sciendo

ISMSME International Society for Manufacturing, Service and Management Engineering

received: 10 August 2021
accepted: 1 December 2021

pages: 115-130

Challenges and barriers to connecting World Class Manufacturing and continuous improvement processes to Industry 4.0 paradigms

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ABSTRACT
This paper exposes the difficulties in integrating "Industry 4.0 Practices" and "World-Class Manufacturing" due to the rapid expansion of production systems and the increasingly complex data monitoring. The applied methodology was to study multiple cases with the aid of a semi-structured questionnaire. The analysis comprised responses of 15 large companies with different expertise from five countries and three continents. The results show that when a company's strategy is linked to Industry 4.0 practices and the World-Class Manufacturing method, they boost productivity by monitoring the shop floor, applying analytical tools, and spreading the organisational culture aimed at improving processes. The results also indicate that human resources are essential in this integration. The conclusion indicates robust barriers to the increasing progress of these procedures, such as the costs associated with the use of technologies, the lack of knowledge of the applied methods and tools, the lack of trained and qualified human resources, and the resistance of people to the use and application of the newly adopted practices. The continuous improvement practices do not keep up with the speed of development that the Industry 4.0 practices propose, requiring studies directed to "World-Class Manufacturing" and "Industry 4.0 practices". Although there is a coexistence of improvement and innovation in world-class manufacturers, the literature has not yet provided a complete understanding of how this coexistence can be achieved at the manufacturing level. Therefore, the paper presents the main actions to overcome these barriers.

KEY WORDS
Industry 4.0, World-Class Manufacturing (WCM), continuous improvement

10.2478/emj-2021-0035

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Introduction

In the last ten years, companies have been led to reorganising their productive arrangements, considering the technological development associated with their processes, directing them towards the implementation of technologies that bring greater efficiency as a result. The paper studies this technological advance in productive means and the barriers encountered to implementing the World Class Manufacturing (WCM) method in an environment that uses

Terra, J. D. R., Berssaneti, F. T., & Quintanilha, J. A. (2021). Challenges and barriers to connecting World Class Manufacturing and continuous improvement processes to Industry 4.0 paradigms. *Engineering Management in Production and Services*, *13*(4), 115-130. doi: 10.2478/emj-2021-0035

Industry 4.0 practices. The WCM method consists of a set of tools and procedures to improve the operational performance of companies, making them more efficient and integrating the entire corporation, from operational to strategic management.

The core of Industry 4.0 practices lies in increasing production efficiency and making companies competitive at a global level through the massive use of digital technologies.

Carefully identified operational barriers allow adding value to products and services, establishing the necessary conditions for the encouragement, advancement, and definition of new technologies, as well as adopting decentralised policies that help the preparation and composition of organisational systems in this new reality.

This new organisational composition leads to questions regarding different continuous development forms, maximising organisational possibilities and results, with the commitment to expanding knowledge and the need for staff corresponding to the needs of increasingly structural companies.

Considering this new organisational arrangement — continuous process improvement through the application of the WCM method and Industry 4.0 practices — this paper seeks to answer the following question: "What are the challenges in the management of operations and performance of companies, when considering the necessary adaptations in the WCM method for transformations that Industry 4.0 practices propose?"

Apart from the Introduction, the paper contains four parts: Literature Review, Research Methods, Discussion of the Results, and Conclusions.

1. Literature review

According to Paranitharan et al. (2017), integrated manufacturing systems are one of the main operational strategies adopted by companies to overcome the uncertainties of Industry 4.0 practices. Ebrahimi, Baboli and Rother (2019) affirmed that strategy forces companies to transform their production systems to be much more flexible and agile. Traditional mass production systems must evolve towards on-demand mass production to achieve this objective.

The association between World-Class Manufacturing (WCM) and Industry 4.0 Industry practices fits this profile. While WCM values production efficiency, Industry 4.0 practices allow for a rapid expansion of production systems.

There are some important differences between the principles of WCM and Industry 4.0. While WCM is mainly based on continuous improvement and cost reduction, Industry 4.0 is based on using all accessible information and data of systems and making decentralised decisions, both involving a global vision and a systemic approach to global profit optimisation (Ebrahimi, Baboli, & Rother, 2019).

In this context, the connection between WCM and Industry 4.0 practices paradigm should transform the factory into a fully interconnected environment, where decisions can be quickly made based on reliable, accurate, precise, and real-time data (D'Orazio, Messina, & Schiraldi, 2020).

Besides, other challenges must be overcome: the barriers to continuous assessment of organisational performance (Sangwa & Sangwan, 2018), the resilience of companies to unforeseen changes in business environments (Lotfi & Saghiri, 2018), the use of technologies, and the ability to assimilate new knowledge quickly (Sartal et al., 2017), and the variety and speed of data that drives companies to adopt and improve data analysis functions to improve current processes and their performance (Dubey et al., 2016).

