa-Dewar	2011	267	International Journal of Nursing Studies
Deploying Fog Computing in Industrial Internet of Things and Industry 4.0	Mohammad Aazam, Sherali Zeadally and Khaled A. Harras	2018	259	IEEE Transactions on Industrial Informatics
Towards Lean Production in Industry 4.0	Beata Mrugalska and Magdalena K. Wyrwicka	2017	242	Procedia Engineering
Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal	Daniel Luiz Mattos Nascimento, Viviam Alencastro, Osvaldo Luiz Gonçalves Quelhas, Rodrigo Goyannes Gusmão Caiado, Jose Arturo Garza-Reyes, Luis	2019	231	Journal of Manufacturing Technology Management

Rocha-Lona and
Guilherme Tortorella,

Research methods and organization studies	Alan Bryman	2009	212	Research Methods and Organization Studies
The service revolution and the transformation of marketing science	Roland T. Rust and Ming-Hui Huang	2014	209	Marketing Science
The impact of big data on world-class sustainable manufacturing	Rameshwar Dubey, Angappa Gunasekaran, Stephen J. Childe, Samuel Fosso Wamba and Thanos Papadopoulos	2016	194	International Journal of Advanced Manufacturing Technology
Industry 4.0 – Are we ready?	Ślusarczyk B.	2018	174	Polish Journal of Management Studies
SDMSim: A manufacturing service supply-demand matching simulator under cloud environment	Fei Tao, Jiangfeng Cheng, Ying Cheng, Shixin Gu, Tianyu Zheng and Hao Yang	2017	156	Robotics and Computer-Integrated Manufacturing
Factors influencing employee perceptions in lean transformations	David Losonci, Krisztina Demeter and Istvan Jenei	2011	135	International Journal of Production Economics
Towards a lean automation interface for workstations	Dennis Kolberg, Joshua Knobloch and Detlef Zühlke	2017	126	International Journal of Production Research
Industry 4.0 and lean management: a proposed integration model and research propositions	Michael Sony	2018	118	Production and Manufacturing Research
Engineering Methods and Tools for Cyber-Physical Automation Systems	Robert Harrison, Daniel Vera and Bilal Ahmad	2016	108	Proceedings of the IEEE

The next analyses were performed into VOSviewer software, version 1.6.9, in order to evaluate the analysis of contents from relationship networks built between articles into sample.

BIBLIOMETRIC ANALYSIS

Firstly, analysing the sample of 167 papers, it shows that no journal stands out with many publications. Thus, it means that relationship between the main three topics of study – World-Class Manufacturing, Lean Manufacturing and Industry 4.0 – has not yet been explored in depth. Furthermore, it highlights the existing gap in literature, which needs to be exploited by future studies.

Consecutively, it was performance an assessment of 167 papers' content in order to raise the most themes mentioned by them. In Figure 1, these main themes are summarized and it considers evolution of a subject throughout years and representativeness of each subject.

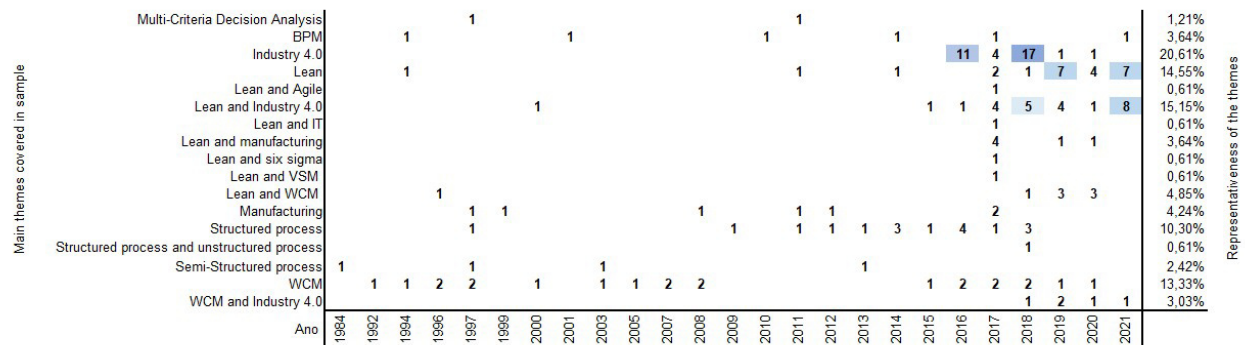


Figure 1 – Themes covered by papers throughout years (1984-2021).

This Figure 1 shows that Industry 4.0 was the most theme discussed by authors into 34 papers, following by Lean and Industry 4.0 (25 papers), Lean (24 papers) and WCM (22 papers). In other words, the relationship between Lean and Industry 4.0 practices has been largely explored in literature. Whereas papers that brought out the discussion of Lean and WCM (8 papers) and Industry 4.0 and WCM (5 papers) were not in large majority.

