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Developing a Lean Implementation Framework for SMEs through Case Research

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Abstract:

Purpose: The implementation of Lean Manufacturing (LM) is a challenge for many companies and especially for small and medium-sized enterprises (SMEs) which, despite the potential of LM, still find it difficult to implement it correctly. The aim of this article is to present a new framework that allows SMEs to implement LM correctly and to obtain the expected result.

Design/methodology/approach: A theoretical approach to LM implementation has been developed, including Critical Success Factors (CSFs) to be considered during implementation. The framework has been validated using case research methodology.

Findings: A literature review has been carried out to identify the main gaps in the current frameworks for LM implementation. Thus, it has been concluded that there is no framework that is adapted to the specific characteristics and needs of each SME. The analysis also reveals that the appropriate selection of Lean tools is a critical issue for the successful implementation of LM.

Research limitations/implications: The framework has been validated through its application in 6 industrial companies. Further research should be carried out to take into account service companies as well.

Practical implications: Managers, practitioners and researchers can have a framework for successful LM implementation, which means that the expected improvements in productivity can be achieved.

Social implications: The correct implementation of LM allows companies to increase their productivity, which favours their growth and job creation, thus making a positive contribution to society.

Originality/value: The proposed framework offers a solution to the problem of LM implementation in SMEs, being the only one that allows the selection of LM tools according to the needs of the SME and that includes the CSFs to be considered.

Keywords: lean, lean manufacturing, lean implementation, case research, critical success factors, framework, SMEs

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1. Introduction

Companies compete nowadays in a global market and face to continuous changes, striving to achieve certain competitive advantages through Operations Management (Greasley, 2010). Lean Manufacturing (LM or Lean from now on) is a widely known methodology within Operations Management and has been referred to in the literature by many researchers as an important methodology for performance improvement (Alhuraish, Robledo & Kobi, 2017; Mohd-Amin, 2018; Shah & Ward, 2007).

It is widely recognised that LM can bring significant benefits to companies if implemented correctly (Alhuraish et al., 2017; AlManei, Salonitis & Tsinopoulos, 2018). However, the process to implement LM is unclear for many companies and failure rates are high (Netland, 2016; Vlachos, 2015). For example, (Almanei et al., 2017) mention that at least 75 % of Lean initiatives in companies end up failing. A failed Lean implementation has several negative impacts, such as loss of organizational resources and decreased employee confidence (AlManei et al., 2018).

The causes for the lack of success are varied, one of the most common being the difficulty of LM "tool" selection (Godinho Filho & Barco, 2015; Herron & Braiden, 2006), which is even more critical in the case of SMEs, due to the lack of resources and/or knowledge compared to large companies (Almanei, Salonitis & Xu, 2017; Belhadi, Sha'ri, Touriki & El Fezazi, 2018; Godinho-Filho & Barco, 2015; Herron & Braiden, 2006). Moreover, for SMEs, the implementation of LM tools poses serious challenges, as the implementation process is not clear to them (Inuwa & Rahim, 2020).

As will be shown, there are some gaps in the existing frameworks, such as having a clear systematic procedure adapted to the needs of each company and allowing the selection of the appropriate Lean tool according to the needs of the SME. This leads to the conclusion that there is a need for a framework for Lean implementation adapted to the characteristics of SMEs.

Therefore, the objective of the study is to develop a framework that facilitates the successful implementation of LM and that is adapted to the needs of the SME.

To this end, a theoretical framework is proposed that will be validated through implementation in 6 companies from different sectors using the Case Research methodology.

This article is organized as follows. First, after this introduction, a brief explanation of LM and a review of the problems related to the implementation of LM is given.

Next, a literature review of the main LM implementation frameworks is presented, followed by a summary of the main issues related to KM. Next, the main limitations and gaps of existing frameworks are identified.

In the next section, a theoretical approach related to LM implementation is presented, which will be applied in 6 companies through the case research methodology, which will also serve to validate the theoretical approach.

The article ends with conclusions and limitations to be considered.

2. Lean Manufacturing

LM is a manufacturing system related to the Toyota Production System (Ohno, 1988). A brief summary of the history of Lean (Shah & Ward, 2003):

- In 1988 Ohno published the Toyota Production System as a result of the tools and manufacturing system applied at Toyota for many years, with the aim of reducing cost and improving performance by eliminating waste.
- Womack, Jones and Roos (1990) described for the first time all the tools used in TPS under the term Lean and their application to any company, not just the automotive sector.
- During the 1990s and 2000s, many authors focused on different aspects of Lean, such as the different tools included in the Lean concept, how to measure Lean implementation and how these tools can help companies improve their performance.

- 2010's and 2020's, Lean continues to be a methodology that is widely used for improving competitiveness in many companies regardless of sector or company size.

Although LM can be formally described in many ways, it can be defined as "a socio-technical system whose main objective is to eliminate waste by simultaneously reducing or minimising supplier, customer and internal variability and involving the people of the firm" (Shah & Ward, 2007). Lean has a multidimensional nature and is composed of different tools that can be applied (Shah & Ward, 2003; Abdulmalek, Rajgopal & Lascola, 2006). From now on, when referring to LM tools we will refer to both LM tools and techniques.

LM tools can be considered as a set of management practices that can be directly observed (Shah & Ward, 2003). Different LM tools have been proposed in the literature, such as SMED, standard operations, Kaizen, problem solving, 5S, Value Stream Mapping, Kanban and others (Abdulmalek et al., 2006; Herron & Braiden, 2006), and, as we will see, the selection of these tools is one of the key aspects in LM implementation.

Once the LM has been defined, its implementation process will now be studied, given that this is one of the challenges facing companies, as we will see in the following section.

3. Framework for LM Implementation

3.1. Difficulties in Implementing LM

As discussed above, despite the potential of Lean methodology, it is still a challenge for many companies to achieve a successful implementation of LM (Secchi & Camuffo, 2019; Vlachos, 2015) mentions that only 5 % of Lean projects achieved expected results in 2011. Furthermore, (Almanei et al., 2017) mention Kotter's study (Kotter, 1996), indicating that at least 75 % of LM initiatives in companies end up failing.

The reasons for this failed implementation can be various, such as misunderstanding of the methodology, use of the wrong tool, use of the same tool to solve different types of problems, lack of leadership, lack of commitment of people or issues related to cultural change, among others (AlManei et al., 2017; Vlachos, 2015)

Related to the selection of the Lean tool, some authors state that it is not always easy for companies to select the right tool to apply, being one of the main reasons for failure (Godinho-Filho & Barco, 2015; Herron & Braiden, 2006).

