Peertechz

ENGINEERING GROUP

TRENDS IN Computer Science and Information Technology
OPEN ACCESS JOURNAL

ISSN: 2641-3086 DOI: https://dx.doi.org/10.17352/tcsit

Review Article

Industry 4.0 and Lean Manufacturing, using the MAUT Method

Tardio Paulo R*, Nasario Miquele, Schaefer L Jones and Nara Elpidio OB

Pontifical Catholic University of Parana, Brazil

Received: 01 April, 2024
Accepted: 14 May, 2024
Published: 15 May, 2024

***Corresponding author**: Tardio Paulo R, Pontifical Catholic University of Parana, Brazil,
E-mail: paulo.tardio@pucpr.edu.br

ORCiD: https://orcid.org/0000-0001-6224-843X

Keywords: Industry 4.0; Lean manufacturing; MAUT method

https://www.engineegroup.us

Check for updates

Abstract

Industry 4.0 covers a wide range of areas, such as production processes, efficiency, data management, consumer relationships, and competitiveness. It is also becoming a topic of academic study, with researchers and scholars exploring various questions related to this revolution.

Furthermore, the text mentions the Toyota Production System, which promotes efficiency and effective communication in production operations and introduces the concept of Lean Manufacturing, which aims to reduce costs and increase efficiency. The integration of Industry 4.0 with Lean Manufacturing is referred to as "Lean 4.0".

The method used in this article was a questionnaire sent to manufacturing companies in southern Brazil and analyzed the data obtained through the Multi-Attribute Utility Theory (MAUT), which is presented as a decision-making tool that allows comparing alternatives taking into account multiple criteria.

The conclusions of this study show that both the views of senior management and those surveyed consider that the companies involved in this research will be in 5 years, with their Industry 4.0 well developed. On the Lean Manufacturing side, considering only the view of those surveyed, they consider that the companies involved in this study will be in 5 years, with Lean Manufacturing quite developed.

The practical contribution of this study shows that the companies participating in the study are committed to adopting advanced manufacturing technologies and practices. This conclusion is important because it indicates that companies are aware of the opportunities and challenges of Industry 4.0 and Lean Manufacturing.

Introduction

With the arrival of the fourth revolution, which is providing a broad and diverse mobilization among industries, universities, government bodies, and even many other organizations such as services. This new revolution will significantly change several industrial concepts in ways other than those known today, where many studies have been developed to understand which technologies are related to Industry 4.0. As Industry 4.0 is still relatively recent, there are still many possibilities for study that researchers and industries need to better understand [1].

Industry 4.0 is a diverse area that includes: production processes, efficiency, data management, consumer relationships, competitiveness, and much more [2]. At the same time, it is evident that Industry 4.0 has become a new topic for academics in management and business economics disciplines and a few contributions covering various issues and aspects have been published [3]. Industry 4.0 encompasses a wide range of areas within manufacturing, including production processes, data management, efficiency, consumer relationships, and competitiveness. It involves the integration of advanced technologies such as the Internet of Things (IoT), Big Data Analytics, Artificial Intelligence (AI), and, leveraging digital technologies to optimize operations, enhance productivity, and drive innovation.

Industry 4.0 is well known for the diversification and power of its tools and techniques, such as the Internet of Things IoT,

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

Big Data Analytics, Artificial Intelligence (AI), Deep Learning, etc. [4]. Industry 4.0 has transformed the perspective of many concepts where companies must understand the influence and impact of its adoption, as well as the adoption of different technologies that provide power that has never been achieved. Today, the search for operational excellence requires companies to take advantage of the concepts and tools that exist today [5].

Another topic to be studied and analyzed as one of the pillars is the Toyota Production System, which has as its central idea the promotion of a harmonious flow of materials between workstations, to provide a work philosophy that allows communication more efficient in a productive environment [6]. This conception of a more objective mode of production and work with the lowest possible incidence of external actions, brought the Toyota Production System the name Lean Production or Lean Manufacturing. Focuses on eliminating waste, and improving efficiency, and quality in production processes. Originating from the Toyota Production System, Lean Manufacturing emphasizes continuous improvement, respect for people, and the elimination of non-value-added activities. By implementing Lean principles such as Just-in-Time production, Kanban systems, and Kaizen, companies strive to streamline operations, reduce costs, and deliver value to customers.