About the evolution of papers over the years, Figure 2 exhibits this trend. This graphic shows that number of publications had increased until 2018, with the main peak. From then on, there was a drop in the number of papers in the last 3 years, but starting to recover in 2021. In addition, it was observed that between 2016 and 2021 is the gold era regarding this theme if compared with previous years, due to aggressive competition imposed to organization, which has to look for alternatives such as World-Class Manufacturing, Industry 4.0 and Lean methodology to overcome those new challenges.

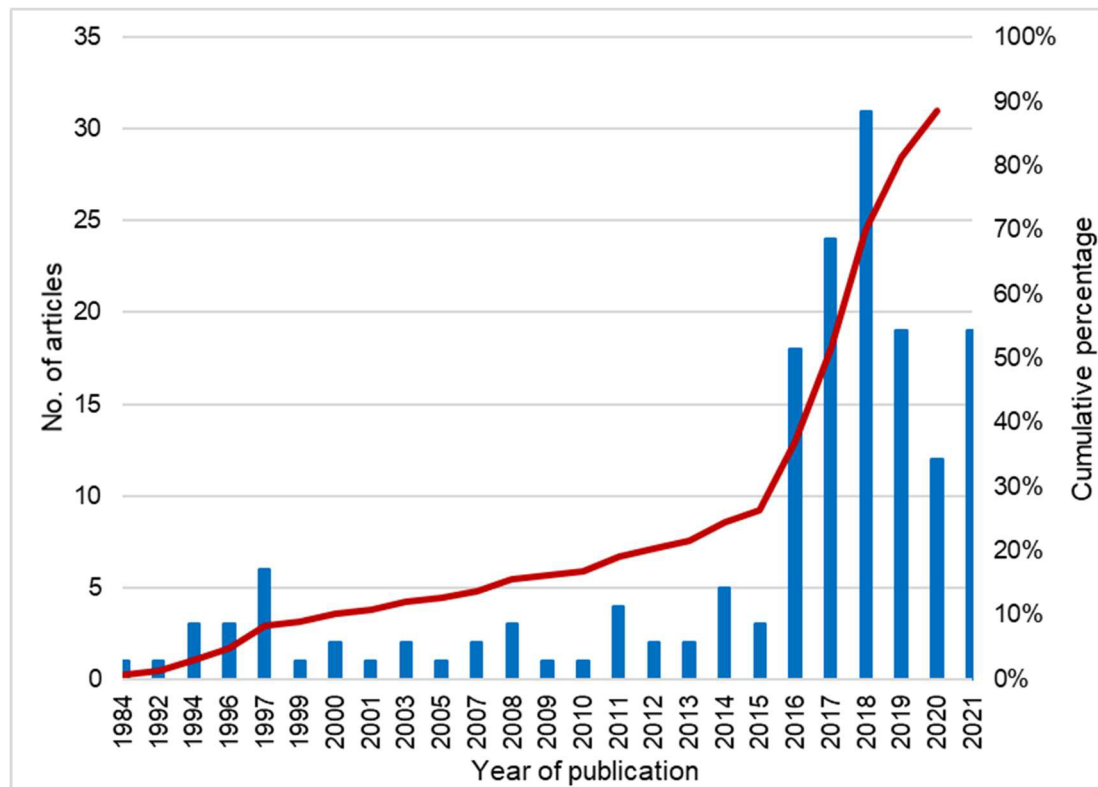


Figure 2 – Evolution of papers over years.

This study also examined the most cited papers of sample. The paper with the most citations was “Dynamic capabilities and strategic management” (Teece et al., 1997). It had 15,1912 citations, which corresponds to 46.6% of total number of citations in sample. This paper discussed about dynamic capabilities, i.e., continuous improvement, and how they influence the manufacturing processes and service environment. As WCM is directly influenced by continuous improvement processes, this paper has many ramifications and citations, thus it has been a relevant reference for the study of Lean methodologies and improvement processes.

The second most cited paper was “Dynamic capabilities: What are they?” (Eisenhardt and Martin, 2000). This paper has at least half of number of citations of previous most cited paper, with 7,881 which represents 23.1% of total number of citations. In this paper, the authors complemented the theories of Teece et al. (1997) and enlarged a greater understanding of the process of continuous improvement in manufacturing and service processes. In addition, they introduced – albeit superficially – about the work and human relationships in this process, triggering a set of factors that are decisive for the advancement of Lean methodologies and the WCM method in manufacturing processes.

The first and second papers, together, corresponded to 69.6% of total of sampling citation. The remaining 167 papers correspond to 30,4% of total citations. The third paper most cited was

“Opportunities of Sustainable Manufacturing in Industry 4.0” (Stock and Seliger, 2016), and it had 805 citations (2.5%).