WCM assists with these challenges. It consists of a set of tools and procedures aimed at improving the operational performance of companies. The method is applied from top to down, i.e., from strategic to operational management, integrating the entire corporation. Being an organisation classified as WCM means not accepting to be the second-best (Nagaprasad & Yogesha, 2008). It means being more competitive in price, quality and offering a set of associated products and services.

The objective of the method is to establish strategies capable of facing the competitiveness between companies, mainly in the global scenario (Khan et al., 2007). As a result, there is a greater direction for the use of best management practices. The cost analysis, the integration of people, the flexibility in processes, and technological innovation stand out, corroborating Ebrahimi, Baboli and Rother (2019).

Furlan and Vinelli (2018) stated that even if world-class manufacturers attested to the coexistence of improvement and innovation, the literature had not yet provided an understanding of how this coexistence could be achieved at the manufacturing level. No definitions exist for the minimum efficiency parameters, and the results have not yet been demonstrated satisfactorily, showing a gap in this area. To date, the scientific literature does not include studies specifi-

cally focused on the relationship between Industry 4.0 practices and WCM. On the other hand, numerous papers and isolated case reports are available on applying Industry 4.0 practices in different industrial contexts (D'Orazio, Messina, & Schiraldi, 2020). However, this does not help analyse differences and similarities between Industry 4.0 practices and WCM.

Current continuous improvement practices do not have the speed of this new technological standard (Rossini et al., 2019), and there is not much research regarding the holistic application of Industry 4.0 concepts towards continuous improvement, which clarifies the potential for improving its effectiveness (Peças et al., 2021). Therefore, this can lead to divergences during the transition from the current model to the proposed technological model.

The Industry 4.0 practices comprise a variety of technologies that allow the development and integration of different areas (Kamble et al., 2018) and also constitutes an important opportunity for the improvement of industrial management (Nota, Peluso, & Lazo, 2021). However, the transition from the traditional industry, with little or no technologies introduced in its processes, to the Industry 4.0 practices requires a complete review of operations (Ghobakhloo, 2018). This new industrial paradigm changes the roles of human resources and machines in production processes, restructuring the very essence of the workforce concept (Terziyan et al., 2018).

Workforce routines need to be designed to guarantee the quality of processes. The information must be incorporated into products and services in an organised manner and reflect how automation helps human work (Sartal & Vázquez, 2017). Besides, the change in the mindset of the workforce is identified as a contribution to the adoption of Industry 4.0 practices (Maisiri & Van Dyk, 2021). Industry 4.0 practices are more than technology-oriented policies, making human resources stand out (Schallock et al., 2018). The demands and challenges point out the importance of qualifying and developing human resources.

Papetti et al. (2021) affirm that integration of human factors in the (re)design of production systems is essential. Kazancoglu and Ozkan-Ozen (2018) assert that some criteria are important in the workforce, considering the implementation of Industry 4.0 practices. The ability to deal with complexity and problem solving, thinking about overlapping processes and flexibility to adapt new roles to work environments, organisational and procedural understanding, and the ability to interact with modern interfaces stand out, with collaborative technology and human approach (Turner et al., 2021; Gajdzik et al., 2021; Kohnová et al., 2019).

In this new model, it becomes important to invest in organisational knowledge and learning from a strategic perspective (Synnes & Welo, 2016). Dalenogare et al. (2018) argued that companies wanting to start their journey towards Industry 4.0 practices must first think about their strategic objectives before implementing any technology.

The identification of relevant strategies leads to a structure that accommodates skills and technology, governance, and collaborative practices in different environments (Hamersly & Land, 2015). Competitive manufacturing, which delights customers, requires not only the development of WCM but also the continuous evolution and improvement of processes (Peças et al., 2021; Arms et al., 1994).

The real incentive to implement Industry 4.0 practices is to maintain a competitive advantage (Davies et al., 2017). Although this model is considered a new industrial stage, where the integration of processes and connectivity with services can help companies achieve higher performance, little is known about how to do this (Dalenogare et al., 2018).

Buer, Strandhagen and Chan (2018) affirmed that ideas related to Industry 4.0 and lean practices reveal different gaps that guided this paper. The authors highlighted the paradox between continuous improvement, which considers the employee possibilities to get involved in projects for continuous improvement and optimised processes, leading to a decrease in low-skilled work and an increase in high-skilled activities, and making the human aspect the biggest challenge to achieving excellence in this new industrial age (Ebrahimi, Baboli, & Rother, 2019; Tiep et al., 2020).

However, continuous improvement processes are in an incipient state concerning the implementation of Industry 4.0 practices, requiring advanced studies that relate them to WCM (Fettermann et al., 2018). Besides, the inexistence of an effective information system and its documentation management leads to not using knowledge acquired in previous continuous improvement initiatives, which might result in reworks in finding root causes (Peças et al., 2021).

It is necessary to consider behavioural and technological aspects and skills that include greater flexibility, human and material resources to increase productivity (Luthra & Mangla, 2018), all playing a vital role in this phase in the manufacturing and services.