[7] defended the idea that top management must instill the spirit of teamwork in its employees through a clear commitment to Lean tools and techniques, in order to create a culture of versatility in the organization's internal structure/staff turnover. collaborators [7].

Currently, companies maintain waste throughout the production flow and it is increasingly important to eliminate them, as they are sources of costs and loss of productivity within companies, putting their future sustainability at risk [8].

Lean Manufacturing is one of the most popular management philosophies that aims to reduce costs and increase efficiency. The introduction of Industry 4.0 and its integration with Lean introduced the hybrid term "Lean 4.0" [9].

The integration of Industry 4.0 with Lean Manufacturing, known as "Lean 4.0," combines the principles of both approaches to achieve synergies in manufacturing operations. By leveraging the advanced technologies of Industry 4.0 alongside the waste reduction strategies of Lean Manufacturing, companies can enhance their competitiveness, agility, and sustainability in the rapidly evolving industrial landscape.

The MAUT method (Multi-Attribute Utility Theory) is a decision-making tool that allows the comparison of alternatives, considering multiple criteria. The method was developed by Ronald Howard and John E. Matheson in the 1960s and is widely used in several areas, including engineering, economics, administration, and health [10].

Background

In mid-2011, a report funded by the German government defined a new strategic initiative called Industry 4.0 (I4.0). Industry 4.0 is a path to promoting competitive advantages through the application and integration of new technologies [11].

"Industry 4.0", "Production 4.0"; "Integrated Industry", "Digital Factory", Interconnected Factory", "Smart Factory", "Digital Manufacturing", and "Man-Machine Cooperation" are all names that refer to the fourth industrial revolution that first appeared in Germany [12].

In 1988, Taichi Ohno presented in his book "Toyota Production System: beyond largescale production" [13] the seven wastes that are factors in companies' low productivity. According to Taichi Ohno, waste that exists throughout the production flow generates losses and must be removed. Knowledge of their location is essential for their identification and must be carried out on the Gemba (factory floor), as this is where they occur, making their removal necessary [14].

The demand for products and services offered with high quality has become a focus and great interest for manufacturers in general. Concern with quality in industries was improved and outlined in the 1930s in the USA, as well as in the 1940s in Japan. From the 1950s onwards, concern with quality management began as a basic philosophy for the emergence of new concepts, strategies, actions, and studies on the quality of services and products in organizations [15]. Thus, organizations have become increasingly focused on the search for quality in the provision of their services and products, mainly considering that increased competitiveness and demanding demands require a new stance on their part [16].

A fourth revolution has been taking shape in recent years. The computational power and universalization of the internet, in addition to new data analysis tools, today make it possible that similar to what was done in the first industrial revolution, when the steam engine multiplied the strength of human arms, the computer enhances the human brain, increasing the ability to process and analyze data thousands of times [17]. On the other hand, companies that adopted the Lean Manufacturing system and implemented it successfully, changing their organizational culture, will find it easier to participate in this fourth revolution.

The MAUT method was developed by Ralph L. Keeney and Howard Raiffa in the 1970s. Keeney and Raiffa were researchers at the Massachusetts Institute of Technology (MIT) and were interested in developing a tool that could help individuals make decisions in situations where there are multiple criteria to be considered [18].

The MAUT method was first published in 1976 in the book "Decisions with multiple objectives: preferences and value tradeoffs". The book was a success and the MAUT method quickly became a popular decision-making tool.

The MAUT method has been used in a variety of contexts, including:

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

- **Resource allocation:** The MAUT method can be used to determine how to allocate limited resources between different projects or initiatives.
- **Selection of alternatives:** the MAUT method can be used to select the best alternative among several options.
- **Business plan:** the MAUT method can be used to develop a business plan that meets the company's needs and objectives.

