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# A New Framework to Support Lean Six Sigma Deployment in SMEs

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## Abstract

**Purpose** - The purpose of this paper is to propose an assessment approach to evaluate the organizational capabilities to deploy a Lean Six Sigma (LSS) strategy.

**Design/methodology/approach** – Based on a comprehensive literature review, critical success factors required to deploy LSS were defined. These key factors are evaluated by a questionnaire based on maturity grids and structured as a multi-criteria model to compute a potential LSS performance indicator. This approach is illustrated through two case studies.

**Findings** – To promote a successful implementation of LSS in SMEs, it is necessary to consider five main critical factors. The evaluation of these factors could be achieved thanks to a multi-criterion-based maturity indicator for the LSS implementation. The case studies show that this approach allows SMEs to understand their strengths and weaknesses and thus better prepare the implementation of LSS.

**Research limitations/implications** – The proposed tool identifies characteristics of companies leading to successful LSS implementation; but is not yet able to provide a detailed strategy to improve them. The case studies were applied to manufacturing companies; therefore, there is no evidence of conclusions in the context of services.

**Practical implications** – The proposed methodology will help managers and practitioners to evaluate the readiness level of a company to implement LSS. Then, estimate the effort required to achieve the LLS deployment

**Originality/value**– This paper proposes a new metric of the capacity to implement the LSS successfully in SMEs: the Lean Six Sigma Global Index. This indicator is based on a survey completed by managers and supported by observable phenomena to establish a tailored diagnosis before the LSS implementation.

**Keywords:** Lean Six Sigma, SMEs, AHP, Assessment tool, Maturity grid

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## **1. Introduction**

Within the context of globalization, small and medium enterprises (SMEs) have been confronted with fierce competition. SMEs are, more than ever, forced to rationalize resource utilization and constantly improve the effectiveness of the entire organization. Integrating world-class manufacturing and organizational strategies such as Lean Six Sigma (LSS), among others, becomes of paramount relevance to build up the firm's competitive advantage.

The productivity gains that companies obtain after the implementation of methodologies such as Lean production or Six Sigma are unmistakable (Mason et al., 2015). But the implementation of this type of initiative is difficult in certain cases, because not all companies have the same context, resources or capabilities (Antony et al., 2016; Antony and Banuelas, 2002; Wessel and Burcher, 2004). SMEs generally have difficulties mobilizing the necessary resources for the deployment of these strategies (Etemad, 2009). Moreover, these types of manufacturing strategies have been mainly conceived to be deployed in large organizations. As a consequence, for SMEs to deal with such a type of project is a risky decision that must be prepared in a convenient manner.

Several authors highlighted the difficulty of integrating those methods by the SMEs (Antony et al., 2005; Kumar et al., 2014; Pingyu and Yu, 2010; Vienazindiene and Ciarniene, 2013). However, despite the difficulties, it is possible to deploy these methodologies in SMEs context (Antony, 2008; Antony et al., 2016).

Some studies have identified certain factors that favor the implementation of these methodologies in SMEs. For example, Achanga et al. (2006) identified that the key factors in the success of Lean implementation in SMEs are leadership, skills and expertise, financial capacity and organizational culture. For Dora et al. (2013), organizational culture is an important factor in the implementation of Lean; they added within this dimension the skills of employees and internal experience.

Authors like Raja Sreedharan and Raju (2016), Yadav and Desai (2016) and Muraliraj et al. (2018) show a lack of models for the LSS implementation in companies; Timans et al. (2016) highlights the need for specific LSS deployment frameworks in SMEs, because regular tools are complex for SMEs context (Ben Romdhane et al., 2017). There appears to be no adapted approach to strategically guide the implementation of LSS based on a particular SMEs's

available resources and skills. Therefore, the objective of this work is the development of an assessment tool to determine the SMEs' capabilities necessary for the organization to deploy an LSS project.

The proposed assessment is based on the principle of the analytical hierarchical process (AHP) multi-criteria decision aid method (Saaty, 1987, 1990) and maturity grids. The multi-criteria model is used to structure the tool, and the grids are used to perform the evaluation. First, to develop the LSS readiness assessment, a review of the literature was performed, enabling authors to identify the key factors and activities determining the success of LSS projects in small companies. Second, a group of experts validated these factors and defined the maturity grid levels associated with their evaluation. Finally, the set of factors and activities was aggregated using the AHP-based method to propose an index called Lean Six Sigma Global Index (LSSGI) which determines the global readiness of the firm to integrate LSS and according to this diagnosis establish a set of actions to be accomplished to mitigate the process's fail risk.

