

# Lean Tools Selector – A Decision Support System

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**Abstract**— Small and Medium Enterprises (SMEs) contribute significantly to the economy of any country, but in return, they are limited in their resources. A large part of these companies, when setting out to promote the Lean Manufacturing (LM) have difficulties with the selection and analysis of Lean tools to implement. Eventually, if the improvement actions aren't properly planned, structured or supported by the whole organization then, they end up failing in their implementation. Besides this problem, the literature on LM does not provide enough information about how the selection of Lean tools or practices should be conducted. Therefore, this study presents a decision support system that can help organizations to identify waste and to select the most appropriate tools or Lean practices to implement. It should be noted that, before any implementation of a Lean tool or practice, the organization should take care of knowing its stakeholders, define its system, be informed of the current state of the organization, and identify all the processes that add value to the organization. The correct selection of Lean tools or practices does not ensure the success of the Lean philosophy in any organization, because there are some factors that must be required, namely, the commitment of top management, knowing how to lead and communicate with all employees, being the education and training a crucial point to ensure a good cultural change in the organization.

**Keywords**— *Lean Manufacturing; Process Industries; Lean Tools; Decision support systems; SMEs*

## I. INTRODUCTION

Nowadays, with the increasing requirements of customers, the competitiveness between companies and the constant market dynamics, forces the companies to search for methods to optimize and make all their processes more efficient. One of these methods involves the use of Lean Manufacturing (LM) strategies in companies. However, it is usual for companies to face difficulties in integrating the structure of LM, since it is a complex system, especially in the selection and evaluation of appropriate methods and/or tools to apply [1].

Large companies are able to provide necessary resources and specialized employees in the implementation of the LM. In contrast, small and medium-sized enterprises (SMEs) are limited in their resources, either financially or organizationally [2]. Due to the importance of SMEs for the economy of any country and given the current pandemic situation, the optimization and management of an organization is crucial.

A large part of the problem in the implementation of the LM in this type of company, is in the selection and evaluation of the best suited tools or practices to implement. The

objective of this study is the development of a decision support system to assist the organization in that choice.

## II. LEAN PHILOSOPHY

### A. Lean History

Frederick Taylor stands out for the importance of work standardization, so that all non-value adding activities could be eliminated [3], [4]. The application of Taylor's management system, known as Taylorism, contributed to a better factory organization and to a more united work environment between employees [3]. Henry Ford was famous for the change of approach in manufacturing from manual labour to the mass production system and the creation of assembly lines in the automobile industry. He designed his production system by adopting and refining Taylor's principles. The mass production system was developed and systematized based on the reduction of time and the reduction of movements associated with a certain task. Its ideology became known as "Fordism" and, however, it required additional improvements to become more competitive and keep up with market dynamics. Its limitations were in its ability to change and innovate [3]–[5].

The demand for vehicles in the Japanese market was insufficient to sustain high production volumes compared to the United States of America. In the 1950s, Taiichi Ohno stood out in the Japanese market, developed a new production system, later called Toyota Production System (TPS). This production system, allows all products, procedures or activities to be in a constant process of continuous improvement in order to ensure the best quality, lowest cost and to ensure that all waste generated was minimized. These processes should be in agreement with the criteria established by the customers and, it should be assured that all workers collaborated with that system [3], [6], [7].

In 1988, John F. Krafcik was the first to introduce the term Lean through his study "Triumph of the Lean Production System" [8]. However, one of the most influential works to date was "The Machine That Changed the World" by Womack, Jones and Roos, written in the early 1990s, where the concept "Lean" was popularized worldwide [9].

### B. Lean Principles

Womack and Jones [10] identified five principles that are the basis for the Lean philosophy: create value, define the value chain, optimize the flow, Pull System and perfection. However, according to Pinto [11] these five principles present some limitations. So, in order to improve the organization performance two more principles were added:

knowing the stakeholders and innovation. The systematic review of Karim and Arif-Uz-Zaman [12] allowed to present a general approach in the implementation of Lean philosophy based on its principles and on the discussion of methods and techniques of continuous improvement. Considering also the two principles inserted by Pinto [11], to know the stakeholders and innovation, it was possible to elaborate a schematic representation of the Lean implementation, based on its principles, shown in Figure 1.

### C. The eight wastes of Lean

Eliminating waste, is one of the ways to achieve success within any organization. In an organization, more than 95% of time is spent performing tasks that do not add value to the product [11]. Identifying and eliminating waste in the steps that do not add value, helps in simplifying procedures and increases process efficiency [13]. Today, there are eight types of waste known worldwide: Overproduction, Transportation, Waiting, Overprocessing, Inventory, Motion, Defects and Unused Talent. In Table 1, besides the definition of each waste, there are also some causes corresponding to each one. Table 1 serves as a reference for the construction of questionnaire to the decision support system.