Implementation in SMEs is even more difficult, as they have fewer resources compared to large companies (Almanei et al., 2017), in addition to other obstacles, such as lack of technical and managerial knowledge (Belhadi, Touriki & El Fezazi, 2016).

To overcome these difficulties, it is necessary to have a roadmap or guidelines (which we call a framework), with clear steps, that facilitates companies to implement LM and achieve the expected results (Herron & Braiden, 2006; AlManei et al., 2017).

The following section reviews the literature on the implementation of LM in companies and more specifically in SMEs.

3.2. Lean Manufacturing Implementation. Literature Review

A review of the literature related to the implementation of LM has been carried out.

The search was carried out in the SCOPUS database, focusing on "articles", "reviews" and "conference papers" as document types. At the same time, the search focused on the areas of "Engineering" and "Business, Management and Accounting", as these are the most representative in relation to the subject of the research.

Furthermore, the search was limited to articles written in English. No restriction was placed on the year of publication.

The topics used for the search were "LEAN", "LEAN MANUFACTURING" and "LEAN MANAGEMENT". With these topics, 499 documents were obtained.

A new search was then carried out, including the terms "FRAMEWORK" OR "IMPLEMENTATION". With these new restrictions, 214 documents were obtained.

Finally, a final search including the terms "SMALL AND MEDIUM-SIZED ENTERPRISE" OR "SME" OR "SMALL AND MEDIUM ENTERPRISE" was carried out, resulting in 20 documents. However, in order not to leave behind any reference that could be relevant, an analysis of the 214 documents was carried out taking into account certain criteria.

The review has been carried out by the author of the article, as a lean expert. At the same time, it has been reviewed by an expert in operations management from the University where the author of the article carries out his research work, the latter expert acting as tutor and director of the research. Following criteria have been considered:

- The proposal for a specific framework to be used by companies of different sectors of activity and size.
- The proposal of a framework that can be adapted to the needs of the company or the problem to be solved, which we will call the Need for Improvement (NOI) and which can be considered as a key aspect for the implementation of LM (Yamamoto & Bellgran, 2010). The NOI can be associated with the improvements to be achieved or the problems to be solved, as referred to by (Herron & Braiden, 2006). Once the NOI is specified, the framework should allow the selection of the tool(s) based on that NOI.
- A framework that can be adapted to the characteristics of SMEs, which means having a simple structure that is general enough to adapt to different contexts (Belhadi et al., 2016).
- A framework including the CSF, as commented by (Mohammad & Oduoza, 2020).

The search results have been analysed according to these criteria and a summary of the analysis is shown in Table 1. In the second column, the table shows information regarding the application of the LM and, in the third column, information regarding the number of cases considered. The table also shows information regarding whether the framework allows the selection of the Lean tool according to the NOI, whether the framework is adapted to the characteristics of SMEs and whether CSFs are included. Finally, the table shows a summary of the main limitations, not only in terms of the criteria, but also additional ones, such as whether the study is oriented to a single sector or considers only a specific Lean tool.

Authors	LM implementation	Number of cases	Selection of tools according to NOI	Adapted to SME characteristics	Consideration of CSF	Limitations
(Driouach, Zarbane & Beidouri, 2019)	Approach for Lean implementation in Very Small Enterprises.	Conceptual	No	Yes	No	No specific framework is proposed.
(Mohd-Amin, 2018)	Conceptual framework of Lean and ergonomics, for assembly manufacturing, based in PDCA approach	Conceptual	No	Yes	No	The criteria for tool selection are not clear. Only for manufacturing assembly and integrating ergonomics.
(Mohammad & Oduoza, 2020)	Approach based on the Malcolm Baldrige National Quality Award (MBNQA) for SME companies of a region in IRAK	Several cases	No	Yes	Yes	Tools cannot be selected along the frame. CSF not considered.
(Jasti, Kota & Kale, 2020)	Conceptual framework.	Literature review	No	No	No	Framework just conceptual and not validated with any implementation. CSF not considered.

Authors	LM implementation	Number of cases	Selection of tools according to NOI	Adapted to SME characteristics	Consideration of CSF	Limitations
(Herron & Braiden, 2006)	Methodology to deploy LM, establishing a relation between problems, tools, process, and measures	1 case	Yes	No	No	The approach is complex and not suitable for a SME to deploy. CSF not considered.
(Belhadi et al., 2016)	Methodology for Lean deployment	Several cases	No	Yes	Yes	Lean tools are generic and not oriented to the needs of the company.
(AlManei et al., 2018)	Framework based on change management theory	Conceptual	No	Yes	No	Not validated with any implementation. Tools selection is not considered. CSF not considered.
(Vlachos, 2015)	Model based in Lean thinking for SME food manufacturers.	1 case	No	Yes	Yes	Only for SME food manufacturers. No framework is proposed.
(Bulhões, Picchi & Granja, 2005)	Implementation of Lean concepts and tools in construction companies.	1 case	No	No	No	Only for construction companies. No framework is proposed.
(Gibbons & Burgess, 2010)	Framework based in the use and analysis of OEE	1 case	No	No	No	Only based in one Lean tool (OEE)
(Mostafa, Dumrak & Soltan, 2013)	Framework for Lean implementation using QFD.	Conceptual	No	No	Yes	Not adapted to SME characteristics.
(Okhovat, Khairol, Ariffin, Nehzati & Hosseini, 2012)	Implementation of Lean integrating six-sigma and TPM	Conceptual	No	No	No	Conceptual model. Criteria for Lean tools selection are not considered.
(Perez, de Castro, Simons & Gimenez, 2010)	Model for Lean in pork industry in supply chain.	Several cases	No	No	No	No framework is proposed.
(Rishi, Srinivas, Ramachandra & Ashok, 2018)	Implementation of Lean in a SME company.	1 case	No	Yes	No	No framework is proposed.
(Rose, Deros & Rahman, 2010)	Framework for Lean implementation in SME companies	Conceptual	No.	Yes	No	Criteria for selection of the tool to apply are not established.