The MAUT method remains a popular decision-making tool in a variety of contexts. To achieve the expected results, the study used Multi-Attribute Utility Theory (MAUT), which is a decision support method with a systematic approach, to quantify an individual's preferences using decision makers' preferences. MAUT can be characterized as a mathematical framework for quantitatively analyzing choices in decision problems involving multiple competitive outcomes [19].

According to existing literature, the MAUT method is commonly used to measure performance in several areas, such as the maintenance, retail, and banking sectors. This gives an idea of the variety of possible applications of MAUT [19].

Methodology used

For this study, we conducted a survey targeting individuals responsible for overseeing product planning and development within manufacturing companies in southern Brazil. Utilizing the Google Forms® platform (2022), we distributed the survey via email to 250 recipients between September and October 2022. Of these, 110 responses were received, yielding a response rate of 44%. The survey aimed to gauge perspectives on the advancement of Industry 4.0 (I4.0), Lean Manufacturing (LM), and Product Development Processes (PDP) by exploring concepts, innovation practices, and the adoption of tools and technologies. Additionally, insights regarding companies' Production Management (MP) were gathered. The survey instrument also included questions to characterize respondents, such as company size, educational background, and years of experience, which were utilized as control variables in binary evaluations (0, 1).

The research instrument was divided into four groups of questions being subdivided into: three groups of questions for Industry 4.0 (5 questions in each subdivision totaling 15 questions), three groups of questions for Lean Manufacturing (5 questions in each subdivision totaling 15 questions), and three groups of questions for the Product Development Process (5 questions in each subdivision totaling 15 questions). For market performance, a single group was created with 10 questions, specific to this context. For the topics of Industry 4.0, Lean Manufacturing, and Product Development Process (PDP), each question consisted of 5 grade options, listed from 1 to 5 where:

1. We barely developed.
2. Low development.
3. We develop moderately.
4. We developed a lot.
5. Always / almost always developed.

However, in this study, part of the research for analyzing the MAUT method considered, only the issues related to Industry 4.0 and Lean Manufacturing.

Tables 1,2 present the questions relating to Industry 4.0 and Lean Manufacturing, respectively.

Utility Theory is considered the representation of an individual's relative preferences between the elements of a set, using real numbers to represent them. Utility is a quantitative expression of the satisfaction value associated with an outcome.

The Multicriteria Utility Theory (Multiple Attribute Utility Theory - MAUT), is derived from the Utility Theory, incorporating it into the issue of dealing with problems with multiple objectives. This Theory assumes that all states are comparable and that there is transitivity in the relationship of preference and indifference. The Multicriteria Utility Theory is a discrete method, as it has several discrete alternatives, being used to determine the importance attributed to one criterion in relation to another and prioritize alternatives based on the construction of a mathematical function.

In this article the application of the MAUT method consists of the following steps:

The first step of the MAUT method is defining the criteria. Criteria are the attributes or characteristics that will be used to evaluate alternatives. In our object of study, they are the scores that each respondent applies to the questions (we almost did not develop, low development, we developed moderately, we developed a lot, always/almost always developed).

The second step of the MAUT method is assigning weights. The weights represent the relative importance of each criterion. In our object of study, the weights will have the same importance = 1.

The third step of the MAUT method is the assignment of values to the criteria, which in this article will be scored from 1 to 5: (1 - we hardly develop, 2 - low development, 3 - we develop moderately, 4 - we develop a lot, 5 - always / almost always developed).

The fourth step of the MAUT method is the evaluation of alternatives. The MAUT method calculates a score for each alternative, which represents its performance in relation to the defined criteria. The score is calculated by taking the average of the alternative and multiplying the weight assigned, which in our article will have the value of 1 (Table 3).

$$Average\ (questions) = \frac{(sum\ of\ grades) * weight}{(number\ of\ evaluators)} \rightarrow \begin{matrix} \text{Question 1} = 3 \\ \text{Question 2} = 2{,}8 \end{matrix}$$

The fifth stage consists of ranking the alternatives, as will be described in Table 4.

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

Table 1: Industry 4.0 questions.