The remainder of the paper is organized as follows: Section 2 gives an overview of the LSS concepts and SME features. Section 3 describes the proposed methodology. In Section 4, two illustrative case studies of application in manufacturing firms are described. This application is discussed in Section 5, and managerial implications are examined in Section 6. Finally, limitations and future research are presented in Section 7. actions to be accomplished in order to mitigate the process's fail risk.

## **2. Overview of the Lean Six Sigma and small and medium enterprises**

### ***2.1 Lean Production, Six Sigma and Lean Six Sigma***

Lean Production was born in the Toyota production system. Lean is a system formed by a set of principles and tools with the objective of eliminating the waste in a manufacturing process (Liker 2004). Waste is any item that does not generate added value (Womack & DT 2003) and the idea is to highlight what adds some value to the customer or process, eliminating the others (Barbosa et al. 2013). In fact, if the waste of the process is eliminated, product quality will increase and the time and production costs will decrease.

The researchers of Lean (Massachusetts Institute of Technology, Toyota, etc.) originally identified seven areas of waste that must be eliminated: transport, inventory, waiting times, overproduction, excess of processing, defects and unnecessary movement (Womack & DT 2003; Ohno 1988). Other important concept in Lean are Just in Time (JIT) and Autonomation (Jidoka) (Elmoselhy 2013; Hedelind & Jackson 2011).

In addition, Six Sigma is a methodology developed at General Electric Co. for increasing quality based on the DMAIC (Define, Measure, Analyse, Improve and Control) methodology, which looks for improvements of the process by means of the elimination of variability in the product. The rate of defects or errors should be reduced by eliminating variability, so to get the maximum customer satisfaction (Antony & Banuelas 2002; Smith 2003; Antony et al. 2005).

Roughly speaking, the profits that the implementation of Six Sigma brings are the improvements of product quality, which is associated with customer satisfaction and increase in sales, while production costs also decrease because the waste generated by the errors decreases (Pakdil & Leonard 2014; Kumar et al. 2014; Arslankaya & Atay 2015).

Finally, although Lean Production and Six Sigma are two methodologies that have been developed in different ways and with different points of views, they are complementary as they share some goals and deployment strategies. Consequently, several authors proposed the term Lean Six Sigma, which combines the two ideas (Arnheiter & Maleyeff 2005; Hoerl & Snee 2010; Zajkowska 2012; Mantilla Celis & Sánchez García 2012; Maleyeff 2012; Chan et al. 2014; Panat et al. 2014). This new methodology exploits the methodological structure and the statistical tools of Six Sigma with the principles of the process that manages Lean. The goal is to reduce costs without compromising quality and service, because for the customer the quality and the characteristics of the product are as important as the price. When Lean and Six Sigma are unified, it creates a synergy that enhances the strength and reduces the weaknesses of each method taken separately, which is the reason that many companies opt for the combination of the two.

## ***2.2 Barriers and Challenges for small and medium enterprises***

Beyond the classification by number of workers, turnover or balance sheet total, the importance of SMEs lies in their rising participation in the economy, innovation and R&D (Antony et al., 2016). Authors such as Lande et al. (2016) and Belhadi et al. (2017) use previous work to highlight the importance of SMEs in terms of total companies, economic

growth and job supply. They also explain that SMEs are exposed to fast changes in the business scenario and increasingly demanding customers. Therefore, to comply with quality requirements and delivery times, among others, SMEs must attack waste such as inventory and variations. In this context, the adoption of new methodologies focusing on quality and flow such as Lean, Six Sigma or LSS appears as an alternative.