Authors	LM implementation	Number of cases	Selection of tools according to NOI	Adapted to SME characteristics	Consideration of CSF	Limitations
(Hussain, Munive-Hernandez & Campean, 2020)	Implementation of Lean in a high mix low products manufacturer.	1 case	No	No	No	Study limited to a single production line of a high-mix base products company. CSFs are not considered.
(Ferreira, Ferreira, Lopes, Pereira & Silva, 2020)	Implementation of Lean tools in a woodwork company based in the DMAIC methodology for solving problems.	1 case	No	No	No	Study limited to the woodwork sector. No framework is proposed.
(Grewal, 2008)	Lean implementation process based in the use on the value stream mapping.	1 case	No	Yes	No	Only one Lean tool is considered. No framework is proposed.
(Alkhoraif & McLaughlin, 2021)	Impact of cultural aspects during Lean implementation in SMEs companies	1 case	No	Yes	Yes	No framework is proposed.
(Mor, Bhardwaj, Singh & Sachdeva, 2019)	Identification and elimination of Non-Value Activities (NVA) through Work Standardisation (WS)	1 case	No	No	No	Only one Lean tool is considered. No framework is proposed.
(Yuik & Puvanasvaran, 2020)	Framework to deploy Lean in SMEs companies	Several cases	No	Yes	Yes	Criteria for Lean tools selection are not established.
(Chong & Perumal, 2020)	Conceptual framework for Lean implementation in SMEs companies.	Conceptu al	No	Yes	Yes	Criteria for Lean tools are not established.
(Wong, Wong & Ali, 2009)	Lean implementation process in electrical companies in Malaysia.	Several cases	No	No	No	No framework is proposed.
(Sahwan, Rahman & Dero, 2014)	Lean implementation process in the automotive industry	Several cases	No	No	Yes	No framework is proposed.

Table 1. LM implementation. Literature review

To summarise, some of the studies are oriented towards specific sectors or specific situations (Bulhões et al., 2005; Ferreira et al., 2020; Hussain et al., 2020) and others propose LM approaches based on a single Lean tool (Gibbons & Burgess, 2010; Grewal, 2008; Mor et al., 2019). There are several authors who, while studying the application of LM, do not propose any specific framework (Alkhoraif & McLaughlin, 2021; Driouach et al., 2019; Perez et al., 2010; Sahwan et al., 2014; Wong et al., 2009). Some others, while proposing a framework for the application of LM, are not suited to the characteristics of SMEs (Herron & Braiden, 2006; Mostafa et al., 2013), while others do not establish criteria for the selection of tools based on the NOI (Jasti et al., 2020; Mohd-Amin, 2018; Okhovat et al., 2012; Rose et al., 2010).

On the other hand, there are other frameworks that, although adapted to the characteristics of SMEs, do not allow the selection of Lean tools according to their needs (AlManei et al., 2018; Belhadi et al., 2016; Chong & Perumal, 2020; Driouach et al., 2019; Mohammad & Oduoza, 2020; Yuik & Puvanasvaran, 2020).

Finally, only a few of the frameworks analysed include CSFs (Belhadi et al., 2016; Bhat, Gijo, Rego & Bhat, 2021; Mohammad & Oduoza, 2020; Mostafa et al., 2013); although they have the other limitations.

Another limitation is in relation to the results of LM implementation, so that most of the frameworks analysed do not demonstrate that productivity improvements can be achieved based on the initial objectives (AlManei et al., 2018; Belhadi et al., 2016; Driouach et al., 2019; Godinho-Filho & Barco, 2015; Mohd-Amin, 2018).

In summary, there is a significant gap in the literature related to the framework for the implementation of LM in SMEs, due to a lack of orientation to the characteristics of SMEs, to the selection of Lean tools according to the needs of SMEs and in relation to the consideration of Critical Success Factors (CSFs).

Ultimately, a specific framework is needed to address these limitations. To the author's knowledge, the proposed framework is the only one that meets the above requirements.

3.3. Framework for LM implementation. Theoretical approach

The theoretical approach is based on the above-mentioned literature review and considering following aspects.

Lean implementation needs a systematic process to correctly apply the different tools (Mohammad & Oduoza, 2020). This approach can be achieved by establishing different stages to be followed, such as (AlManei et al., 2017; Belhadi et al., 2016; Mohammad & Oduoza, 2020). The stages to be followed in our study have been selected according to the literature review and are Preparation, Lean Strategy, Implementation and Evaluation, while they would be part of a process of continuous improvement. The approach also includes a proposal of the Critical Success Factors to consider.

- PREPARATION Stage. There is no single roadmap for implementing LM and it must be adapted to each organisation differently (AlManei et al., 2017). The identification of the NOI will determine the tools to be implemented and thus the customization of Lean. In addition, the NOI will help us to determine whether the implementation has been successful or not, as we can compare the results obtained with them. Likewise, implementing the right tools is crucial for maximum performance improvement, as not all tools are appropriate in terms of the improvement to be achieved (Chong & Perumal, 2020; Herron & Braiden, 2006).
- LEAN STRATEGY Stage. In relation to the selection and implementation of the right tool, the Lean dimensions proposed by (Shah & Ward, 2007) will be considered. The authors proposed a way to measure Lean implementation through the assessment of 10 dimensions containing a set of Lean practices/tools. These dimensions are interrelated and give Lean its specific and unique character, which enables the achievement of sustainable performance objectives (Shah & Ward, 2007). Thus, following the Lean assessment of the SME and depending on its needs, one or more Lean tools can be selected from one or more dimensions.
- IMPLEMENTATION AND EVALUATION Stage. Performance measurement is crucial to determine whether the expected degree of improvement has been achieved, being part of the Lean continuous improvement approach (Vo, Kongar & Suárez-Barraza, 2019).
- CSF (Critical Success Factors). Some authors have proposed a set of CSFs to consider (Lodgaard, Ingvaldsen, Gamme & Aschehoug, 2016; Mohammad & Oduoza, 2020; Netland, 2016); while others provided information on the most critical CSFs. On the other hand, (Mostafa et al., 2013) highlighted the importance of including CSFs in the implementation process. Accordingly, the CSFs proposed in our framework will be associated with the different stages of the framework.

The proposed approach would be valid for industrial companies, without being limited to any specific sector, which gives our proposal greater versatility and applicability.

4. Case Research Methodology

Case research is especially useful in Operations Management, as this discipline contains not only quantitative but also qualitative aspects, which makes it particularly complex and interesting (Meredith, 1998; Yin, 2018).

Case Research uses one or several case studies and considers data from different sources, e.g. information system data, questionnaires, organisation charts, direct observations, interviews, etc. All this information must be handled in a situation of normal organisational development, without any manipulation. Case research methodology can be used for different research purposes, such as exploration; theory building or theory development; validation of theories or frameworks; extension or elaboration of theories (Ketokivi & Choi, 2014; Voss, Tsikriktsis & Frohlich, 2002).