### D. Lean Tools and Practices

There are many Lean tools that have been proved to be able to help companies improving their efficiency, quality, costs and deliveries [14]. For an effective selection of Lean tools, it is important to collect information relative to the organization. The involvement and acceptance of employees concerning the culture change, are also critical points to lead to a better working environment [15]. However, many tools have the same objectives and functionalities and should be reviewed e.g. in terms of cost and expected time in order to determine the most suitable tool or method to implement [16].

### E. Critical Factors

As mentioned, SMEs are the most important economic units in the world and the Lean implementation is highly likely to fail if the critical factors are not achieved. Critical factors are the goals that must be achieved to ensure the success of any Lean approach or technique. Through the study of Elkhairi *et al.* [1], the following critical factors were identified and categorized: leadership, cultural change, competence and experience, top management commitment, education and training, and communication. The results of the success of Lean implementation are mostly related to the knowledge of Lean in the organization.

### F. Case Studies

The analysis of practical cases in the textile, metallurgical and metalworking and, automotive sectors is fundamental to obtain information about the applicability of Lean tools and practices to combat waste in these sectors. That analysis allows the system to automatically consider a set of tools that have the most successful application in the chosen sector. After the analysis of the case studies, there is a set of tools that can be used as a basis for the implementation of Lean practices in any organization, independent of the sector chosen. Perhaps one of the most important Lean tools is value stream mapping (VSM), because it can be used in any area and can provide an excellent starting point for identifying waste.