Other analysis was about keywords used by author in sampling papers. It is important to highlight that the keywords lean management and lean were unified, throughout the paper, in the word lean, to simplify the analysis.

Figure 3 shows the occurrence of keywords. Most keywords emphasized by papers are “Lean” (45 papers), “Industry 4.0” (35 papers), “Internet of Things” (21 papers), WCM (20 papers). The other ones have less than 20 references. Based on most cited keywords, it observed that they are closed related with the theme discussed by this study – relationship between WCM, Industry 4.0 practices and Lean.

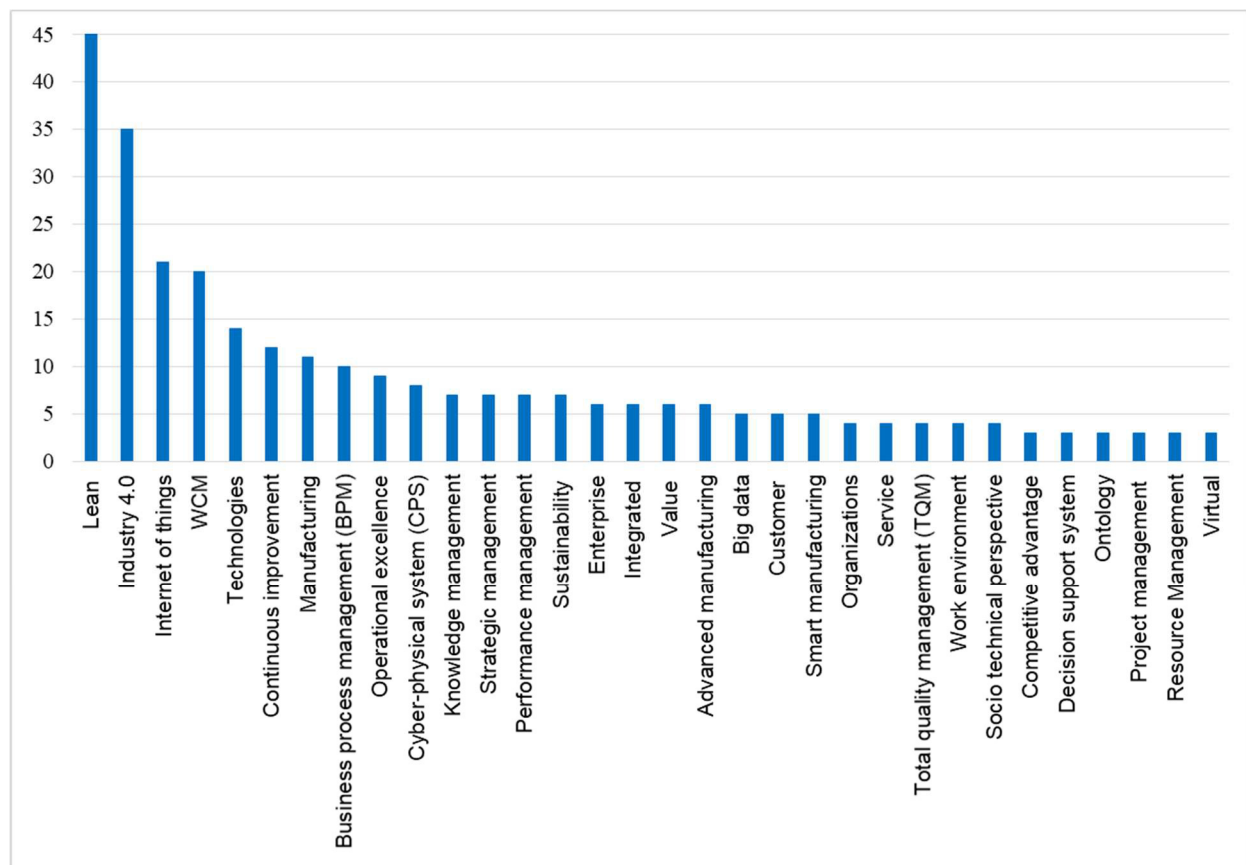


Figure 3 – Keywords occurrence.

NETWORKING ANALYSIS

The next analysis realized were networking analysis throughout co-occurrence of authors’ keywords. The authors’ keywords network map shows the relationship between the words used to search for papers and the frequency with which they occur. The proposed criterion for cutting was five occurrences, it means that keywords cited five times or more were considered to build the map.

Additionally, keywords that were not related to the study were excluded from the analysis. Figure 4 illustrates three well-defined cores that were formed based on relationship between co-occurrence of keywords; they are: i) concepts of manufacturing and production processes (orange); ii) lean and improvement processes (green) and iii) Industry 4.0 practices and technological processes (blue). Each of these topics will be discussed in the next paragraphs.