In our case, Case Research will be used to validate the theoretical approach of the Lean implementation framework in SMEs, as it has also been used by some other authors (Mohammad & Oduoza, 2020; Yuik & Puvanasvaran, 2020; Alkhoraif & McLaughlin, 2021; Belhadi et al., 2016; Vlachos, 2015; Bulhões et al., 2005; Perez et al., 2010).

The validation of the framework will be done through application in 6 companies. This validation must be carried out with the necessary rigour, through the fulfilment of certain conditions, such as controlled observations, controlled deductions, replicability and generalisability (Meredith, 1998).

In our case, controlled observations are guaranteed throughout the entire process by the lead consultant, who also has the role of a researcher. Indeed, during the different stages of the Lean implementation process in each company (preparation, design, implementation and evaluation), no changes were introduced in the company except for the actions that were planned to be introduced. For example, during the Lean evaluation, no actions were introduced in the company except for the interviews and data collection for the evaluation.

The condition concerning controlled deductions is also fulfilled. Indeed, the fact that only planned actions were implemented during the implementation stage makes it possible to ensure that the improvements obtained are the result of these actions.

Replicability is the possibility of applying the theory resulting from the case to other conditions (Meredith, 1998). Since there is no restriction in the framework on the conditions and situation of the company, the theory obtained can be applied to other companies with other conditions.

Finally, the condition of generalizability, also known as external validity, was also met. In case research methodologies, case studies, like the experiment in scientific trials, do not represent "samples" generalizable to universes or populations, but to theoretical propositions (Yin, 2018). As in our case we are trying to validate a theoretical approach to Lean implementation, and companies from different sectors have been considered, generalisability is achieved, and the proposed theory is extensible to other types of companies.

5. Case Research Deployment in 6 Companies

The implementation was carried out in 6 companies that had decided to undertake a Lean project with the support of an external consultant, who also plays the role of researcher in this study. A common characteristic of all the companies is that all of them had decided to implement LM as an alternative to achieve an improvement in their performance.

All the participating companies are industrial, focusing on 4 sectors (chemical, aerospace, packaging and furniture). On the one hand, the fact that they are from different sectors gives validity to our proposal. At the same time, it has not been implemented in other sectors, which would be an opportunity to extend the study.

The project was presented to the companies, and it was decided to undertake the theoretical approach after discussion with the managers of the different companies.

Table 2 provides information on the companies selected for the study. This table indicates the sector of the company and the size (number of employees). It also indicates the need for improvement (NOI) of each company, which was identified during the preparation stage.

Company	Sector	Turnover	Size (employees)	Need of improvement
CO1	Aerospace equipment manufacturer	17 M€	95	Productivity improvement, improvement
CO2	Chemical manufacturer	15 M€	50	Cost reduction, delivery time
CO3	Furniture manufacturer	19 M€	130	Delivery time reduct
CO4	Aerospace components manufacturer	35 M€	160	Delivery time reduct
CO5	Packaging manufacturer	9 M€	48	Productivity improvement, improvement
CO6	Chemical manufacturer	12 M€	83	Productivity improvement

Table 2. Companies selected for the study and needs of improvement

The different stages of the implementation will be indicated below as well as the steps followed for each stage in each company, indicating "Y" (Yes) when the step was carried out and "N" (No) when it was not carried out.

5.1. Preparation Stage

Table 3 presents the steps carried out by each company during the preparation stage. Steps 1.1, 1.2, 1.7 and 1.9 were included to consider change management to increase the chances of successful implementation (AlManei et al., 2018). The step 1.3 is necessary as explained in the theoretical approach. Its consideration will allow us to tailor the implementation of the LM to the needs of the company. Steps 1.4 and 1.5 are included because they will be useful for later checking the results during the implementation and evaluation stage. At the same time, it is necessary to specify the scope in the implementation of the case (step 1.8) (Yin, 2018).

With the step 1.6 (Setting up the Lean team), the aim was to involve people from different areas, adding to the team functions such as purchasing manager, R&D manager, customer service manager, logistics manager, quality manager, shift managers or others. Their participation was important because of their knowledge of the company and the need for their commitment during the implementation of the improvement actions. The involvement of the lead consultant was also that of the principal researcher, who ensured that the methodology was correctly applied and that the results obtained met the necessary rigour.

The needs for improvement were discussed during the first meeting between the consultant and the company representatives and are summarized in Table 2. For this purpose, a brainstorming session was held first and then agreed upon by the team members.

Stage	Company					
1. PREPARATION	CO1	CO2	CO3	CO4	CO5	CO6
1.1. Recognizing the need/urgence for change	Y	N	Y	Y	Y	Y
1.2. Involvement of a change agent as facilitator	Y	Y	Y	Y	Y	Y
1.3. Identification of Need of Improvement	Y	Y	Y	Y	Y	Y
1.4. Establishing the objectives	Y	Y	Y	N	Y	N
1.5. Definition of Lean indicators	Y	Y	Y	Y	Y	Y
1.6. Setting up the Lean team	N	N	Y	Y	N	N
1.7. Training in Lean management	Y	Y	Y	Y	N	N
1.8. Definition of the scope for Lean implementation	Y	Y	Y	Y	Y	Y
1.9. Identification of barriers and resistance to change	N	N	N	Y	Y	N

Table 3. Preparation stage

5.2. Lean Strategy Stage

The implementation of the Lean strategy is summarised in Table 4. The objective of this stage is to concretise the action plan by analysing the current situation and involving the team members.

Stage	Company					
2. LEAN STRATEGY	CO1	CO2	CO3	CO4	CO5	CO6
2.1. Lean assessment and analysis of situation	Y	Y	Y	Y	Y	Y
2.2. Feedback meetings	Y	Y	Y	Y	Y	Y
2.3. Identification of improvement opportunities	N	Y	Y	Y	Y	Y
2.4. Identify and prioritize actions	Y	Y	Y	Y	Y	Y
2.5. Selection of pilot projects for deployment	Y	Y	N	N	Y	Y
2.6. Establishment of plan for Lean deployment	N	N	Y	Y	N	Y

Table 4. Lean Strategy stage

The step "Lean Assessment" is useful to make an analysis of the situation and to identify opportunities for improvement under a lean perspective. For this we will use the approach proposed by (Shah & Ward, 2007), who proposed a way of measuring lean through 48 factors classified into 10 dimensions.