Lean and Six Sigma have been researched by various stakeholders (universities, consulting groups, research laboratories, etc.), generating a large amount of literature on the experiences of these methodologies in large companies. However, some authors claim that there is a lack of information on Lean and Six Sigma experiences in small companies

(Antony et al., 2005; Pingyu and Yu, 2010; Timans et al., 2016), making the deployment of continuous improvement methodologies complex in this type of company (Barbosa et al., 2013). More recently, other articles have related the links between Lean, Six Sigma or both and SMEs. Antony et al. (2017) summarizes some of the papers presented in the literature on LSS in SMEs. The positive results obtained by some companies in terms of cost reduction and company performance are highlighted. Other authors also summarize previous trying to implement Lean or LSS in SMEs (Belhadi et al., 2017; Lande et al., 2016), and conclude that in most cases the expected results are not achieved. One of the reasons is that there are a number of barriers to the success of solutions in SMEs (Belhadi et al., 2017; Yadav and Desai, 2017). Knowing the list of barriers is important because companies cannot mitigate them all at the same time. Belhadi et al. (2017) identify in the literature 20 barriers to Lean implementation in SMEs. It then ranks the barriers, concluding that the five most important are the lack of management involvement, a lack of methodology adapted to Lean implementation, short-term vision, fear and resistance to change and, finally, a failure to understand Lean. Yadav and Desai (2017) also aim to identify and prioritize the barriers which hinder the implementation of LSS in companies. 27 barriers were identified from the existing literature, the five most important being “lack of management attitude, commitment and involvement”; “lack of LSS project training and education”; “lack of strategic planning”; “lack of technological resources”; and “lack of financial resources”.

However, some of the barriers presented by the research are not specific to LSS projects but are typical features of SMEs. One is the limited availability of economic resources and time. The difficulty for SMEs to provide a budget for deploying these methodologies is

documented (Antony et al., 2005). For this reason, some SMEs drop the idea of implementing LSS because they appeal to consultants who are not always SMEs experts and then face exorbitant fees. Also, SMEs have little availability of time (Antony et al., 2005; Kundu and Manohar, 2012; Smith, 2003). The time needed to deploy an LSS project is variable, but it is always a long-term process, because training employees and making changes is time consuming and difficult, as employees are essential to the daily operation of the company (Antony, 2008). Lack of training is another characteristic of SMEs (Kumar et al., 2014; Suárez et al., 2011), together with failure to define their objectives and a strategic vision, internal resistance to change, poor employee participation and ineffective communication (Kumar et al., 2014).

To overcome these barriers, the next section will propose an original approach based on a set of factors allowing SMEs to increase their probability of success in an LSS project.

### **3. Proposed Methodology**

The objective of this study is to develop an assessment tool for SMEs that allows us to prepare an implementation plan appropriate to each company. In the literature, several studies attempt to evaluate the companies with respect to Lean Production or Six Sigma. Khadem et al. (2008) seek to evaluate the companies focused on the performance of Lean Manufacturing system in terms of production rate, quality, lead-time, etc. without considering the financial and accounting aspects. Maasouman and Demirli (2015) propose a framework for assessing if the company follows the path of implementation initially defined in the project. Pakdil and Leonard (2014) propose the Leanness Assessment Tool (LAT) to measure the effectiveness and efficiency of Lean implementation. In a review of 2,407 works over a 30-year period, Raval and Kant (2017) found a total of 58 Lean, Six Sigma or LSS frameworks. Each of them was analyzed under different parameters (novelty, source, verification, etc.) to make comparisons. One conclusion is that academics have proposed more frameworks than consultants. In addition, the case study is the most widely used method of verifying frameworks, showing that LSS is in the early stages of development. Of the 58 papers found, only 13 mention a framework that focuses on Lean, Six Sigma or LSS implementation. Timans et al. (2016) propose a framework based on “Kumar, M., Antony, J., and Tiwari, M. K. (2011). Six Sigma implementation framework for SMEs”, to facilitate the implementation of LSS in SMEs. The methodology initially proposed has four phases, but in this revised version, it is reduced to three and presents a multi-step roadmap for the

implementation of LSS in SMEs. The phases are recognize and prepare, initialize, institutionalize and sustain.

From the previous research studies mentioned before, Timans et al.'s (2016) is the closest to giving a proposal that considers a specific tool for SMEs starting from the step of “recognise the need to change”. In fact, the authors argue that there is a need for an implementation framework to deploy LSS in SMEs and that the success of this project depends on the consideration of the specific properties of SMEs. However, this paper proposes a roadmap for the implementation of LSS in SMEs, but lacks a prior assessment of the capacities of SMEs to guide and prepare an appropriate LSS implementation project.