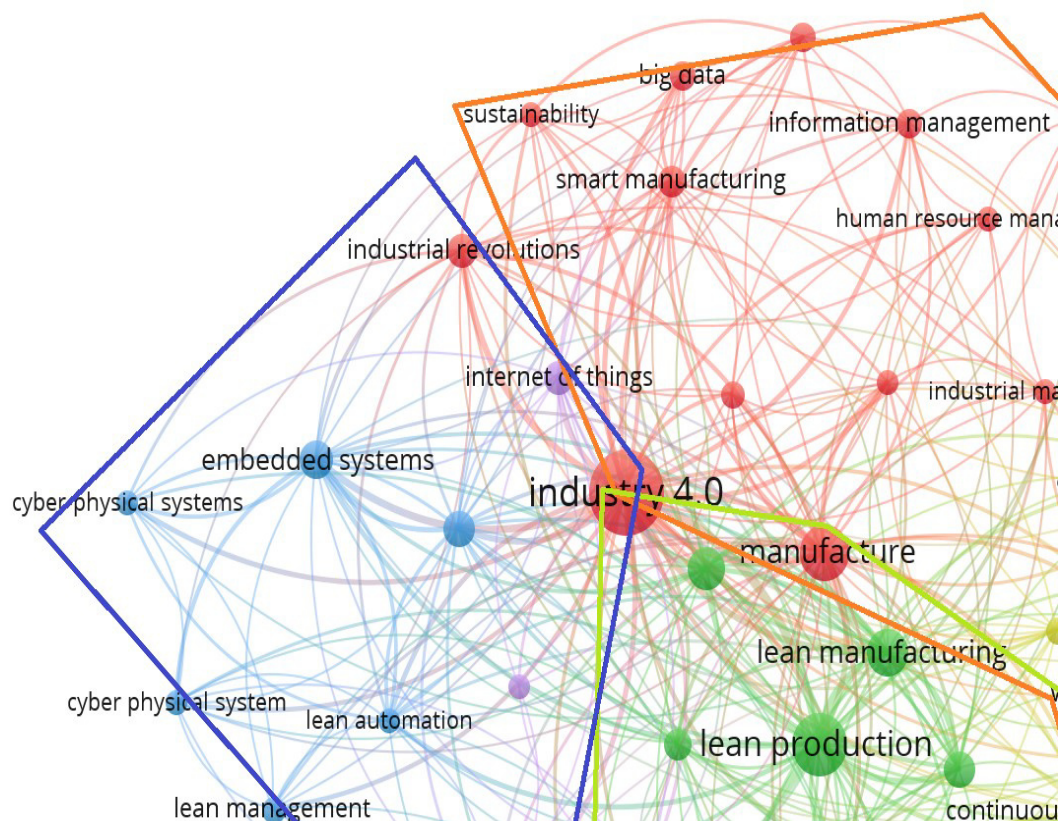


Figure 4 – Occurrence of Keywords network map.

Concepts of manufacturing and production processes (orange ring): World-Class Manufacturing also points in the direction of inefficiencies and reduction waste. Lee and Oakes (1996) declared that a new approach to manufacturing can support in waste removal and improvements of quality of products and services. This leads to a culture of quality that generates a proactive approach, with the involvement of team members, whose objective is to improve productivity, facilitate innovation processes and encourage workers to engage in self-development (Mróz, 2018). For this to run steadily, it is important to integrate available human and material resources (Mendes and Mattos, 2017), creating a sustainable cycle. Thus, the implementation of an organizational environment that facilitates the transition of organizations to world-class performance (Satolo et al., 2018), associated with a strong digital component, generating opportunities to innovate in products, processes and goals of innovation (Furlan and Vinelli, 2018).

Lean and improvement processes (green ring): The keyword “Lean” has a strong relationship with manufacturing processes. The connections between Lean and the concepts of operational excellence led to continuous improvement, whose objective has been focused on elimination of wastes. Barker (1994) stated that waste can be considered as a potential opportunity to be explored, since it exists throughout the value addition chain, thus eliminating those inefficiencies could help to greatly improve the performance of the organization. Organizations have increasingly understood that the continuous assessment of organizational performance is necessary to remain competitive (Sangwa and Sangwan, 2018), reducing economic vulnerability, making organizations more resilient in their operations, in such a way that the relevant strategies to production efficiency and capacity are fundamental (Lotfi and Saghiri, 2018). This makes current business models require a modeling of their processes for later use of technologies (Azevedo, 2017). However, it requires more robust projects with continuous improvement practices that are constantly used, since the technological model of Industry 4.0 practices requires constant updates (Rossini et al., 2019), both in manufacturing processes and associated services.