For the evaluation of the factors we will use the criteria proposed by (Tortorella, Miorando & Marodin, 2017), who designed a questionnaire to evaluate various implementations of Lean tools, assessing them from 1 (not implemented at all) to 5 (100 % implemented). In our case, more specific criteria are established to determine the level of implementation (from 1 to 5), as follows:

- Level 1: The aspect has not been implemented at all.
- Level 2: The aspect has been implemented in a specific area or machine, but no results or conclusions have been obtained yet.
- Level 3: The aspect has been implemented in a specific area or machine and the results are as expected. Some conclusions have also been drawn.
- Level 4: The aspect has been implemented in several areas or machines, but no results or conclusions have been drawn yet.
- Level 5: The aspect has been implemented in all areas of the company. The results obtained are as expected.

In this way, we obtain the questionnaire shown in Annex I. The evaluation was led by the principal investigator. The score obtained was the result of the evidence obtained for each factor in each company. In any case, this evaluation was validated by the project team during "feedback meetings" step and adjusted when necessary. This gave validity to the results obtained, which served as a basis for the next steps of implementation. The result of the assessment is shown in Table 4.

The table shows the result of the assessment of each lean dimension for each company. A first general analysis shows that the "Suppliers JIT" dimension has the highest evaluation, which may be due to the need to demand suppliers to deliver on time and reduce stocks. Likewise, the lowest results are for the dimensions "Pull" and "Setup", which shows the need for general improvement in adapting to customer demand and improving flexibility.

On the other hand, it can also be observed how the 2 companies in the aerospace sector have the highest results in the "Customer involvement" dimension, which may be related to the requirements imposed by the OEMs in the sector (Original Equipment Manufacturers), which generally carry out a very exhaustive monitoring of their suppliers, which is transmitted throughout the supply chain.

On the other hand, continuing with the steps to follow, "Feedback meetings" were necessary to validate the information obtained through the analysis of the current situation and the Lean assessment, as commented previously.

Company	LEAN DIMENSION									
	1. Suppliers Feedback	2. Suppliers JIT	3. Suppliers development	4. Customers involvement	5. Pull	6. Flow	7. Setup	8. SPC	9. Employees involvement	10. TPM
CO1	3,0	3,7	3,5	4,0	1,8	1,6	1,4	2,2	1,5	2,5
CO2	3,6	4,3	3,2	3,3	1,8	2,8	1,6	3,4	3,3	3,8
CO3	2,2	2,7	2,5	2,4	1,8	1,6	1,8	2,2	2,5	2,5
CO4	2,8	3,7	3,2	4,1	2,0	2,2	2,2	3,2	3,3	3,5
CO5	2,2	3,3	1,8	2,1	1,8	2,2	2,0	3,0	3,3	4,0
CO6	3,2	3,3	2,7	2,6	2,5	2,8	2,6	3,6	3,8	4,5
Average	2,6	3,1	2,6	2,5	1,7	2,2	1,8	2,9	2,9	2,9

Table 4. Results of the assessment

Following the assessment and feedback meetings, opportunities for improvement were identified, usually through interviews with employees and/or observation of the process. Subsequently, specific actions had to be identified and prioritised.

- The prioritisation of actions was done in each company according to the following criteria:
- The lower the rating of the Lean dimensions, the higher the possibility to improve the performance related to that dimension. In this way, improvement actions can be identified in each dimension taking into account the different factors that appear in the proposed questionnaire (see Annex I).
- Consideration of the current situation and circumstances of the company. For example, if the company has limited resources in a certain area, such as one or more bottlenecks, it may be necessary to focus some of the actions on these areas.

Actions should also be prioritised according to the established NOI. To facilitate the identification of actions, criteria have been developed which, although not mandatory, can serve as a guide for the identification of actions based on the NOI (Table 5).

Need of improvement (NOI)	Priority dimensions	Justification	References
Flexibility improvement	Setup (7) Employees involvement (9) Customer involvement (4)	Initiatives to reduce setup times contribute to the improvement of flexibility, with the involvement of people and the involvement of customers being key to a better understanding of their needs.	(Ohno, 1988; Shah & Ward, 2007; Spear & Bowen, 1999; Womack et al.,1990)
Delivery time reduction	Setup (7) Customer involvement (4) Pull (5)	Improved flexibility helps to reduce lead times, as does keeping pace with demand.	(Jasti et al., 2020; Shah & Ward, 2007; Womack et al., 1990)
Quality improvement	SPC (9) Employees involvement (9) Customer involvement (4) Supplier development (3)	Statistical process control and supplier development are essential to quality assurance. Also, key elements are the involvement of employees and customers for a better understanding of their needs.	(Garza-Reyes, Rocha-Lona & Kumar, 2015; Shah & Ward, 2007; Womack et al., 1990)
Productivity improvement / Cost reduction	Customer involvement (4) Employees involvement (9) TPM (10)	Customer involvement is crucial to better understand customer needs, and employee participation in improvement programmes is also essential. TPM initiatives lead to cost reductions.	(Herron & Braiden, 2006; Ohno, 1988; Shah & Ward, 2007; Womack, et al., 1990)

Table 5. Criteria for actions selection

This table is organised as follows. For each NOI, some lean dimensions have been proposed on which to identify possible actions. In the next column, the rationale for the selection is briefly described, while in the last column a brief review of the literature justifying it is given. In any case, these are only possible alternatives for improvement, since performance improvement can be achieved by acting on several lean dimensions (Shah & Ward, 2007).

Taking into account the priorities established in each company and the criteria in Table 5, the actions that were finally selected are shown in Table 6.

Company	Need of improvement	Actions
CO1	Productivity improvement, flexibility improvement	(1) Implementation of SMED in 2 CNC's machines. (2) Definition of Standards & operations times. (3) Creation of autonomous teams to improve productivity
CO2	Cost reduction, deliveries reliability	(1) Implementation of SMED in packing lines. (2) Adaptation of batch sizes to setup times. (3) Creation of autonomous teams to improve performance.
CO3	Delivery time reduct	(1) Implementation of Kanban in: assembly line-painting area-machines. (2) Implementation of SMED in machines. (3) Adaptation of batch sizes to setup times.
CO4	Delivery time reduct	(1) Calculate Work Load. Identification of bottlenecks. (2) Implementation of SMED in machines with higher workload. (3) Adecuation of barch sizes
CO5	Productivity improvement, flexibility improvement	(1) Implementation of SMED in printer machines. (2) Creation of autonomous team to improve performance in printer machines. (3) TPM Deployment in CNC machines
CO6	Productivity improvement	(1) Definition of new layout in packaging plant to increase efficiency (2) Implementation of 5S in packaging plant. (3) Creation of autonomous teams to increase performance in packaging area

Table 6. Final actions selected for each company

In relation to actions, these can involve the whole company or only specific areas that can be selected as pilot projects. This is a strategic decision related to different factors, which in the case of the selected companies were: the availability of resources to tackle the project, time constraints or the need to show tangible results as soon as possible, among others.