Thus, this paper aims to contribute with answers to the presented gaps by identifying barriers that

impact the processes, operations management, and organisational performance when considering the integration between WCM and Industry 4.0 practices.

2. Research methods

Yin (2017) stated that a case study is an empirical investigation examining a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and the context are defined indistinctly.

In this perspective, this study evaluated multiple cases transversally. All corporations were large, with more than 1000 employees. The sample included 15 companies with different expertise from five countries and three different continents: South Africa, Argentina, Brazil, and the United States in the Americas, and France in Europe.

The study proposal was based on the literature review, which indicated gaps that gave rise to the research question. In addition, the literature review also provided the necessary subterfuges to design the survey. The research flowchart is shown in Fig. 1.

The collection of information from the companies took place through a semi-structured questionnaire, shown in the appendix. The questionnaires were sent, by email, to employees directly linked to the production process. This guaranteed the confidentiality of the source and the protection of the answers from the

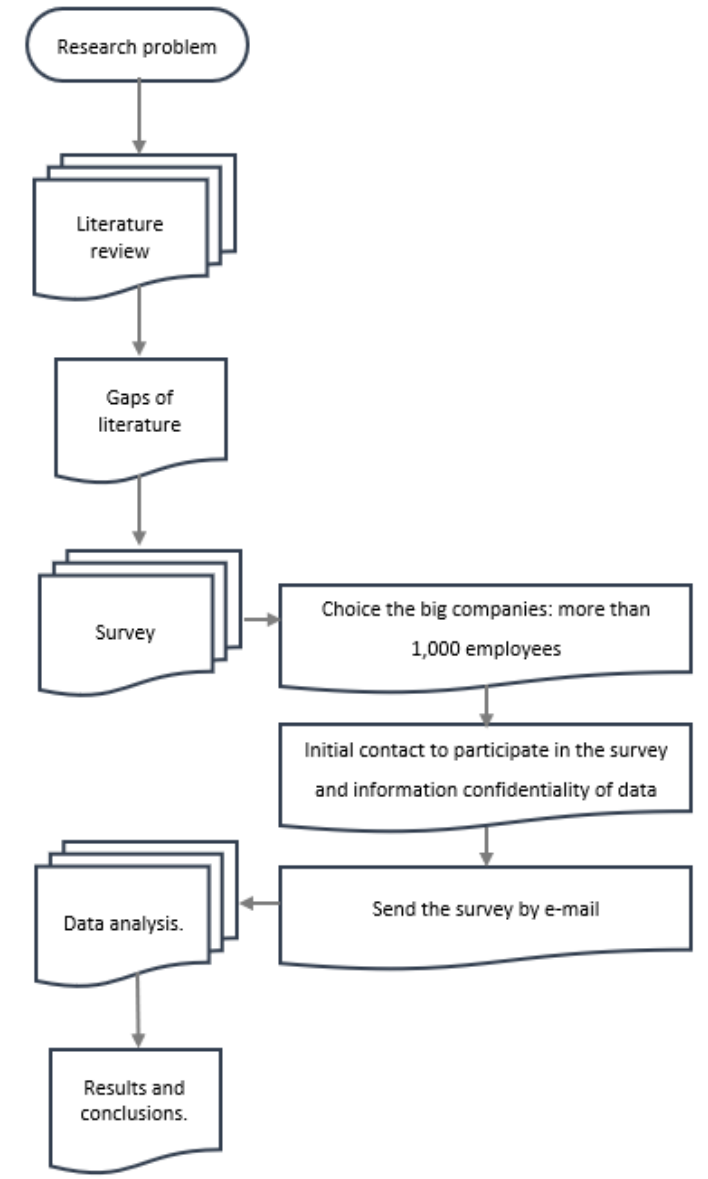

Fig. 1. Flowchart developed for the research

Tab. 1. Relationship between the expertise of the researched company and the country

	Argentina	Brazil	France	South Africa	United States
Automotive		1			
Chemistry		1			2
Consumer goods		1			
Electric materials	1		1		
Food		1		1	
Industrial components					1
Industrial equipment		2			
Metal mechanics			1		
Pharmaceutical		1			
Services		1			

influence of the researchers. The questionnaire assessed the relationship between process improvement, used tools, adopted strategies, and human resources for each organisation. Table 1 presents a summary of the answers.

The relationship between the country and the expertise of the companies shows the transversal nature of the study. This made it possible to analyse, more robustly, the connections between WCM, Industry 4.0 practices and the adopted strategic guidelines. It also allows carrying out analyses that consider not the expertise of the companies but the application of the WCM method and Industry 4.0 practices by these companies, as per the objective of the study.

3. Discussion of the results

The results show the relationship between continuous improvement processes from the viewpoint of applying the WCM method with integrated Industry 4.0 practices. Fig. 2 presents the summary of this sampling.

All respondent companies stated that they knew the concepts and tools applied in Industry 4.0 practices. This fact is evident from the current popularity of the topic and the position of companies aiming to modernise.