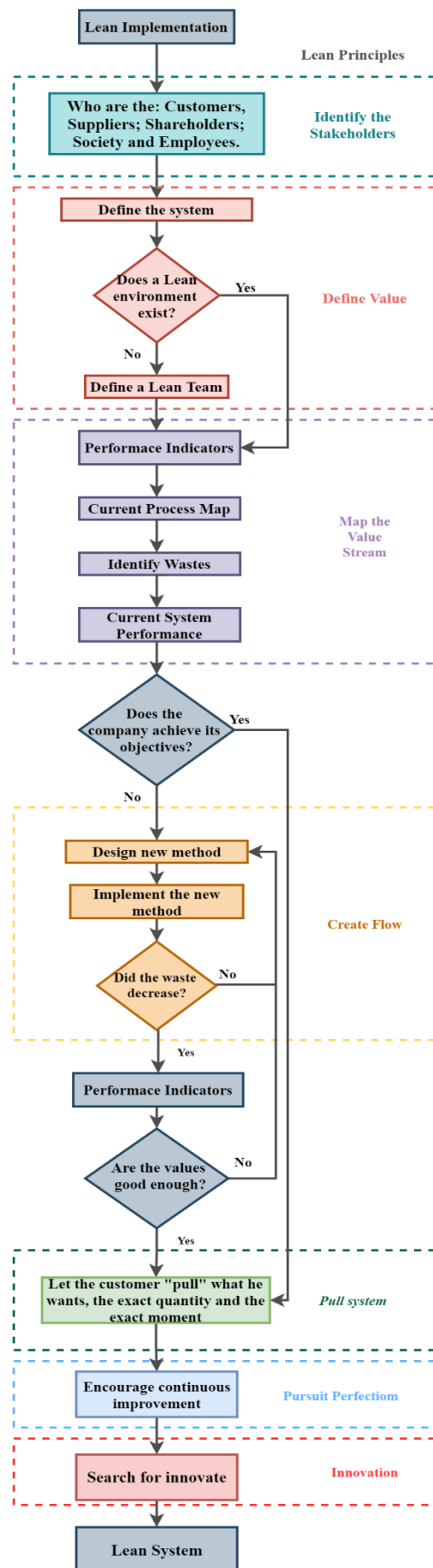


Figure 1: Implementation of Lean based on its principles

**Table 1:** Types of waste and its causes

Type of Waste	Definition	Causes
<b>Overproduction</b>	Overproduction, consists in creating products, services or generate information, beyond the customer's order [12], [14].	<ul style="list-style-type: none"> <li>• Production above the demand;</li> <li>• High transportation costs;</li> <li>• Large stocks of finished products;</li> <li>• Just-in-Case (JIC) Production;</li> <li>• Excessive use of material resources and energy;</li> <li>• Early purchase of parts and materials;</li> <li>• Lack of flexibility in planning.</li> </ul>
<b>Transportation</b>	Customers will only invest in products based on their needs , so any movement of the product, transportation of parts, materials, or equipment, the customer will not pay directly for that	<ul style="list-style-type: none"> <li>• Unnecessary movement of material between operations (Inappropriate layouts);</li> <li>• Displacement for document approval;</li> <li>• Transportation of finished products between sectors, stocks and shipping;</li> <li>• Unsuccessful communication: unreliability and data loss;</li> <li>• No proper handling equipment.</li> </ul>
<b>Waiting</b>	Any event that involves a person waiting for parts, tools, work instructions, a completion of an automated machine cycle, or even the approval of a document [13];	<ul style="list-style-type: none"> <li>• Slow response between operations;</li> <li>• Deficient production and process planning;</li> <li>• Waiting for approval or signature;</li> <li>• Untimely delivery from the supplier;</li> <li>• Waiting for parts, tools, instructions, or information;</li> <li>• Slow transition of changing tools, procedures, or processes;</li> <li>• Production of large batches, with the purpose of reducing associated fixed costs;</li> <li>• Unreliable technological equipment or without preventive maintenance;</li> <li>• Obstructed flow (failures, defects or accidents);</li> <li>• Employees standing still while automatic machines execute cycles.</li> </ul>
<b>Overprocessing</b>	Doing more work, adding more parts or performing more steps on a product or service, beyond the needs of the consumer. Steps that add qualities above the request and unnecessary or excessive documentation are also forms of this waste [14];	<ul style="list-style-type: none"> <li>• Unreliable or defective technological equipment;</li> <li>• Bad product designs require too much processing;</li> <li>• Using inadequate tools;</li> <li>• Producing parts with a quality level above specification;</li> <li>• Processes that are poorly defined or documented;</li> <li>• Manual processes that can be automated;</li> <li>• Performing unnecessary operations;</li> <li>• Unclear specifications;</li> </ul>
<b>Inventory</b>	Inventories are defined by unusual amounts of stored products (finished or incomplete), parts or raw materials [15];	<ul style="list-style-type: none"> <li>• High setup times;</li> <li>• Excess of raw material;</li> <li>• Large batch production;</li> <li>• Excessive amounts of unnecessary data in the logs;</li> <li>• Just-in-Case (JIC) Production;</li> <li>• Incomplete projects;</li> <li>• Difficulty and inefficiency in dealing with market instability;</li> </ul>
<b>Motion</b>	Excessive movement of people, data, decisions, or information [16];	<ul style="list-style-type: none"> <li>• Inadequate layout of machines;</li> <li>• Workers "wandering" for information;</li> <li>• Poor workplace ergonomics;</li> <li>• Searching for tools or materials;</li> <li>• No instructions about the procedures;</li> <li>• Poor workstation organization.</li> </ul>
<b>Defects</b>	It is defined as the production of a defective product or parts, which will consequently compromise the safety and quality of the product [11];	<ul style="list-style-type: none"> <li>• Interruption of the production flow, because of bad information;</li> <li>• No time for correcting defects;</li> <li>• Lack of education and training;</li> <li>• Defective raw material;</li> <li>• Inadequate manufacturing processes;</li> <li>• No control and inspection actions;</li> </ul>
<b>Unused Talent</b>	The organization does not take into account the full capabilities of the workers. The people are the most valuable resource in an organization [14].	<ul style="list-style-type: none"> <li>• Insufficient inclusion of workers in improvement actions;</li> <li>• Lack of education and training;</li> <li>• No knowledge and information sharing between departments;</li> <li>• The organization's internal skills are not fully used.</li> </ul>

In the same way, standard work, 5S practices and visual management systems, besides being able to solve several wastes by themselves, also provide great complement to other Lean tools.

### III. DECISION SUPPORT SYSTEM

#### A. System Overview

Initially, it was important to proceed to the analysis of the Lean philosophy and its practices and tools. The connection between the tools and waste and the association of causes/situations to each waste were the pillars for the conception of this decision support system (DSS). Contents shown in Table 1 were the reference for the elaboration of a questionnaire. The purpose of this questionnaire is to identify the wastes associated to a company. Secondly, the practical cases were analysed to conclude about the applicability of Lean tools and practices in the textile, metallurgical and metalworking and, automotive sectors. When the user selects the economic activity of the organization, the system will automatically consider the Lean tools or practices with higher applicability in each sector of the case studies.