Finally, the "Establishment of a master plan for Lean deployment" consisted of defining an overall plan for the implementation of Lean in the whole company, not only in relation to the pilot project.

5.3. Implementation and Evaluation

Table 7 shows the stages corresponding to Stage 3, Implementation and Evaluation. Firstly, the "Implementation of actions" corresponds to the deployment of the previously selected actions. For the follow-up of the action plan, weekly meetings were held with those involved in order to identify and remove possible roadblocks that could hinder the deployment of the actions.

The "Monitoring of results" was deployed to check whether the actions were producing the expected results. "Visual management" is a complementary step that can help to visualise the information. The indicators used to monitor performance were oriented towards efficiency improvement and were related to the NOIs set out for each company. The indicators selected in each case are shown in Table 8.

'Training of operators' could contribute to a better understanding of Lean actions and tools by operators. This was validated when operators received a Lean training programme. The "standardisation of improvements" provides a system to ensure consistency of results, while the "extension of good practices" is an opportunity to take improvements to other areas and/or processes in the company. This was verified through the existence of procedures that reflect good practices and the new way of operating, with the participation of employees in the development of these procedures.

Stage	Company					
3. IMPLEMENTATION AND EVALUATION	CO1	CO2	CO3	CO4	CO5	CO6
3.1. Implementation of actions	Y	Y	Y	Y	Y	Y
3.2. Monitoring the results	Y	Y	Y	Y	Y	Y
3.3. Implementation of visual management	N	N	N	N	Y	Y
3.4. Training of operators	Y	Y	N	Y	Y	Y
3.5. Standardization of improvements	Y	Y	N	N	Y	Y
3.6. Extension of good practices	N	Y	N	N	Y	Y

Table 7. Implementation and evaluation stage

The results (Table 8) are aligned with the previously identified NOIs, so that improvements were achieved for each of the NOIs in all cases. Thus, we can say that the implementation of LM has been successful.

Company	Need of improvement	Indicators	Results
CO1	Productivity improvement, flexibility improvement	Indicator (1) = % Setup time reduction. Indicator (2) = % Efficiency improvement (units / hours)	(1) Reduction of setup times in 35 %. (2) Increase of efficiency in machines in 15 %.
CO2	Cost reduction, deliveries reliability	Indicator (1) = % Stock reduction. Indicator (2) = % Efficiency improvement (kgs / hours) Indicator (3) = % Setup time reduction	(1) Average stock reduction in 25 %. (2) Increase productivity in 8 % (kgs processed / hours)
CO3	Delivery time reduct	Indicator (1) = % Delivery time reduction	(1) Reduction of average delivery time from 15 days to 7 days (53 % reduction)
CO4	Delivery time reduct	Indicator (1) = % Leadtime reduction	(1) Reduction of average leadtime from 40 days to 18 days (55 % reduction)
CO5	Productivity improvement, flexibility improvement	Indicator (1) = % Setup time reduction. Indicator (2) = % Efficiency improvement (units / hours)	(1) Derease average setup time in 40 %. (2) Increase efficiency in printer machines in 15 %.
CO6	Productivity improvement	Indicator (1) = % Efficiency improvement (units / hours)	(1) Increase efficiency in packaging area in 28 %.

Table 8. Results obtained

5.4. CSF Considered

This section describes the Critical Success Factors (CSFs) that have been considered. Some of the CSFs are as follows:

- Communication. This is pointed out by different authors, such as (Alhuraish et al., 2017; Mostafa et al., 2013; Netland, 2016). In the preparation stage, the aim should be to involve all the people needed for the project, while during implementation the aim should be to get employees involved in order to favour the implementation of the actions.
- Managers commitment and support, without which implementation is unlikely to succeed (Lodgaard et al., 2016).
- Project management skills (Alhuraish et al., 2017) and other related factors, such as dedication of human resources, investing time in the improvement project and having regular meetings (Netland, 2016), or the consideration of Lean as a change to be managed, as proposed by (AlManei et al., 2018).

- Skills and experience are other important factors (Alhuraish et al., 2017). In our case, the Lean project facilitator is an external Lean consultant, who also ensures knowledge transfer to others in the team.

Some other CSFs are integrated in some of the steps of the different stages. They are the following:

- Linking Lean tools to the company's strategy (Alhuraish et al., 2017); which is ensured in our case, as the Lean assessment and action plan are carried out after the identification of NOIs.
- The reward system (Alhuraish et al., 2017; Netland, 2016) has only been used by one of the companies in our study, which implemented a "variable" reward system for shop floor employees in case certain targets were reached.
- Training is another important factor, as stated by several authors, and is included in the framework in stages 1 and 3. Cultural change is a factor that has been taken into account in stage 2; it is also included in the training and in the Lean deployment process itself.
- Involvement of employees (Alhuraish et al., 2017) was ensured through face-to-face interviews with employees and awareness-raising workshops. This CSF is related to other CSFs, such as "management commitment and support" and "communication".

The final CSFs considered are shown in Table 9. Note that a "Y" has been marked when considering the CSF for the company at each stage.

	Company					
	CO1	CO2	CO3	CO4	CO5	CO6
1. PREPARATION STAGE						
Communication	Y		Y	Y	Y	Y
Managers commitment and support	Y	Y	Y	Y	Y	Y
Project management skills		Y	Y	Y	Y	Y
Training and education	Y		Y	Y	Y	
Skills and expertise	Y	Y	Y	Y	Y	Y
2. LEAN STRATEGY						
Communication	Y		Y	Y		Y
Linking Lean tools to business strategy	Y	Y	Y	Y	Y	Y
Managers commitment and support	Y	Y	Y	Y	Y	Y
Project management skills	Y		Y	Y	Y	
Cultural change			Y	Y		Y
Skills and expertise	Y	Y	Y	Y	Y	Y
3. IMPLEMENTATION AND EVALUATION						
Communication	Y	Y	Y	Y	Y	Y
Managers commitment and support	Y	Y	Y	Y	Y	Y
Project management skills	Y		Y	Y	Y	
Employees engagement	Y	Y		Y	Y	Y
Reward system		Y				
Skills and expertise	Y	Y	Y	Y	Y	Y
Training in Lean to operators		Y	Y	Y	Y	Y

Table 9. CSF considered during Lean implementation

6. Framework Proposed for Lean Implementation

Figure 1 shows the outline of the proposed framework for the implementation of Lean.