These practices are not yet rooted in companies; three of them (20 %) did not adopt the practices of Industry 4.0, and four (27 %) did not employ these practices in the development of the strategic plan.

Many Industry 4.0 practices are innovative and drive different knowledge. The massive use of data, the integration between different production systems, and real-time analysis stand out. This knowledge causes significant changes in production systems and business models, adding disruptive technologies and methods. They usually cross the barrier of established standards and models.

Companies face several difficulties in striving for these goals. Examples are the reconfiguration of manufacturing systems and business processes. Malavasi and Schenetti (2017) highlighted the drastic and radical changes that Industry 4.0 could generate in production systems.

The WCM method used for continuous process improvement also finds it difficult to disseminate its practices. Of 15 companies, two responded not knowing the method (13 %), and three did not apply the method in their processes (20 %).

Of the companies that apply the WCM method (12), only 10 involve employees in training, i.e., 17 % do not have qualification measures for human resources. Training emphasises the importance of professional development and investment in human resources. These measures increase the ability to apply tools aimed at Industry 4.0 practices and continuous improvement.

Regarding the strategic plan and From among the companies that knew the WCM method, only nine (69 %) adopted the WCM method in their strategic plan. These companies seek to foster and disseminate the continuous improvement culture through different operations.

3.1. Continuous improvement

The association of methods for continuous improvement and technologies faces various difficulties. For 93 % of the evaluated companies, the use of technologies depends on organised and effective

Fig. 2. Knowledge and application of the WCM method and Industry 4.0 practices

operational management and requires the availability of qualified human and technological resources, which are not always present in companies or available in the market.

The development of methods and the use of appropriate tools for the manufacturing systems assist in the use of long-term continuous improvement practices, facilitating application and collaborating in the understanding of internal processes. Fig. 3 shows this perspective.

Six Sigma is the most used tool by companies in the continuous improvement process, followed by Plan, Do, Check and Action (PDCA), Value Stream Mapping (VSM) and Kanban and 5S.

All companies highlighted associating one or more tools to problem-solving, depending on the application. They also asserted that the unfolding of improvement practices, associated with the continued use of these tools, favoured the breaking of operational barriers, making it more flexible and facilitating the insertion of continuous improvement in the organisational culture.

The improvement process includes product modification and refinement activities associated with existing services, equipment, process technologies and operating practices. Such actions involve the use of tools to eliminate variation in processes and increase the stability of operations (Furlan & Vinelli, 2018), the fundamentals of WCM.

For 47 % of the companies, a barrier to these applications was the employee resistance to the imposed changes. Companies that achieved the most success with continuous improvement programmes extensively use practices related to human resources, such as training employees to perform multiple tasks, partnering with suppliers and engaging the customer, together with technical and analytical tools.

The companies' expertise and the type of market in which they operate influence how improvement processes are implemented. For the production chain to be included in a constant evolution cycle, combinations between different types of resources, technical or human, are essential.

Most companies (60 %) considered that the implementation of the WCM method in factories with high variability and production on demand did not jeopardise the integrated management of operations. For the other 40 %, this statement was not true since companies supplying products manufactured on demand found it difficult to maintain the balance between a non-repetitive process and increased operational efficiency. The non-repeatability of processes