An analogy could be made with the field of innovation capabilities management in SMEs, which has evolved from input- and output-based assessment models to evaluating the internal practices that characterize a company’s potential to successfully pilot innovative projects (Boly et al., 2014; Chiesa, 1996). These models are currently used as tools for managing the innovation capability in companies. The construction of these models is based on identifying a list of factors or practices that promote the innovation of companies; this group of factors is then aggregated by means of a multi-criteria method obtaining a global indicator of innovation capability. From the new trends in evaluating innovation practices, maturity grids are defined to assess the performance level in each practice (Boly et al., 2014, 2016; Morel, 2007). As the objective of the present research is to evaluate the capability of an SME to develop LSS projects, the characteristics of innovation capability management models will be taken as a framework. Thus, the research was conducted following a five-stage methodology, as shown in Figure 1.

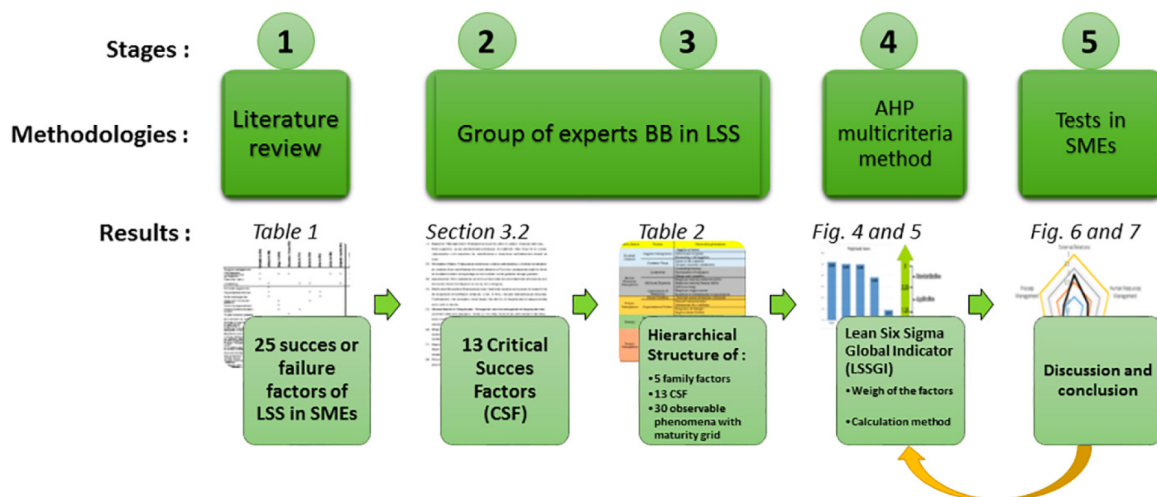




Figure 1. Overview of the research methodology

The first stage is the *literature review*: the aim is to identify the list of factors that are related to the success or failure of LSS in SMEs. Subsequently, in stage 2 the factors are validated and defined by an expert group to define the set of Critical Success Factors (CSF). Then, in stage 3, a hierarchical structure is established and the maturity grids are defined to complete the evaluation method. In the fourth stage, the AHP multi-criteria method allows us to weigh the factors with the help of an expert group and to define the calculation method of the final indicator. Finally, the tool obtained is tested in companies from different countries (Chile and France), which yields the first results and conclusions.

### 3.1 Literature Review

In the review of the literature, is important to identify the Critical Success Factors that help us overcome the barriers to implement a LSS project (section 2.2). For Boynton and Zmud (1986) the CSF are the factors that, if present, ensure the success of a project. Other writers, such as Mann and Kehoe (1999), argue that a good identification of the CSF encourages the development of an appropriate action plan in project implementation.

Table 1 summarizes the CSF identified in the scientific literature linked to the implementation of methodologies such as LSS in SMEs. Some of them, such as *management involvement* or *education and training* were commonly cited but others have resulted from specific studies. At the end of this stage, a list of 25 potential factors was then obtained.

Table 1. List of Potential Factors

	Supplier management	Management involvement and participation	Customer focus	Leadership	Financial capabilities	Organizational culture	Skills and expertise	Good communication platform	Learning organizations
(Hibadullah <i>et al.</i> , 2014)	x	x	x						
(Achanga <i>et al.</i> , 2006)				x	x	x	x		
(Pingyu and Yu, 2010)		x						x	x
(Vienazindiene and Ciarniene, 2013)		x							
(Bakás <i>et al.</i> , 2011)				x					
(Kumar <i>et al.</i> , 2014)				x		x		x	
(Dora <i>et al.</i> , 2013)						x	x		
(Antony <i>et al.</i> , 2005)		x							
(Raghunath and Jayathirtha, 2014)		x		x					
(Kumar <i>et al.</i> , 2009)		x	x					x	
(Timans <i>et al.</i> , 2012)	x	x					x		
(Abu Bakar <i>et al.</i> , 2015)		x		x					
(Lande <i>et al.</i> , 2016)		x	x	x					
(Stankalla <i>et al.</i> , 2018)		x						x	