The framework is composed of 3 main stages and steps within each stage, providing a simple structure, which makes the framework easy to follow and suitable for SME companies (Belhadi et al., 2016). The stages represent the sequence to be followed during implementation, while the steps represent the actions to be taken within each stage. There are numbers associated with each of the steps that represent a suggestion of the order in which they should be performed. All steps have been included in the framework, even if some of them have not been considered for some of the companies.

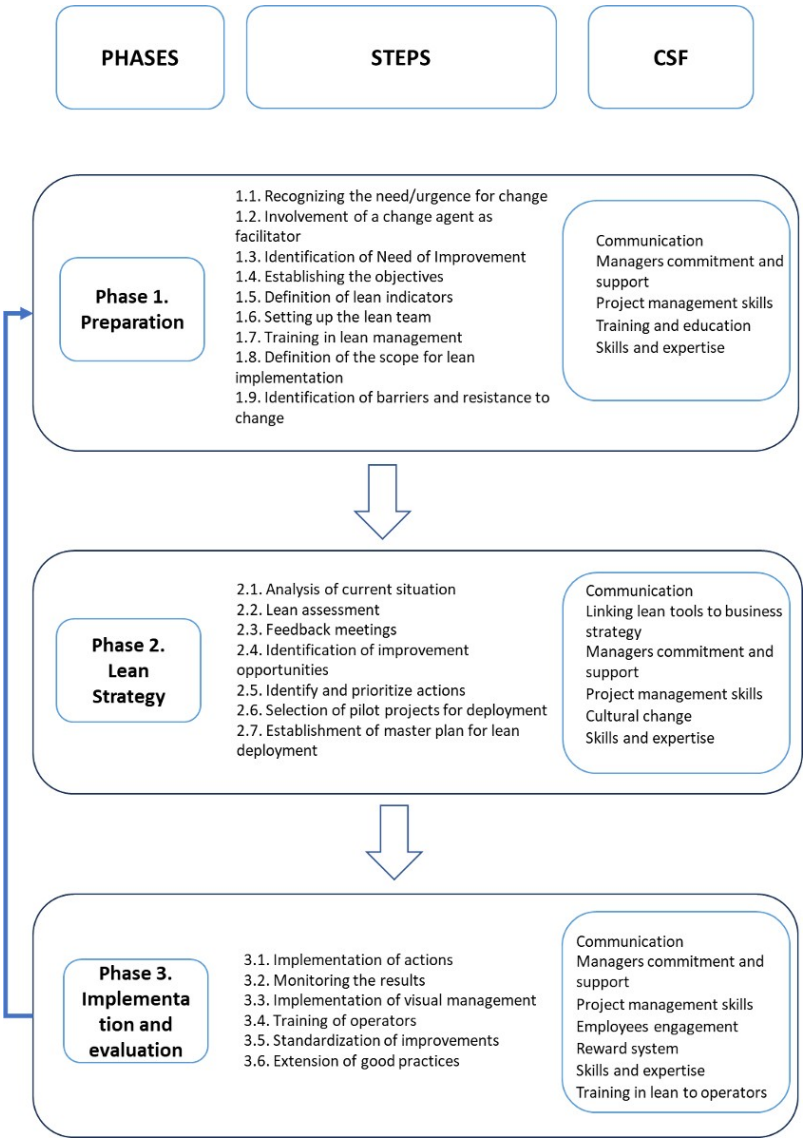

Figure 1. Schema of the framework proposed for Lean implementation

At the same time, it is possible to go back to an earlier step if deemed necessary. As an example, after step 1.6 "Setting up the Lean team", it might be necessary to go back to step 1.3 "Identification of Needs of Improvement", to modify the NOIs or to include additional ones. This is part of the continuous improvement and PDCA (Plan-Do-Check-Act) cycle of the Lean approach, which can be applied systematically (Gubinelli, Cesarotti & Introna, 2020; Mohd-Amin, 2018). Also in line with the continuous improvement approach, the framework can be applied systematically. Also as part of the continuous improvement process, from stage 3 we would go back to stage 1 to start the process all over again.

In addition, the framework includes a proposal of CSFs, some of which are associated with particular stages. This allows for a more effective focus on the CSFs to be considered, given that although many CSFs have been proposed in the literature, not all factors are of equal importance.

7. Conclusions

This section presents some conclusions following the application of the framework, which can be summarised as follows.

This study proposes a framework for the implementation of LM in SMEs. Despite the potential of LM in terms of productivity improvement for companies (Alhuraish et al., 2017; Mohd-Amin, 2018; Shah & Ward, 2007), the literature review has highlighted the difficulties that companies, and in particular SMEs, encounter in its successful implementation (Secchi & Camuffo, 2019; Vlachos, 2015). Thus, researchers state the need for a framework that facilitates the implementation of the methodology so that they can achieve the expected results (Herron & Braiden, 2006; Almanei et al., 2017).

For the development of the proposed framework, a review of the literature has been carried out, which has allowed us to identify the limitations of existing frameworks; these have served as a reference for the proposal of a framework for the implementation of LM. This gives our framework an innovative character, since it provides a solution to some of the limitations raised in the literature.

In this respect, some of the novel aspects of our framework are outlined below. Firstly, the framework allows the selection of the appropriate LM tool(s) according to the needs and priorities of the companies, which was a difficulty in relation to the implementation of LM (Almanei et al., 2017). In addition to the tools to be implemented, the framework includes the steps to be taken and the CSFs to be considered, which contribute to the success of Lean implementation (Netland, 2016).

On the other hand, the framework is suitable for SMEs as it is clearly structured and easy to understand (Belhadi et al., 2016). However, the help of a Lean expert may be needed, acting as a facilitator and filling in if necessary, the possible lack of knowledge of the LEAN methodology in the SME.

On the other hand, the framework has allowed the companies that have applied it to achieve the desired improvements in each case (NOI), which in particular have consisted of improved productivity and/or efficiency, improved flexibility and reduced delivery times; therefore, we can deduce that the framework allows companies to improve their competitiveness, which would mean achieving a successful implementation of LM.