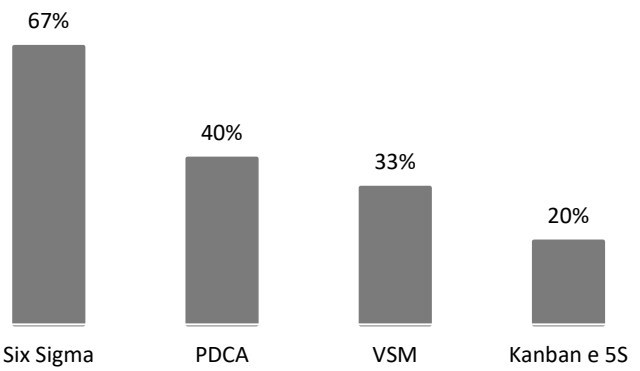

Fig. 3. Tools mostly used by the companies in the continuous improvement process

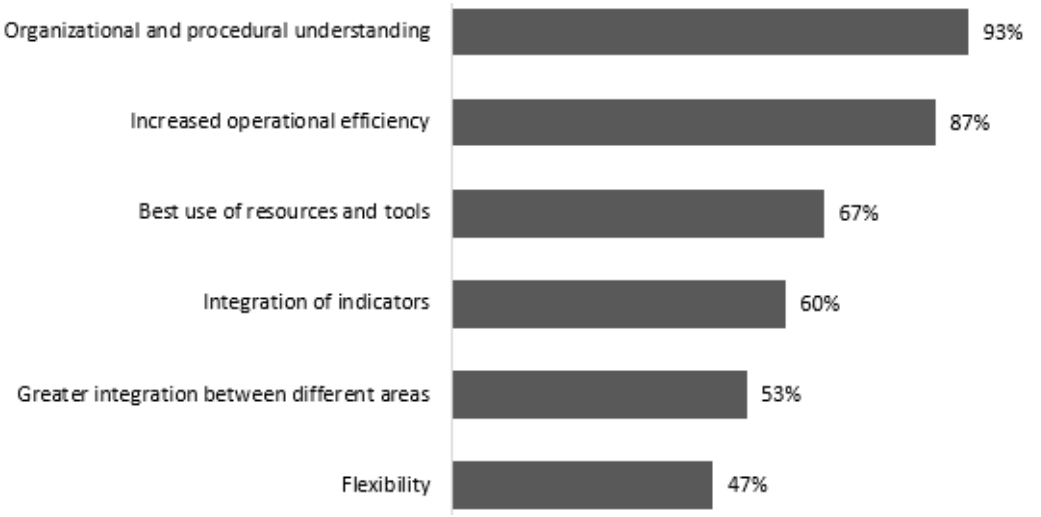

Fig. 4. Practices used by companies to reduce digital barriers

becomes a barrier to the standardisation of procedures.

Digital production systems tend to start breaking down these barriers and facilitate the adaptability of used Industry 4.0 practices in processes, as shown in Fig. 4.

For these companies, improvements occur through organisational and procedural understanding and increased operational efficiencies, such as the redistribution of skills and the involvement of people, facilitating innovation processes (Mróz, 2018), continuous assessment of activities (Sangwa & Sangwan, 2018), the use of associated technologies and the ability to assimilate new knowledge quickly (Sartal & Vázquez, 2017), and the adoption of new tools for data analysis (Dubey et al., 2016).

Also, better use of resources and tools, i.e., six sigma, standardised work and 5S, stand out by their use and implementation (Satolo et al., 2018). The connection between products, people, processes, tools and technologies as a single system (Synnes & Welo, 2016) highlights the importance to invest in knowledge and learning. Integration is another important aspect, touching upon the integration of indicators, i.e., the integration of process indicators with human resources, finance, administration, supplier and customer management (Sangwa & Sangwan, 2018), and the integration between different areas for development, with more efficient processes, resulting in reduced manufacturing lead times and better product quality (Dalenogare et al., 2018; Kamble, Gunasekaran, & Gawankar, 2018). This also results in facilitated communication of lean production in a digital network, the facilitated emergence of a unified and common communication interface (Kolberg, Knobloch, & Zühlke, 2017), and flexibility with the possibility to adapt new features in the work environment and the ability to interact with modern interfaces (Kazancoglu & Ozkan-ozen, 2018). The ability to adapt behavioural and technological skills (Buer, Strandhagen, & Chan, 2018; Luthra & Mangla, 2018; Kolberg, Knobloch, & Zühlke, 2017) allows an integrated evolution of companies (Villalba-diez et al., 2018; Mrugalska & Wyrwicka, 2017). As a consequence, the maturity degree of companies to use Industry 4.0 practices increases, generating a cycle of self-development and greater capacity to respond to unforeseen events, according to different circumstances.

3.2. Strategy

Paranitharan et al. (2017) claim that to compete in the current market, companies need to redesign their strategies, which allows not only the best allocation of resources but also dynamic gains over time. Besides, to compete globally, it is necessary to invest in changing strategic paradigms for manufacturing and in the manufacturers' mentality.

Companies need to adopt a mix of concepts and principles as a strategy with a focus on best manufacturing practices, reducing delivery times, developing suppliers and improving productivity. Table 2 presents a summary of the main technologies used by the companies to increase competitiveness.

According to Table 2, the use of technologies in their processes helps to increase productivity for 73 %

Tab. 2. Main technologies used by the companies to increase competitivity

	Additive manufacturing	Big data	Shop floor management	Internet of Things — IoT
Technologies that increase productivity and are oriented to the strategy	27 %	53 %	67 %	73 %
Technologies that allow the association between WCM and a strategic model for creating and adding value	20 %	67 %	73 %	60 %

of companies. This is due to the constant transformation of companies, adding value to their products, leveraging the application and use of a set of tools, methods and procedures. Shop floor management was cited by 67 % of companies and the use of big data by 53 %, but only 27 % had perspectives about different technologies used in their flow production. This suggests that the use of technologies is more frequent. However, the full automation of processes and the use of more advanced technologies still face barriers as they require the most capable and trained human resources, e. g., in the application of additive manufacturing.

Table 2 shows that the use of complementary technologies assists in the development of continuous improvement procedures. From the perspective of the association between WCM and a strategic model for creating and adding value, the shop floor management percentage changed from 67 % to 73 %, and big data — from 53% to 67%, allowing companies to make the transition to a strategic model for creating and adding value associated with continuous improvement processes.

Integration facilitates strategic adaptations. On the one hand, companies seek to achieve excellent levels of efficiency and productivity using existing methods, while on the other hand, they also try to associate new technologies in their processes. WCM allows the use of a wider range of tools and procedures capable of increasing and improving productivity. This relates the method to the strategic guidelines, causing a greater impact on companies.