Industry 4.0 practices and technological processes (blue ring): The relationship between Lean and Industry 4.0 practices is aimed at improving productivity and flexibility (Buer et al., 2018; Sordan et al., 2021), reducing complexity and focusing on tasks that add value (Kolberg et al., 2018). The challenge is to allow a similar level of evolution, both at the operational and managerial levels, aligned with the possibility of an integrated evolution (Villalba-diez et al., 2018). Ciano et al. (2021) proposed a framework to help organizations to reach a better synergy between those two practices in order to improve their operations by showing many tools that if works together can promote an effective gain, like autonomous robots and Internet of Things working with SMED and standardised work. In practice, the stimulus to the continuous use of technologies associated with Lean is in the integration between the technologies and the expected results for the investment made, i.e., it is in allowing greater flexibility to the processes (Ciano et al., 2021). However, the connections between productive efficiency, represented here by WCM and have a secondary connection with technological processes, as shown in Figure 5.

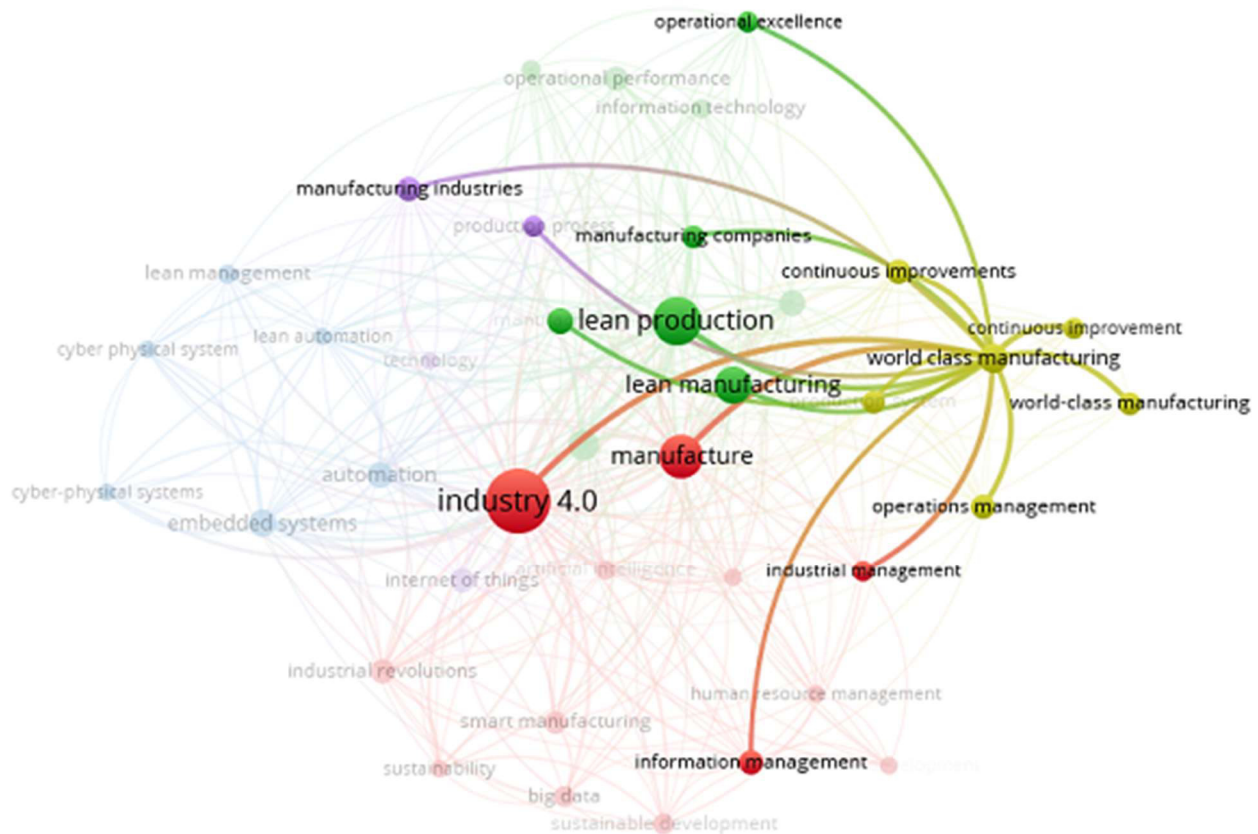


Figure 5 – World-Class manufacturing keywords occurrences network map.

Oliveira et al. (2016) stated that organizations that want to build long-term competitive advantages seek to develop World-Class Manufacturing practices and, at the same time, remain flexible enough to maintain themselves. Thus, the need for integration between the efficiency shown by the WCM and the flexibility in the processes, shown by the practices of Industry 4.0 practices, stands out.

Another relevant keyword was “information management”, showing the need to maintain reliable databases in manufacturing processes: without information there is no sustainable improvement process.