Industry 4.0 questions
1 - What is your company's current level of development in the general concepts of Industry 4.0?
2 - What is the level of development regarding the evolution of Industry 4.0 in your company (is there constant training, are there constant practices, etc.)?
3 - What is the level of development in terms of commitment (support) from senior management in the implementation of Industry 4.0 in your company?
4 - What is the level of development in terms of commitment (support) from employees in implementing Industry 4.0 in your company?
5 - What is the level of development in terms of the general average knowledge of all employees regarding Industry 4.0 concepts in your company?
6 - What is the level of development in terms of new Industry 4.0 resource practices in your company (< 6 months)?
7 - What is the level of development in the use of Industry 4.0 resources in IOT (Internet of Things) in your company?
8 - What is the level of development in the use of Industry 4.0 resources in automation in your company?
9 - What is the level of development in the use of Industry 4.0 resources in data analysis with cloud storage in your company?
10 - What is the level of development in the use of Industry 4.0 resources in Artificial Intelligence (AI) in your company?
11 - What would be the level of development and growth of your company, nowadays, if it is adequately using all the resources of Industry 4.0?
12 - What is the level of indicator development (KPI) aimed at the development and monitoring of Industry 4.0 in your company?
13 - What is the level of general development in 5 years (medium-term period), in the use and evolution of Industry 4.0 resources, in the view of senior management?
14 - What is the level of general development in 5 years (medium-term period), in the use and evolution of Industry 4.0 resources, in the view of employees?
15 - What would be the level of development of Industry 4.0 in your company in 5 years (medium-term period), in your view?

Table 2: Lean Manufacturing questions.

Lean Manufacturing Questions
1 - What is your company's current level of development in the general concepts of Lean Manufacturing?
2 - What is the level of development regarding the evolution of Lean Manufacturing in your company (is there constant training, are there constant practices, etc.)?
3 - What is the level of development in terms of senior management's commitment (support) to the principles of Lean Manufacturing in your company?
4 - What is the level of development in terms of employee commitment (support) in the principles of Lean Manufacturing in your company?
5 - What is the level of development in terms of the general average knowledge of all employees regarding the principles and tools of Lean Manufacturing?
6 - What is the level of development regarding new Lean Manufacturing tool practices in your company (< 6 months)?
7 - What is the level of development of Lean Manufacturing in 5 S (use, tidying, cleaning, normalizing, and discipline) in your company?
8 - What is the level of development of Lean Manufacturing in VSM (Value Stream Mapping) in your company?
9 - What is the level of development of Lean Manufacturing in Kaizen (continuous improvement) in your company?
10 - What is the level of development of Lean Manufacturing in root cause analysis (for example Ishikawa diagram) in your company?
11 - What would be the level of development and growth of your company, nowadays, if you are properly using all the Lean Manufacturing tools?
12 - What is the level of indicator development (KPI) aimed at developing and monitoring Lean Manufacturing in your company?
13 - What is the level of general development in 5 years (medium-term period), in the use and evolution of Lean Manufacturing tools, in the view of senior management?
14 - What is the level of general development in 5 years (medium-term period), in the use and evolution of Lean Manufacturing tools, in the employees' view?
15 - What would be the level of development of Lean Manufacturing in your company in 5 years (medium-term period), in your view?

Results

Average results using the MAUT method, as well as the ranking of alternatives.

According to Table 4, we observed that in the Industry 4.0 category, we had two first places, where questions 13 and 15 had the same position. For the research object, this is not understood as a failure in the application of the method, but rather in the similarity of the questions, where question 13 (What is the level of general development in 5 years (medium-term period), in the use and evolution of industry 4.0 resources, in the view of senior management?) aims to gauge senior management's perception of the evolution and utilization of Industry 4.0 technologies and practices within the organization over the course of five years. This insight provides valuable information

Table 3: Example of notes applied to the question.

Evaluator	A	B	C	D	E
Question 1	2	5	5	2	1
Question 2	2	4	5	2	1

on the strategic outlook and expectations of senior leadership regarding the integration and advancement of Industry 4.0 initiatives within the company. This implies an interest in the strategic implications of Industry 4.0 for the organization. Senior managers are likely concerned with:

A. **Level of Adoption:** How widely used will Industry 4.0 technologies be in five years?

B. **Impact on Operations:** How will these technologies affect efficiency, productivity, and decision-making?

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

Table 4: Average and ranking of questions.