(continued)

	Performance evaluation system	Implementation process	Environment for change	Sufficient time for preparing the organization	Creating motivation to complete initiatives	Education and training	Linking LSS project to employees, customer and/or suppliers	Project management skills
(Hibadullah <i>et al.</i> , 2014)								
(Achanga <i>et al.</i> , 2006)								
(Pingyu and Yu, 2010)	x							
(Vienazindiene and Ciarniene, 2013)		x	x			x		
(Bakás <i>et al.</i> , 2011)	x			x	x	x		
(Kumar <i>et al.</i> , 2014)						x	x	x
(Dora <i>et al.</i> , 2013)								
(Antony <i>et al.</i> , 2005)						x	x	x
(Raghunath and Jayathirtha, 2014)						x		
(Kumar <i>et al.</i> , 2009)						x	x	x
(Timans <i>et al.</i> , 2012)						x	x	x
(Abu Bakar <i>et al.</i> , 2015)						x	x	x
(Lande <i>et al.</i> , 2016)						x	x	
(Stankalla <i>et al.</i> , 2018)							x	

(continued)

	Link LSS project to business strategy	Cultural change	Organizational infrastructure	Project periodization and selection	Understanding LSS methodology	Utilization of LSS tools	Vision and plan statement	Development of project leader's soft skills
(Hibadullah <i>et al.</i> , 2014)						x		
(Achanga <i>et al.</i> , 2006)								
(Pingyu and Yu, 2010)								
(Vienazindiene and Ciarniene, 2013)								
(Bakás <i>et al.</i> , 2011)								
(Kumar <i>et al.</i> , 2014)	x							
(Dora <i>et al.</i> , 2013)								
(Antony <i>et al.</i> , 2005)	x	x	x	x	x			
(Raghunath and Jayathirtha, 2014)	x					x		
(Kumar <i>et al.</i> , 2009)	x	x		x				
(Timans <i>et al.</i> , 2012)	x	x	x	x	x		x	x
(Abu Bakar <i>et al.</i> , 2015)	x		x	x				
(Lande <i>et al.</i> , 2016)		x		x	x			
(Stankalla <i>et al.</i> , 2018)	x		x					

### 3.2 Definition of the of the critical success factors

After the literature review, the list of 25 potential factors was submitted to a group of experts for validation. The experts were consultants and researchers certified Black Belt in LSS. For validation, in a roundtable the experts chose, after a Delphi type consensus, they regrouped and defined the final factors based on their frequency of appearance in the literature and the importance they had. Finally, the list of 13 final factors and their definitions are as follows:

- (1) **Supplier Management:** Companies must be able to select, manage and control their suppliers, using standardized processes. In addition, they must have a close relationship with suppliers by establishing a long-term collaboration based on trust.
- (2) **Customer Focus:** Companies must have a close relationship with their customers, by making their satisfaction the main objective. For this, companies need to listen to customer needs and perhaps involve them in the product design process.
- (3) **Leadership:** The leadership style must facilitate the development of projects and the achievement of objectives set by the company.

- (4) **Skills and Expertise:** Companies must facilitate employee training to benefit the development of different projects, even if they include technological changes. Furthermore, the company must boost the ability of employees to communicate and work in teams.
- (5) **Commitment of Employees:** Companies must be composed of employees that are motivated and engaged, which is why they need to be stimulated to develop their tasks allowing them autonomy for certain decisions. Stimuli can be economic or improvements in working conditions.
- (6) **Organizational Culture:** Companies must be able to integrate a culture of continuous improvement that should favour their flexibility and their processes of communication at an internal level as much as an external.
- (7) **Strategy and Objectives:** The strategy of the company has to clarify the objectives and the orientation both internally and externally. This strategy must communicate within the entire organization in defining the resource allocation.
- (8) **Financial capacity:** Companies must have the resources to finance various projects, staff training and possible structural changes within the organization.
- (9) **Just in time (JIT):** Companies must promote cost reduction solutions to increase the organization's profits. The implementation of JIT seeks to reduce lead-time and inventories.
- (10) **Quality management:** Companies must have initiatives related to quality management, such as obtaining certifications, or practice certain TQM tools.
- (11) **Measure and control:** Companies must have systems and methods of measurement to identify and evaluate the key variables (those that are important to control).
- (12) **Information management:** Companies must be able to distribute, store and process information effectively within the organization to make informed decisions based on data analysis.
- (13) **Project Portfolio:** Companies must be able to define the most important projects to be developed, which allows them to prioritize projects and manage the resources accordingly.