Finally, this study examines the relationship of co-authorship. The formation of the most cited authors' network had been built considering those who were cited at least hundred times. Figure 6 shows the network of relationships among the major cited authors of sample. However, the analysis of the paper considers the most cited authors, as this is the list available in the network analysis program.

Teece et al. (1997) were the most cited authors in the database and they debated about dynamic capabilities, strategies and how they influence processes. The same authors argued that the strategic theory is full of analyses that support and safeguard the combinations between technological competences, product and process development, technology transfer, intellectual property,

manufacturing and human resources and are linked to a greater competitive advantage, supported by in different processes.

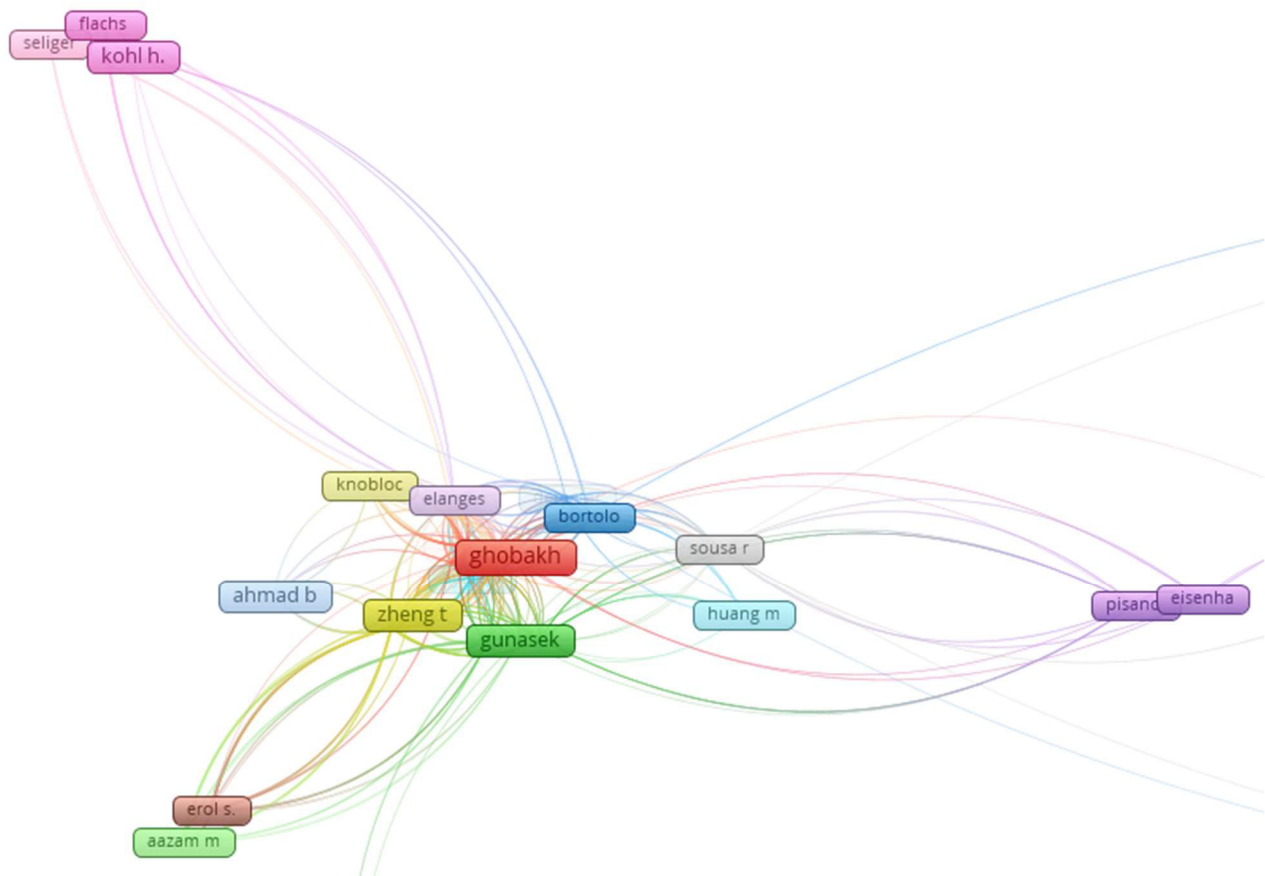


Figure 6 – Most cited author's network.

Eisenhardt and Martin (2000) also had a high number of citations. They asserted that the organizational processes associated with the organizations' strategy are capable of creating value in markets with dynamic characteristics, where the structure of the industry is undefined. They claimed that processes are generally simple, experimental and unstable and that they rely on new knowledge created quickly, iteratively, to produce adaptable results. This makes manufacturing processes more flexible and reconfigurable, as well as requiring a dynamic value stream mapping (Tran et al., 2021).