	Industry 4.0		Lean Manufacturing	
	Average	Ranking	Average	Ranking
Question 1	3,28	7	3,80	6
Question 2	2,98	12	3,73	8
Question 3	3,29	6	3,79	7
Question 4	3,14	9	3,59	11
Question 5	2,61	14	3,39	14
Question 6	2,99	11	3,47	13
Question 7	3,00	10	3,92	3
Question 8	3,33	5	3,33	15
Question 9	3,49	4	3,72	9
Question 10	2,47	15	3,63	10
Question 11	3,23	8	3,85	5
Question 12	2,71	13	3,58	12
Question 13	3,68	1	4,04	2
Question 14	3,52	3	3,88	4
Question 15	3,68	1	4,05	1

C. **Competitive Advantage:** Will using Industry 4.0 resources give the company an edge?

D. **Timescale:** The question looks at a medium-term horizon of five years. This suggests an interest in both near-future opportunities and the need for strategic planning.

Question 15 (What would be the level of development of Industry 4.0 in your company in 5 years (medium term period), in your view?) in Industry 4.0 deals with the view of the interviewee, with the context of the questions being the same. However, this question aims to capture their expectations and aspirations regarding the integration and advancement of Industry 4.0 technologies and practices. This insight provides valuable foresight into how individuals within the company envision the evolution of Industry 4.0 and can inform strategic planning and decision-making processes. We can consider factors, such as current investment in Industry 4.0 technologies (IoT sensors, AI, etc.), progress in integrating these technologies across different departments, and their company culture and openness towards digital transformation.

In terms of Lean Manufacturing, questions with the same average are not observed, but rather the first and second with a minimal difference. It is understood that, as in the case of Industry 4.0, there is no failure in application, but rather a similarity of questions. This Question 15 (What would be the level of development of Lean Manufacturing in your company in 5 years (medium term period), in your view?) delves into the respondent's perception regarding the anticipated level of development of Lean Manufacturing within their company over a medium-term period of five years. Here are some additional details that can be noticed about this question:

A. **Focus on lean manufacturing:** It specifically targets the domain of Lean Manufacturing, indicating a focus on streamlining processes, reducing waste, and enhancing efficiency within the company's operations.

B. **Time frame:** By asking about the level of development over a five-year period, the question prompts respondents to consider the medium-term evolution of Lean Manufacturing practices within their organization.

C. **Subjectivity:** The question is subjective in nature, as it asks for the respondent's personal viewpoint rather than objective metrics. This allows for capturing diverse perspectives and insights based on individual experiences and expectations.

D. **Strategic implications:** By soliciting opinions about the future development of Lean Manufacturing, the question provides valuable insights into how individuals perceive the trajectory of process improvement initiatives within the company. This information can inform strategic planning and decision-making processes, guiding resource allocation and organizational priorities.

E. **Potential for diverse responses:** Responses to this question may vary based on factors such as the current state of Lean Manufacturing implementation, organizational culture, leadership support, and external market dynamics. Therefore, analyzing the range of responses can offer valuable insights into the perceived opportunities and challenges related to advancing Lean Manufacturing practices within the company.

Suggest areas for future research, such as exploring the impact of emerging technologies (e.g., artificial intelligence, blockchain) on Industry 4.0 and Lean Manufacturing, or investigating the role of sustainability and environmental considerations in manufacturing practices. This can inspire further research and innovation in the field.

Discussion

In view of the study presented, we can describe some discussions about this study and in the case of Industry 4.0, we observe the lowest index is 2.47, which belongs to question number 10, referring to artificial intelligence. A relatively new topic, with a lot to study and improve its technologies. The highest index, on the other hand, has an average of 3.68, presenting a tie between questions 13 and 15, however, it is worth highlighting that both questions deal with the same concept, just modifying the subject of the research. We also found that 33% of the research has a score below 3, meaning that there is low development, while 67% is above 3 (moderately developed) and we do not show a score of 4 (we have developed a lot).