Creating value for the customer is one of the results brought by WCM. It is in adding value to products that bottlenecks are identified, mitigating errors. When associated with Industry 4.0 practices, these activities allow for continuous monitoring and careful study of information, ensuring process control.

Data collection was cited by 80 % of companies as the main vector that helps the WCM method. This vector leads to constant improvement actions that prioritise competitiveness, training in Industry 4.0 practices and integration between areas. For 47 % of the companies, these actions occur due to the management directed towards different technologies. All companies stated that the technology strategy and skills drove sustainable processes, assisting in operations management. Oliveira et al. (2016) claimed that companies wanting to build long-term competitive advantages seek to develop WCM practices and, at the same time, remain flexible to stay up to date. Thus, technological integration with the sustainability of processes stands out.

For 87 % of companies, the differentiation strategy enabled competitiveness through the digital integration of manufacturing, and 93 % affirmed that the WCM method was capable of determining competitive strategies in different markets worldwide, establishing long-term competitive advantages. This way, companies aim for competitive advantages in their processes, allowing for higher quality products and services and recognition by competitors.

To carry out these actions successfully, companies must maintain their strategies in line with the improvement of processes, technologies and the organisational structure, directing efforts towards critical resources. This work makes it possible to monitor the actions adjacent to the procedures, with the ability to prepare the organisation for sudden changes.

Thinking long-term, the WCM method stands out by valued pursuit of goals in contradiction to short-term financial goals. These results have positive consequences on the processes since they are consolidated in the organisational culture. Consequently, they are used as a basis for the strategic plan to be adopted by companies.

3.3. Human resources

Practices based on human resources, such as training, employee involvement and empowerment, teamwork, qualified and multifunctional workforce (Sangwa & Sangwan, 2018), are considered a strategic

differentiator for companies. All companies consider that the development of human and organisational skills allows them to explore new and different opportunities for innovation and technological enhancement with an impact on strategic management.

For this production chain to work efficiently, it is necessary to continuously develop human resources and compensate for the improvements suggested and implemented. These actions are often overlooked by senior management.

For 93 % of companies, the availability of intellectual capital was increasingly necessary for the development of processes, often created quickly and adapted, producing transformative results. The development of human resource skills with technology was cited by 80 % of companies. Managers need to consider behavioural and technological aspects and skills that include greater flexibility and productivity (Luthra & Mangla, 2018). The short- and long-term strategic impact of Industry 4.0 practices in manufacturing, services, and global markets is immense, difficult to understand and to meet all customer needs efficiently (Sony, 2018).

However, only 67 % of companies consider it important that intellectual capital is associated with process development. Therefore, the transition from traditional industry, with little or no introduction of technologies in its processes, to the Industry 4.0 model requires a complete overhaul of operations, from top management to manufacturing.

WCM is concerned with the integration of strategy and best practices, and human resources. The increase in productivity seeks to maintain and improve human resources before thinking about new equipment and automation. Ghobakhloo (2018) affirms that this model is an integrative value creation system, bringing customers and suppliers closer together. The strategic roadmap points to an increasingly integrated management between human resources, the use of technology and intelligent manufacturing.

The coexistence between technologies and workers becomes a constant learning process since this new industrial paradigm leads to significant benefits in the production processes. Thus, a new model emerges between human resources and Industry 4.0 practices, reorganising the way of working.

Conclusions

With the constant transformation of companies, the application and use of a considerable set of tools, methods, and procedures that lead to increased productivity, continuous improvement in processes, and reduced operating costs have been leveraged. These factors are preponderant for adding value to products, placing companies on a different level compared to the global market.

The WCM method does not excessively demand labour; instead, it changes the way processes are executed, making them simpler and more efficient.

As a result, it seeks to foster and disseminate the culture of continuous improvement through different developed operations focusing on strategic visions of companies. Industry 4.0 practices allow achieving operational excellence, resulting in a structured development capable of leveraging the production systems. Processes tend to be more efficient, resulting in reduced manufacturing times, a better quality of products and services and gradual growth in organisational performance.

This paradigm shift has forced the search for more efficient production means, with greater agility in reaching different customers in a global market. Along with these transformations, the constant evolution of the productive means and how the quality tools work directs companies towards methods that are increasingly engaged in the search for greater efficiency and productivity.

Meanwhile, there are barriers that Industry 4.0 practices do not show. The lack of knowledge in internal processes, the use of correct technologies and trained human resources are the biggest bottlenecks. The consequences are even worse when the processes are designed to analyse the levels of maturity in operations management and to monitor and report information in real time.

For these actions to materialise in a sustainable way, it is necessary to make the processes more flexible. Thus, it is possible to reduce production times and add exclusive services.

Actions aimed at continuous improvement and more frequent use of Industry 4.0 practices become strategic drivers. These actions allow offering products and services with more quality and that reach different and exclusive markets, aiming at project-oriented companies. However, companies face a set of difficulties to implement these changes. Table 3 presents the main barriers to implementing WCM with Industry 4.0 practices.