Eisenhardt and Martin (2000) had worked on dynamic capabilities, processes and strategy, which shows their strong connection with the topics addressed and may explain the high number of citations. Considering the strategic factor, Industry 4.0 practices play an important role. Stock and Seliger (2016) stated that creating value in an organization that adopts the principles of Industry 4.0 practices offers immense opportunities for sustainable manufacturing, interconnecting the entire value chain, offering new opportunities for carrying out continuous development cycles.

It is noted that the dynamic approaches have a strong relationship with the different topics covered. From these perspectives - strategy and technological competencies, value creation and link between manufacturing and strategic management, there is a direction towards more sustainable and efficient

manufacturing process practices in decision making (Dubey et al., 2016). The entire integration of the different actors needs to be recreated, which implies in a horizontal and vertical integration, from end to end (Chiarini and Kumar, 2021).

The practices of Industry 4.0, Lean methodology and World-Class Manufacturing method fit together. Industry 4.0 practices correspond to technological direction and rapid process development, Lean methodology corresponds to the effectiveness and efficiency of these processes and World-Class Manufacturing method directs to the strategic aspect, with a strong application of a tool orientated to human side, such as Kaizen, which is seen as more focused on people (Anosike et al., 2021). Plus, Tran, Ruppert and Abonyi (2021) added that those practices beyond supporting the system optimization, they are a “stress-free” way to manage, so managers can focus on other activities to continuous improvement of systems.

Thus, horizontal integration occurs, characterized by a value creation network, providing a new and innovative business environment and, therefore, leading to a change in markets (Stock and Seliger, 2016), which is also capable of empowering organizations. faster and more flexible responses, considering the complexity of the processes (Mrugalska and Wyrwicka, 2017).

Ghobakhloo (2018) affirm that a blend of ideas, since it encompasses the practices of Industry 4.0 to an integrative system of value creation, composed of process design principles and technological trends. Vlachos et al. (2021) corroborated to this analysis, as they claimed that Lean, associated with processes, has significant managerial implications, helping companies to integrate and focus on people, with the help of technologies that promote process efficiency.

Bortolotti et al. (2015) highlighted about complexity of using this innovative model for workers who have little aptitude for multidisciplinary work. Kolberg et al. (2017) pointed to the growth in the use of Lean associated with technological systems and the need for workers to perform different tasks. However, the effects of technology are only developed at a high level, without a deep and comprehensive analysis (Ciano et al., 2021).

Sanders et al. (2016) addressed the Lean environment in Industry 4.0 practices and the reluctance in the implementation of this new way of producing. In fact, companies are still looking for technological solutions to reduce costs and delivery times, especially if the benefits perceived by companies are related to efficiency gains; however, when companies put these technologies into practice, competence is consistently considered the most significant barrier (Zheng et al., 2021).

Organizations have used Lean concepts to optimize production and eliminate waste (Amjad et al., 2021). Improvements in the flow of information, decision making and productivity are highlighted, combining different actors (Anosike et al., 2021), one of the fundamental principles of the World-

Class Manufacturing. The complexity of the topic involves different scenarios, since it includes not only Lean, WCM and Industry 4.0 practices, but the strategic vision of the business and the way in which work relationships are taking place.

Ejsmont et al. (2020) stated that companies, in order to be competitive, constantly seek continuous increase in productivity, quality and level of services. With the development of the Industry 4.0 concept, organizations are more confident about the new advantages that such technologies allow for systems integration. Still, Sousa and Voss (2008) highlighted this complexity when considering operations management applied to activities that characterize the emergence of a new type of organization, which stands out in the environment in which it is inserted. This idea has a strong bearing on WCM, as it promises to make manufacturing processes more efficient (Santos et al., 2021). Moreover, the powerful combination of different digital principles and technologies accelerates waste identification and mitigation faster than traditional methods, causing solutions to be incorporated by all involved (Tran et al., 2021).

CRITICAL ANALYSIS

In the literature presented, the WCM brings together a set of manufacturing concepts that is related to different quality methods, whose objective is focused in the continuous improvement processes. The method points to the use of best management practices, with emphasis on cost analysis, integration of people, flexibility in processes, focus on efficiency, and technological innovation. However, reliability for Industry 4.0 practices still generate insecurity within organizations, since they are not fully developed and consolidate theme.

In order to help this organizational structure to work properly, the continued development of human resources is necessary, often neglected by top management, and the respective compensation for the suggested and implemented improvements, indicating an increase in the ability to apply tools aimed at continuous improvement, in search of best practices.

Organizations that are most successful with the application of WCM and lean are those that make extensive use of practices that connect people, such as training workers to multitask, partnering within supply chain, customer involvement, and continuous improvement, with technical and analytical tools.