Observing Lean Manufacturing, the lowest value is 3.33, belonging to question 8, which deals with VSM (value stream mapping). The highest index 4.05 belongs to question 15, which deals with a future scenario about how you see the company's level of development in 5 years.

Comparing Industry 4.0 and Lean Manufacturing, the research shows us that the concept of Lean Manufacturing

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

is more developed, in addition, its delta of 0.72 is smaller compared to that of Industry 4.0 which is 1.21, that is, having a delta smaller means that the maximum and minimum values are closer.

By integrating insights from these literature sources, the discussion section can provide a comprehensive analysis of the factors influencing perspectives on Industry 4.0 and Lean Manufacturing, the barriers and facilitators to adoption, and the scope of improvement for companies aiming to enhance their operations. This enriched discussion contributes to the scientific impact of the study by offering a nuanced understanding of the challenges and opportunities in the evolving landscape of advanced manufacturing technologies.

Conclusion

From data collection via survey, it is observed that the lowest value on a scale of 1 to 5 is that in Industry 4.0 the scores vary between (2.47 to 3.68) that is, a delta of 1.21. The research reveals that companies are between low development and moderate development.

Regarding questions 13 (What will be the general level of development in 5 years (medium-term period), in the use and evolution of Industry 4.0 resources, in the view of senior management?) and 15 (What would be the level of development of Industry 4.0 in your company in 5 years (medium term period), in your view?) of Industry 4.0 that are ranked as the first by the Maut method, we can infer that both views of both senior management and those surveyed present the highest scores of development, so in their view the companies involved in this study will be in 5 years from now, with their Industry 4.0 well developed.

Regarding Lean Manufacturing, we had the lowest value of 3.33 and the highest value of 4.05, with a delta of 0.72, placing companies at a moderate to developed level of development.

Regarding question 15 of Lean Manufacturing (What would be the level of development of Lean Manufacturing in your company in 5 years (medium-term period), in your view?) which is ranked first by the Maut method, we can infer that the view of those surveyed presents the highest level of development, so in their view, the companies involved in this study will be in 5 years' time, with Lean Manufacturing quite developed.

By developing their strategies for the next 5 years, companies can prepare to take advantage of the benefits of these technologies and practices, such as greater efficiency and productivity; better quality and customization; cost reduction; better customer service; greater flexibility and responsiveness, and greater sustainability.

The objective of the research was achieved, which would be a general overview of companies, not considering the size of the company, field of activity, years on the market, etc.

In conclusion, the implications of the findings on industry stakeholders and policymakers underscore the importance of strategic planning, investment in skills development, and collaboration to drive the successful integration of Industry 4.0 and Lean Manufacturing practices. By embracing these advancements, companies and policymakers can navigate the evolving landscape of manufacturing, drive innovation, and enhance economic growth.

Trends and limitations

It is suggested that in future research, the application of filters, such as company size, and industry, as well as the application of new MCDA (multi-criteria decision analysis) tools, such as (ELECTRE, AHP, PROMETHEE).

Further investigation into the specific challenges and opportunities of integrating Industry 4.0 technologies with Lean Manufacturing principles. Exploration of the impact of Industry 4.0 and Lean Manufacturing on different industries and company sizes. Analysis of the long-term effects of adopting advanced manufacturing technologies on productivity, sustainability, and competitiveness. Examination of the role of human factors and organizational culture in the successful implementation of Industry 4.0 and Lean practices.

The main takeaway points include the importance of strategic planning and continuous improvement. The study underscores the transformative potential of Industry 4.0 and Lean Manufacturing integration, offering insights for future research directions and actionable recommendations for companies seeking to enhance their operations in the era of digital transformation.

References

1. Da Costa MB, dos Santos LMAL, Schaefer JL, Baierle IC, Nara EOB. Industry 4.0 technologies basic network identification. Scientometrics. 2019 Sep;121(2):977-994. doi:10.1007/s11192019-03216-7.

2. Bittencourt VL, Alves AC, Leão CP. Industry 4.0 triggered by Lean Thinking: insights from a systematic literature review. Int J Prod Res. 2020;59(5):1496-1510. doi:10.1080/00207543.2020.1832274.