### **3.3 Tool Design**

#### *3.3.1 Hierarchical Structure*

The first step is to consider the number of factors chosen, because authors such as Miller (1956) state that short-term memory is limited to a capacity of seven (plus or minus two) elements. Thus, the 13 factors should be regrouped to structure the multicriteria model and facilitate the understanding of experts. In this way, similar factors were aggregated in groups called “Families”. We identified five families, described as follows.

- (1) External Relations: This is evaluating all activities of the company towards its environment, such as suppliers and customers.
- (2) Human Resources Management: This is to assess the leadership aspects in business, including the management skills and commitment of employees at work.
- (3) Project management: This is to evaluate all activities related to corporate projects and the existence of an organizational culture.
- (4) Strategy: This is to evaluate short-term and long-term how the company manages its objectives, and finances their implementation.
- (5) Process management: This evaluates all activities related to the company's production system: production processes, management information, and measures and controls.

It is therefore necessary to define the activities or processes that we will use to evaluate the factors. These activities should be repetitive and measurable allowing allocation of resources to improve them. These activities or processes are called “observable phenomena” and must be associated by the group of experts with one of the 13 factors identified in section 3.2. The group of experts assigned the observable phenomena necessary to evaluate each factor. For example, for the factor “Measure and Control” the observable phenomena are “visual management tools”, “Data treatment registers” and “An active measurement system”.

Table 2 presents the hierarchy with three levels: 5 families of factors, 13 factors and 30 observable phenomena.

Table 2. Framework structure with three levels of aggregation.

Family factors	Factors	Observable phenomena
External relations	Supplier Management	Supplier selection
		Control and reception
		Partnership with suppliers
	Customer Focus	Listen to the customer
Measure customer satisfaction		
Human Resources Management	Leadership	Leadership training
		Participation of managers
		Change and versatility
	Skills and Expertise	Employee training (technical skills)
		Employee training (human skills)
		LSS knowledge
	Commitment of Employees	Employee empowerment
Existence of redistribution or gain sharing		
Project Management	Project Portfolio	Selection and prioritization of projects
	Organizational Culture	Internal communication
		Information for workforce
		Frequency of changes
		Improvements Culture
Strategy	Strategy and Objectives	Existence of a shared strategic vision
		Shared goals
	Financial Capacity	Capacity to finance projects
		Frequency of calls to external consultants
Process Management	LSS tools	Existence of LSS tools
		Existence of TRS
	Quality Management	Quality certifications
		Process of continuous improvement
	Measure and Control	Visual management tools
		Data treatment registers
		An active measuring system
	Information Management	Efficient computer system

### 3.3.2 Definition of the Evaluation Method

The lower aggregation level (Observable phenomena) forms the basis for the construction of the proposed assessment. Consequently, we have to define the evaluation method. In this case, the maturity grid was chosen (Paulk et al. 1996; Maier et al. 2012).

The maturity grid is a tool used to evaluate or improve a process, because it bases its operation on a scale of levels where each level represents a degree of maturity, also known as a “behaviourally anchored scale” (Grant & Pennypacker 2006). This methodology has a large scope since it can be used to evaluate all business processes (Maier et al. 2012).

The scale levels have to show an ascending progress starting at the minimum (level zero) and reaching a maximal level (total maturity). The number of intermediate levels is not fixed

and will depend on the characteristics of the process to be measured. It must be a progressive ascent, because the intermediate levels must show the way to reach the maximum level of maturity. In addition, the maturity grid makes it possible to reduce subjectivity, because it uses accurate descriptive texts to characterize completely each level of maturity.

In this way, it is necessary to associate a grid of maturity to each observable phenomenon. In our case, four levels of maturity for each grid were considered, in order to avoid the tendency of the evaluators to mark the central option. Each level is associated with a numerical value that later allows us to calculate the global indicator. For the first level the value is zero; for the second it is one, two for the third level, and three for the last level. Consequently, an assessment questionnaire of 30 questions was structured (a question is a maturity grid) with the objective that is answered by the managers of the companies.