The DSS was developed on Microsoft Excel software, which is widely used in several industries as a tool for data analysis and visualization. The user starts the questionnaire with a questions asking the economic activity of the organization. If for some reason, the selection of the economic activity of the organization goes beyond the studied sectors, a larger set of Lean tools or practices will be considered. The questionnaire is composed by 40 questions to be answered by anyone in the organization, regardless of whether or not they are familiar with the concepts of Lean philosophy. After the completion of the questionnaire, the DSS will analyse the waste found and define which wastes need immediate measures. The next step consists in associating the Lean tools or practices to the waste found. Depending on the economic activity chosen, the DSS may

present different solutions, because there are Lean tools or practices, which reveal to have a higher success of applicability in other types of sectors in the resolution of the same waste.

#### B. Example of Case Study

The DSS was tested for a possible practical case, in a metallurgical and metalworking industry. Table 2 shows the answers given to some questions of the simulation of the practical case. After the simulation of the questionnaire, the results obtained for this example are provided in Figure 2, where it is possible to see that overproduction, inventory and movements are the wastes with the highest incidence in the organization. The DSS suggests the application of Single Minute Exchange of Die (SMED), Kanban, standard work, 5S and Just in Time (JIT) production, to reduce the occurrence of these wastes. In the results page, the user still has the possibility to interact with the DSS, allowing him to access the contents library, where all the tools or Lean practices are explained in a detailed form. Besides, there is also the possibility for the user to print a report, in PDF format, about the results obtained and the waste found.

The Lean tools or practices that the DSS suggested focused on the production of smaller batches with the aid of SMED, resulting in less need for stock materials, reduced movement and setup times allowing the organization greater flexibility to meet new orders and, satisfying customer needs in terms of time of delivery and quantities.

JIT production means that only the required products are produced, in necessary quantities and according to demand or Takt Time (time in which a product needs to be produced or service must be provided in order to satisfy customer demand). It is essential to ensure that everyone in the company is working together to satisfy customer needs. By producing only what is needed, the company benefits by decreasing the waste of overproduction and as a result, reduces inventory.

**Table 2:** Example of answers given to a few questions from the practice case simulation

Question	Answer
1. Indicate the type of sector related to the company's economic activity:	<b>Metallurgical and Metalworking sector</b>
2. Existence of Lean culture or Lean Teams in the organization?	<b>No</b>
3. Does the organization use or has implemented Lean tools or practices?	<b>Yes</b>
4. Does the company dedicate resources and time for employees' education and training?	<b>No</b>
...	
7. Does the organization have multidisciplinary and qualified work teams?	<b>Yes</b>
8. Does the organization take employees' feedback into account in making decisions, setting goals, and preparing and controlling activities?	<b>No</b>
...	
11. Does the organization usually hold an unusual amount of stock, of finished goods, semi-finished products or raw materials, just in case there are unexpected orders?	<b>Yes</b>
12. Does the organization usually anticipate purchases of materials or parts?	<b>Yes</b>
...	
24. Are there frequently any equipment breakdowns, quality defects, or work accidents?	<b>No</b>
25. Is preventive maintenance applied to all the organization's equipment?	<b>No</b>
...	
32. Does the organization perform operations that are not requested by the customer, in order to add quality to the product?	<b>No</b>
33. Do all workers have access to work instructions, procedure instructions, or indications regarding the correct use and selection of tools for each task?	<b>No</b>
...	
40. Does the organization regularly apply control and inspection actions?	<b>Yes</b>
41. Do the products manufactured in the organization compromise the safety or security of the user?	<b>No</b>