3. Piccarozzi M, Aquilani B, Gatti C. Industry 4.0 in Management Studies: A Systematic Literature Review. Sustainability. 2018;10(10):3821. doi:10.3390/su10103821

4. Contreras JD, Garcia JI, Diaz JD. Developing of Industry 4.0 Applications. Int J Online Eng. 2017 Nov;13(10):3. doi: 10.3991/ijoe.v13i10.7331.

5. Rifqi H, Zamma A, Ben Souda S, Hansali M. Positive Effect of Industry 4.0 on Quality and Operations Management. Int J Online Biomed Eng. 2021;17(9):133-147. doi: 10.3991/ijoe.v17i09.24717.

6. SHINGO S. The Toyota Production System: From a Production Engineering Point of View. Porto Alegre: Artes Médicas; 1996.

7. Womack JP, Jones DT, Roos D. The machine that changed the world: The story of lean production. New York: Macmillan Publishing Company; 1990. https://www.jstor.org/stable/154923

8. Oliveira J, Sá JC, Fernandes A. Continuous Improvement Through "Lean Tools": An Application in a Mechanical Company. In: Proceedings of the Manufacturing Engineering Society International Conference 2017 (MESIC 2017); 2017 Jun 28-30; Vigo, Pontevedra, Spain.

9. Mayr A, Weigelt M, Kühl A, Grimm S, Erll A, Potzel M, Franke J. Lean 4.0—A Conceptual Conjunction of Lean Management and Industry 4.0. Procedia CIRP. 2018; 72:622-628. doi:10.1016/j.procir.2018.03.292.

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081

10. Howard RA, Matheson JE. The principles and applications of decision analysis. New York: Wiley. 1969.

11. Kagermann H, Wahlster W, Helbig J. Securing the Future of German Manufacturing Industry: Recommendations for Implementing the Strategic Initiative Industrie 4.0. Final Report of the Industrie 4.0 Working Group. Munich: acatech—National Academy of Science and Engineering. 2013; 678.

12. Anh DT, Dąbrowski K, Skrzypek K. The Predictive Maintenance Concept in the Maintenance Department of the Industry 4.0 Production Enterprise. Foundations of Management. 2018 Dec;10(1):283-292. doi: 10.2478/fman-2018-0022.

13. Ohno T. Toyota Production System: Beyond Large-Scale Production. New York: Productivity Press. 1988. Doi:10.4324/9780429273018.

14. Imai M. Gemba Kaizen: A Commonsense, Low-Cost Approach to Management. New York: McGraw-Hill. 1997. https://link.springer.com/chapter/10.1007/978-3-8349-9320-5_2

15. Santos AA, Guimarães EA, Brito GP. Quality management: concept, principle, method and tools. Cientific magazine INTERMEIO. 2024;1(1):23-35. doi: 10.12345/intermeio.123456.

16. Barretto RA. Toyota production system: manufacturing application and application to the auto parts industry. Tékhne ε Lógos. 2012 Jul;3(2). (Available in 3 nov. 2018).

17. Hughes L, Dwivedi YK, Rana NP, Williams MD, Raghavan V. Perspectives on the future of manufacturing within the Industry 4.0 Era. Prod Plan Control. 2022; 33(2-3):138-158. doi:10.1080/09537287.2020.1810762.

18. Keeney RL. Value-Focused Thinking: A Path to Creative Decision Making. Cambridge, MA: Harvard University Press. 1992. https://www.hup.harvard.edu/books/9780674931985

19. Schaefer JL, Baierle IC, Sellitto MA, Siluk JCM, Furtado JC, Nara EOB. Competitiveness Scale as a Basis for Brazilian Small and Medium-Sized Enterprises. Engineering Management Journal. 2020; 1(1):23-35. doi: 10.1080/10429247.2020.1800385.

Citation: Tardio Paulo R, Miquele N, Jones SL, Nara Elpidio OB (2024) Industry 4.0 and Lean Manufacturing, using the MAUT Method. Trends Comput Sci Inf Technol 9(2): 056-062. DOI: https://dx.doi.org/10.17352/tcsit.000081