The barriers that hinder the increasing progress of these procedures are robust, given the desired progress. Among them are the costs associated with the use of technologies, the lack of knowledge of the

Tab. 3. Main technologies used by the companies to increase competitivity

	Continuous improvement	Strategy	Human resources
Barriers	Cost to implement new technologies.	The adaptability of WCM to Industry 4.0 practices for on-demand projects.	Intellectual capital and training.
	Add methods and tools for continuous improvement with Industry 4.0 technologies.	Introduction of long-term quality policies and digital manufacturing integration.	Resistance to use and apply new technologies.
	Development of interactive processes with associated technological potential, the integration of different processes and the use of quality tools.	Change in organisational culture through the adoption and implementation of a consistent project of investment in human and material resources.	Adhering to a dynamic management model, where changes occur quickly, from top management to the shop floor.
	Application of methods and tools that allow massive data analysis.	The use of Industry 4.0 practices to identify new strategic trends in product development.	Top management knowledge about the difficulties encountered by the use and application of new technologies by workers.
	Continuous technological innovation and development.		

methods and tools applied, the lack of trained and qualified human resources, and the resistance of people to the use and application of these new tools.

WCM practices can influence the way products are manufactured and services offered. However, there is not enough data to prove that customer perception of the value of products and services is associated with the use of technologies used in the production system.

These barriers apply to WCM and Industry 4.0 practices. In many cases, these factors are neglected by top management, which concurs with Jabbour et al. (2018). They claim that for this to happen coherently, top management has the responsibility to provide organisational opportunities to integrate technology into a manufacturing system.

Another difficulty is the way they are applied. While WCM values slow processes, the Industry 4.0 practices value more dynamic results. Hence the great difficulty: pairing the two vectors, seeking greater productivity and efficiency.

Satolo et al. (2018) stated that lean tools, such as kaizen and 5S, stand out for their simple use and easy implementation. Fettermann et al. (2018) emphasised that companies had to provide the basic tools to assist in the implementation of technologies and overcome technological barriers. The beginning of the paradigm shift requires the use of simple tools that are easy to use by workers. As processes evolve, more complex tools must be inserted into the process. The objective of this gradual process is to implement the culture of continuous improvement and the reduction of costs and waste, converging on simple and practical solutions.

The difficulties encountered with the management of the operation and the standardisation of the production means, especially with products made on-demand, is also a significant obstacle. The ability of manufacturing to run flexibly can become a strategic agent in meeting the diverse needs of an increasingly complex customer base. Although most companies find that Industry 4.0 practices facilitate process adaptability, few link these improvements to cost and waste reduction projects with a broader strategic vision.

There are many difficulties in adapting technologies to existing processes. Although companies consider the process of adding value to the use of technologies, a significant portion of companies does not adopt Industry 4.0 practices and the WCM method in their strategic policies.

The constant monitoring of data, the use of big data and the comparison with other players in the market allow drawing a parallel between different companies and the outline of strategic guidelines.

The sustainable use of resources, including humans, allows the application of technologies in improvement projects through the reorganisation of working methods and the use of correct techniques and tools.

In practical terms, direct efforts towards the continuous monitoring of processes and use of data to generate improvement projects, cross-training of human resources and technological applications, focused on the practices of Industry 4.0, according to the established strategic plan.

For this process to occur, the first step is that the top management must start to focus on very clear objectives and also have a correct understanding of necessary investments. The second step consists of creating an organisational culture focused on innovation and continuous development for all areas of the organisation, from lean office to lean manufacturing,

along with the application of methods and tools that allow massive data and information analysis capable of generating continuous improvement projects associated with operations management. In the third step, the organisation must also be able to understand the deviations that may occur during this transition phase. For this to happen in a less impactful way in the management of operations, the changes should not be abrupt. For each evolution and result achieved, a phase of adaptation to the new concept is necessary, like a PDCA cycle.

Considering the obstacles pointed out to the application of the WCM method associated with the practices of Industry 4.0, future research may direct its efforts in a conceptual framework capable of showing how these associations will occur efficiently, overcoming the existing barriers.

The limitations of this paper include the set of studied companies. Future researchers may include companies of different sizes, analysed by their expertise, generating a more specific set of information and greater diversity of countries involving different cultures.

Acknowledgements

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, CAPES, Brazil.

The publication of the article for 11th International Conference on Engineering, Project, and Production Management - EPPM2021 was financed in the framework of the contract no. DNK/SN/465770/2020 by the Ministry of Science and Higher Education within the "Excellent Science" programme.