The synergy between WCM and lean, as a relevant element for the reduction of waste, the dissemination of a culture of continuous improvement and the practices of Industry 4.0, as a driving force for the implementation of new technologies in the production process, point to greater

transparency in indicators, resulting in organizations that guide their organizational models towards medium and long-term strategic management.

Additionally, about the technological aspects, this integration occurs in a more accentuated and dynamic way, strengthening the connections between WCM, lean and Industry 4.0 practices. These both actors are often used in same place. The difference is that the “consumption” of information becomes more dynamic and assertive, so that communication flows turn heavily intensive.

This integration can provide significant gains in production systems, attracting customers based on strategic issues, such as the high speed in providing a product, service or production on demand. In a more complex and innovative context, they are able to act and modify the environment that they are inserted, reacting to different situations and preventing the factory environment from bad weather or problems arising from a failed process.

However, despite the improvement in processes being increasingly apparent, there is still no significant evidence in the literature that proves that the intense use of technologies, associated with WCM, relate to a higher quality in the products and services offered to customers.

CONCLUSIONS

The present paper carried out an analysis about the relationship between Lean Manufacturing, WCM and Industry 4.0 practices in order to evaluate the main discussion and gains from this synergy. The literature brings together a set of manufacturing concepts that directs to relationships between different quality methods, whose objective is focused and continuous improvement in processes. These concepts pointed to the use of best management practices, with emphasis on the integration of people, flexibility in processes and technological innovation. The use of these techniques focuses on efficiency, through the reduction of operating costs and waste, with the same focus as Lean.

Industry 4.0 practices was the most theme discussed by authors, following by “Lean and Industry 4.0”, “Lean” and “WCM”; major keywords highlighted into papers are “Lean”, “Industry 4.0”, “Internet of Things”, WCM; and it seems to be a “golden era” from 2015 until now in discussing about methodologies that support the continuous improvement of organizations.

In addition, Figure 4 identified three keyword clusters: concepts of manufacturing and production processes, lean and improvement processes and Industry 4.0 practices and technological processes.

Concepts of manufacturing and production processes represents the relationships between production processes and the methods and practices used in manufacturing in search of better performance and efficiency. In this cluster, the relationships with the management of operations and the proximity of the best results with the use and application of WCM stand out. Figure 5 asserts this relationship and

shows the strong influence of lean methodology on the WCM method, being the main vector in its development.

Industry 4.0 practices and technological processes represents themes related to technological innovations. This cluster shows the development of manufacturing through the use and integration of technologies and how they relate to the lean methodology, under the strong influence of continuous improvement processes. The integration with the WCM method and trends in the modernization of manufacturing and associated services stand out.

Lean and improvement processes represent the objectives for the application and use of WCM method and Lean methodology from the point of view of Industry 4.0 practices as a strategic factor for organizations. World-Class Manufacturing stands out with a strong interaction with Lean, but still maintains weak relationships with technology and Industry 4.0 practices, which demonstrates that there is a gap to be developed.

In the network of most cited authors, Teece et al. (1997) and Eisenhardt and Martin (2000) present a large number of citations, thus they are the main references in studies involving continuous improvement. However, Ghobakhloo (2018), Figure 6, is relevant to the network since he assumes a role of linking different topics, and seeking to unify ideas around continuous improvement and technologies used.

While Teece et al. (1997) and Eisenhardt and Martin (2000) focused on developing theory on the subject, Ghobakhloo (2018) sought to unify the concepts more comprehensively, reaching different areas of knowledge. This paper shows a positive evolution as it begins the exploration between Industry 4.0 practices with manufacturing processes. However, it does not introduce into the WCM method.

Kassem and Staudacher (2021) highlighted the central role of competencies, the need for a specialized team to monitor the implementation of improvements, as well as a better formulation of the tool offerings to implement them.

However, the database papers do not show the connection between Lean, WCM and Industry 4.0 practices, making only occasional analysis, without investigate into the subject. Also, considering the WCM vector, no author scales its extent.

Additionally, studies could confirm that WCM does not require excess labor demand. It simply changes the way processes run, making them more efficient. As a result, the World-Class Manufacturing seeks to promote and disseminate the culture of continuous improvement, base of Lean, through the different operations developed by the organization, whose focus is directed towards the strategic vision and advanced technologies, based on Industry 4.0 practices.

This paper has some limitations: i) highlights the combination of string used to search the documents, and it was limited to two databases; ii) the subjectivity of each author in evaluating the sampling papers and reach a consensus; iii) number of papers studied considering the number of papers published, mainly about lean; iv) process ~~first method~~ to analyse the papers, throughout reading only the abstract and title as first filter.

Future research can explore the results raised in this study; considering another method to analyse the networks and papers. Even though presence of those limitations, they do not invalidate the findings of paper. This paper is relevant to operation management literature due to increase interesting of continuous improvement of organizations to remain competitive in market.

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