We must also highlight the research implications of our study. On the one hand, our proposed framework contributes to the increase of knowledge in the field of lean theory by offering solutions in the field of LM deployment to the problems identified by researchers.

The proposed framework has been validated through its implementation in 6 SMEs from different fields, which gives value to our proposal and differentiates it from other conceptual proposals that have not been validated.

On the other hand, our study also has practical implications in the field of operations management in companies. Indeed, given the difficulties that companies, and in particular SMEs, face in implementing LM, the following framework provides managers and practitioners with a tool for the successful deployment of LM to achieve competitive improvements.

Our study also lays the groundwork for future research. Indeed, since we propose a framework for the implementation of LM in companies of diverse scope, researchers can carry out studies aimed at adapting the framework to specific sectors, which would give it greater relevance in terms of the actions to be implemented.

All in all, we can underline the importance of our study. Indeed, on the one hand, the innovative approach of the proposal contributes to scientific knowledge by proposing a new framework for lean deployment that provides solutions to some of the problems raised in the literature. On the other hand, its practical implications are relevant in the business environment, as it provides a tool for improving competitiveness.

In summary, to the best of the author's knowledge, the proposed framework is the only one with the above-mentioned characteristics, offering new possibilities for managers and practitioners in relation to LM implementation.

8. Extension and Limitations

In relation to a possible extension of the framework:

- The framework is applicable to companies in different sectors, although some aspects would need to be adapted for its application to service companies. In particular, the Lean assessment criteria would need to be modified, introducing some factors related to service companies and removing or restricting others, such as those related to TPM or set-up times.
- In addition, the framework could be applied more precisely to companies in specific sectors. Thus, considering that each sector has certain specific characteristics, different frameworks could be created for each sector, e.g. for chemical companies, for aerospace companies, etc. This would allow for a more in-depth analysis and therefore a better possible application. This would allow for a more concrete analysis and possible better implementation.
- The process of selecting the actions to be implemented could also be improved and a clearer system could be established. In this way, the involvement of the Lean expert could become less important.
- Finally, a specific set of indicators could be proposed at the outset. Indeed, given that companies applying this methodology often have a clear need for improvement, some specific indicators could be defined in advance, which would help to better target actions and better measure the effectiveness achieved.

In relation to the main limitations:

- Firstly, although a thorough literature review has been carried out, it is possible that some aspects of Lean implementation have been overlooked and may have influenced the development of the proposed framework.
- On the other hand, although the results obtained in the 6 companies have been positive, the application of the framework does not guarantee that the implementation will always be successful. Indeed, there are many factors affecting the process that can influence the results, such as the understanding of the framework by those involved, the quality of data and evaluation, the selection of actions, among many others.

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Annex I

LEAN DIMENSIONS		FACTORS	EVALUATION (1-5)	GLOBAL
1.Suppliers Feedback	1.1.	We frequently are in close contact with our suppliers		
	1.2.	Our suppliers seldom visit our plants		
	1.3.	We seldom visit our supplier's plants		
	1.4.	We give our suppliers feedback on quality and delivery performance		
	1.5.	We strive to establish long term relationships with our suppliers		
2.Suppliers JIT	2.1.	Suppliers are directly involved in the new product development process		
	2.2.	Our key suppliers deliver to plant on JIT basis		
	2.3.	We have a formal supplier certification program		
3.Suppliers development	3.1.	Our suppliers are contractually committed to annual cost reductions		
	3.2.	Our key suppliers are located in close proximity to our plants		
	3.3.	We have corporate level communication on important issues with key suppliers		
	3.4.	We take active steps to reduce the number of suppliers in each category		
	3.5.	Our key suppliers manage our inventory		
	3.6.	We evaluate suppliers on the basis of total cost and not per unit price		
4.Customers involvement	4.1.	We frequently are in close contact with our customers		
	4.2.	Our customers seldom visit our plants		
	4.3.	Our customers give us feedback on quality and delivery performance		
	4.4.	Our customers are actively involved in current and future product offerings		
	4.5.	Our customers are directly involved in current and future product offerings		
	4.6.	Our customers frequently share current and future demand information with marketing department		
	4.7.	We regularly conduct customer satisfaction surveys		
5.Pull	5.1.	Production is pulled by the shipment of finished goods		
	5.2.	Production at stations is pulled by the current demand of the next station		
	5.3.	We use a pull production system		
	5.4.	We use Kanban, squares, or containers of signals for pdocution control		
6.Flow	6.1.	Products are classified into groups with similar processing requirements		
	6.2.	Products are classified into groups with similar routing requirements		
	6.3.	Equipment is grouped to produce a continuous flow of families of products		
	6.4.	Families of products determine our factory layout		
	6.5.	Pace of production is directly linked with the rate of customer demand		
7.Setup	7.1.	Our employees practice setups to reduce the time required		
	7.2.	We are working to lower setup times in our plant		
	7.3.	We have low set up times of equipment in our plant		
	7.4.	Long production cycle times prevent responsing quickly to customer requests		
	7.5.	Long supply lead times prevent responding quickly to customer requests		
8.SPC	8.1.	Large numer or equipment / processes on shop floor are currently under SPC		
	8.2.	Extensive use of statistical techniques to reduce process variance		
	8.3.	Charts showing defect rates are used as tools on the shop-floor		
	8.4.	We use fishbone type dyagrams to identify causes of quality problems		
	8.5.	We conduct process capability studies before product launch		
9.Employees involvement	9.1.	Shop-floor employees are key to problem solving teams		
	9.2.	Shop-floor employees drive suggestion programs		
	9.3.	Shop-floor employees lead product/process improvement efforts		
	9.4.	Shop-floor employees undergo cross functional training		
10.TPM	10.1.	We dedicate a portion of everyday to planned equipment maintenance related activities		
	10.2.	We maintain all our equipment regularly		
	10.3.	We maintain excellent records of all equipment maintenance related activities		
	10.4.	We post equipment maintenance records on shop floor for active sharing with employees		

Criteria for evaluation:
Level 1: The aspect has not been implemented at all.
Level 2: The aspect has been implemented in a specific area or machine, but no results or conclusions have been obtained yet.
Level 3: The aspect has been implemented in a specific area or machine and the results are as expected. Some conclusions have also been drawn.
Level 4: The aspect has been implemented in several areas or machines, but no results or conclusions have been drawn yet.
Level 5: The aspect has been implemented in all areas of the company. The results obtained are as expected.

Source; The author based on the approach proposed by (Shah & Ward, 2007)