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Appendix – Survey

Block 1 – Interviewee characterisation

Name:_____
Phone (country code + phone number):_____
E-mail:_____
Current position on the company:_____
Time on the company:

[ ] Until 2 years
[ ] More than 2 up to 5 years
[ ] More than 5 up to 10 years
[ ] More than 10 years

Your company:

Know the WCM method?	[ ] Yes [ ] No
Apply the WCM method?	[ ] Yes [ ] No
Know the concept and tools of Industry 4.0?	[ ] Yes [ ] No
Apply the Industry 4.0 concept and tools?	[ ] Yes [ ] No

Block 2 – Company characterisation

Name of the company:_____
Country of the company:_____

Regarding the number of employees, the company or group to which the company belongs has:

[ ] Up to 100 employees
[ ] More than 100 up to 500 employees
[ ] More than 500 up to 1000 employees
[ ] More than 1000 employees

Area of expertise:_____

About the implementation of WCM and Industry 4.0 methods in your company:

Do employees receive training on the WCM method?

[ ] Yes
[ ] No
[ ] I am not sure about that

Is the company's strategic plan related to the WCM method?

[ ] Yes
[ ] No
[ ] I am not sure about that

Is the company's strategic plan related to the Industry 4.0 concept?

[ ] Yes
[ ] No
[ ] I am not sure about that

Block 3 – Characterisation of applied methods

1. The relationship between the WCM method and Industry 4.0.

The development of human and organisational skills allows us to explore new opportunities for innovation and technology enhancement, impacting strategic management.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Through the use of technologies in manufacturing processes, the WCM method is able to establish strategies for competitiveness in different markets, establishing long-term competitive advantages.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Important for the deployment of Industry 4.0 (up to 3):

[ ] Organisational and procedural understanding.
[ ] Flexibility.
[ ] Integration of indicators.
[ ] Complex problem-solving management models.
[ ] Parallel processes.
[ ] Employee resilience to change.
[ ] None.

The availability of intellectual capital is needed to develop processes, often quickly and iteratively created and to produce adaptive results.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Which knowledge, among different manufacturing methods, allows to identify strategic trends in the development of quality products (up to 3)?

[ ] Value Stream Mapping – VSM.
[ ] Kanban e 5S.
[ ] Plan, Do, Check, Action – PDCA.
[ ] Six Sigma.
[ ] Total Productive Maintenance – TPM.
[ ] World Class Manufacturing – WCM.
[ ] None.

Which technologies increase productivity and are oriented to the strategy adopted in your company (up to 3)?

[ ] Big data.
[ ] Internet of Things – IoT.
[ ] Additive manufacturing.
[ ] Factory floor monitoring.
[ ] None.

The use of technologies depends on organised and effective operations management and requires the availability of qualified human and technological resources.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Access by all employees to quality programmes helps to add more value, facilitating problem-solving.

[ ] Yes [ ] No

WCM enables companies to transition to a strategic model of value creation and aggregation with the help of the following technologies (up to 3):

[ ] Big data.
[ ] Internet of Things – IoT.
[ ] Additive manufacturing.
[ ] Factory floor monitoring.
[ ] None.

The company uses as a differentiation strategy in value-adding: technology development, Industry 4.0 deployment and digital integration in manufacturing:

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

In your company, which vectors help the WCM method with strategic policies, which focus on competitiveness and training with Industry 4.0, through management models directed to different technologies (up to 3)?

[ ] Total quality management and continuous data collection.
[ ] Integration of resources and areas.
[ ] Reengineering.
[ ] Process automation (Robotic Process Automation - RPA).
[ ] Process virtualisation.
[ ] None.

2. Strategic definitions of corporate operations management using the WCM method and Industry 4.0.

Developing long-term quality practices and the flexibility to serve customers helps break down operational barriers.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

The difficulty in deploying the WCM method in factories with high variability and on-demand production puts at risk the integrated operations management with Industry 4.0.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

In your company, how mature is operations management in relation to the implementation of Industry 4.0?

[ ] Very good: all processes are virtually interconnected and monitored.
[ ] Good: Processes are interconnected and monitored virtually, with occasional problems.
[ ] Fair: Processes are interconnected but not monitored virtually.
[ ] Bad: Few processes are interconnected and not monitored virtually.
[ ] Too bad: processes are not interconnected.

Technology strategy and competencies drive sustainable processes and assist in operations management.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Companies that use the WCM method are focused on value addition.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

3. The WCM method and Industry 4.0 influence changes in organisational and productive concepts.

Digital production systems facilitate process adaptability based on the value stream model for Industry 4.0.

[ ] Strongly Agree [ ] Agree [ ] Indifferent [ ] Disagree [ ] Strongly disagree

Which methods of Industry 4.0 driven by employee involvement encourage process efficiency, resulting in increased and improved productivity (up to 3)?

[ ] Best use of resources and tools.
[ ] Increased operational efficiency.
[ ] Greater integration between different areas.
[ ] More employee safety.
[ ] Waste reduction.
[ ] None.

The strategic objectives for manufacturing are directed to (up to 3):

[ ] Technology development.
[ ] Technology integration.
[ ] WCM.
[ ] None.

Block 4 – Final considerations

Does the company wish to receive the survey results at the end of the study?

[ ] Yes [ ] No

Does the company allow its name to be included in future publications, the result of this study?