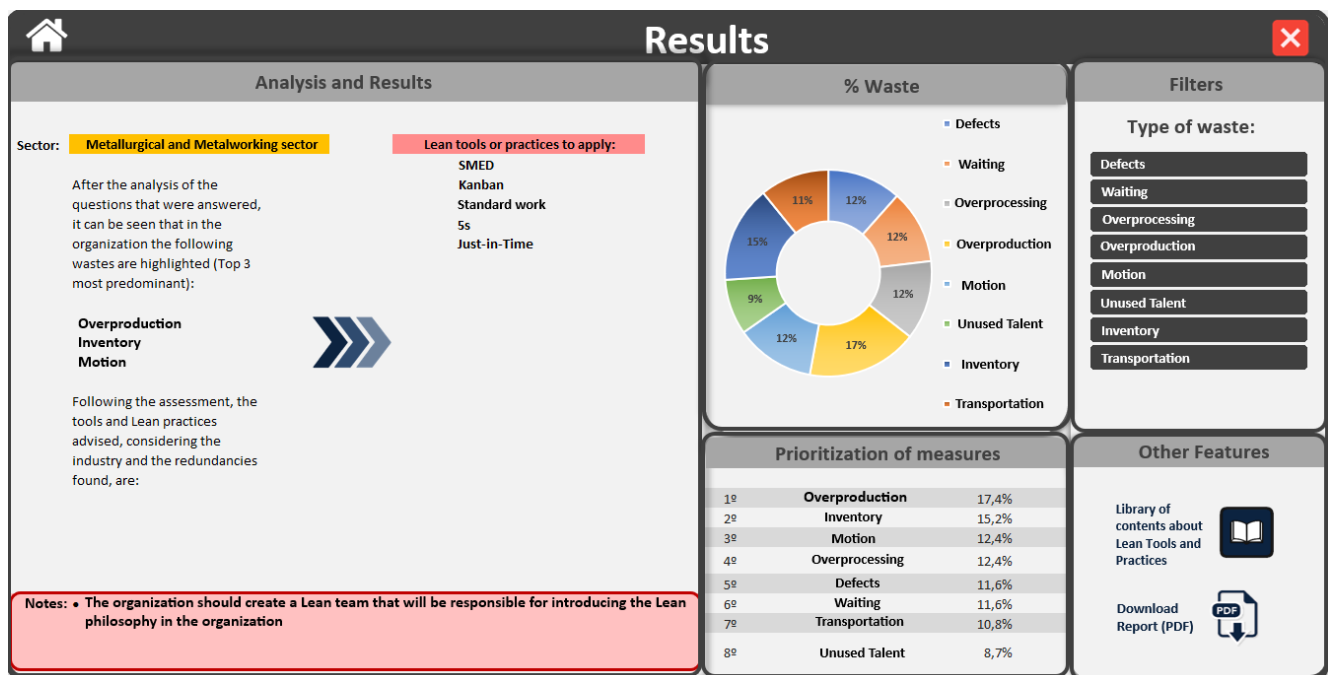


Figure 2: Results for the simulated practical case

Minimizing order lead times, improving quality and increasing efficiency are other associated benefits. Of course, if the company adopts this type of production, it should try to predict product demand and ensure that all suppliers meet the delivery of materials when requested.

The use of Kanban allows the production management and, as a result, the reduction of overproduction and inventory. Most companies use this method to provide flexibility and quick movement between workstations. This ensures more efficiency in the planning of task management and better management by the workers, because there is a better perception of the tasks to be carried out, which in turn, avoids unnecessary displacements to obtain information about the prioritization and distribution of tasks.

The standardization of tasks, movements or procedures are a good strategy to ensure a higher quality, safety and efficiency in the organization. Besides defining the work sequence, it is important to define the Takt Time and ensure a standard inventory to ensure a continuous production flow, without stops. By ensuring standard work, the worker will perform any task in an autonomous, repetitive and consistent way.

To keep workstations organized and avoid unnecessary movement of parts or tools, the use of 5S practices is the best way to ensure this. Their use has the benefit of reducing movement and waiting times to get some tool or equipment. Also, by removing any equipment or tools that are not needed at the workplace, it provides an insight into stock levels and what material, equipment or tools are required.

#### IV. CONCLUSIONS

The construction of this DSS allows assisting companies, more specifically SMEs, with the selection of Lean tool(s) or practice(s), since this was the main difficulty for organizations when they tried to adopt a Lean philosophy.

It is important to mention, that before any implementation, the organization should know its stakeholders, define its system (from product type, target market, volume or demand patterns), should know the current state of the organization and identify the steps or procedures that add value, with the help of the VSM. The organization should also evaluate the current state, using performance indicators and only then should use project tools or the implementation of Lean practices. This projection can be made, for example, through tools such as the Plan-Do-Check-Act (PDCA) cycle and 5W2H, since these tools follow a structure and help identifying and solving several types of problems or wastes. The use of Lean tools or practices such as standard work, 5S, Kanban and SMED, besides being able to solve several types of waste simultaneously, can also be used as complements to other Lean tools. Afterwards, it is up to the organization to adopt routines and implement all the practices consistently, always with a view to continuous improvement.

Even if the organization knows which Lean tools or practices should implement, that is not enough to guarantee its success. That success is mostly determined by the understanding of Lean in the organization. The difficult part is not the implementation of Lean tools or practices itself, but it is the commitment of the organization to adopt leadership behaviours', to make a cultural change within the organization, to focus on the skills and experience of the workers, to know how to communicate and to prioritize the education and training of the workers.

As a proposal for future work, it is suggested to extend the DSS to other sectors besides the processing industry. In other words, a detailed study should be done for the other sectors in order to obtain a more precise response regarding Lean tools or practices.

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