An example of a question is presented in

---

How the company does select its suppliers? In the enterprise, there is a system or a supplier selection process?

I	II	III	IV
The company has no type of supplier selection system	The selection of suppliers is punctual, there are not selection systems	Supplier selection is performed using some methodologies but non-standardized	There is a working group that is responsible for the search and selection of suppliers, applying a defined and standardized protocol

**Note:** Supplier management (Practice), i. Supplier selection (Observable phenomenon)

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Table 3.

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How the company does select its suppliers? In the enterprise, there is a system or a supplier selection process?

I	II	III	IV
The company has no type of supplier selection system	The selection of suppliers is punctual, there are not selection systems	Supplier selection is performed using some methodologies but non-standardized	There is a working group that is responsible for the search and selection of suppliers, applying a defined and standardized protocol

**Note:** Supplier management (Practice), i. Supplier selection (Observable phenomenon)

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Table 3. Example of a question

**3.4 Analytic hierarchy process tool development**

With the hierarchical structure defined and the questionnaire formulated by maturity grids, it is necessary to consolidate the result of evaluation in an overall score that also considers

the opinion of the expert group. Among the different Multi-Criteria Decision Analysis methods (MCDA), the indicator will be structured using the AHP method.

The AHP(Saaty 1987; Saaty 1990) is a method to help decision-making and allows the resolution of multi-criteria problems. The main advantages are that it allows us to easily weigh the criteria using expert opinion and may include the three levels of aggregation defined before. Moreover, it enables us to validate the coherence of the decision makers' preferences thanks to the Consistency Index (CI), which measures the deviation of the judgements from the consistent approximation(Saaty 1990).

The use of AHP in the context of Lean, Six Sigma or LSS is not new; it is advocated by many authors. My Abdelbar et al. (2017) proposes a combination of AHP with Six Sigma to formulate a new maintenance process to improve quality rate. Ben Romdhane et al. (2017) use the AHP for the selection of an appropriate improvement action in the implementation of six-sigma in SMEs.

However, AHP has generally been used to prioritize barriers, enablers or CSFs of Lean, Six Sigma or LSS (Belhadi et al., 2017; Yadav et al., 2018; Yadav and Desai, 2017). For the reasons previously exposed, we can conclude that AHP is a valid tool for the prioritization of CSFs, given its ability to combine a hierarchical structure of several levels and the opinion of various experts.

To use AHP criteria the following procedure was implemented:

#### *3.4.1 Structuring of the problem as a hierarchy*

This is a key characteristic of AHP, consists in modelling our problem as a hierarchy. At the top you will find the objective, in the middle the criteria to consider and below, the alternatives.

In this case, the hierarchy is based on the three levels presented in Table 2. At the top is the goal, that is, the calculation of an index. Then, the intermediate levels are composed by the families of factors, factors and observable phenomena.

### 3.4.2 Establish priorities between factors

From the literature review, it was found that not all the authors agreed in which success factor is the most important for the implementation of LSS in SMEs. An example of this discrepancy is that for Achanga et al. (2006) the most important factor is "leadership", while for Dora et al. (2013) is "skills and expertise". Therefore, in the development of indicator no all factors have the same degree of importance in the capacity of SMEs to develop the LSS and the literature does not allow us to determine the relative importance.

To obtain the weight of each factor, a questionnaire AHP for weighting was built. The questionnaire consisted of several pairwise comparisons (for factors at the same aggregation level) where experts were to mark their preference between one and the other factor using the Saaty Scale (Saaty 1987). The questionnaire was sent to a group of 30 experts in Lean Six Sigma, obtaining 23 responses to the questionnaire. Later, we realized an analysis of the responses to evaluate the inconsistency and five responses were eliminated because they were contradictory or had great inconsistency ( $CI > 20\%$ ). Therefore, 18 valid responses were obtained, corresponding with LSS experts, all of them with Black Belt or Master Black Belt certification. The group of 18 experts was composed of five consultants, specialists in LSS, six managers responsible for the improvement of performance in established companies and seven research professors from the University of Lorraine.

Finally, the individual assignments were then aggregated in an overall weighting of each factor. The weights obtained for the families of factors are shown in

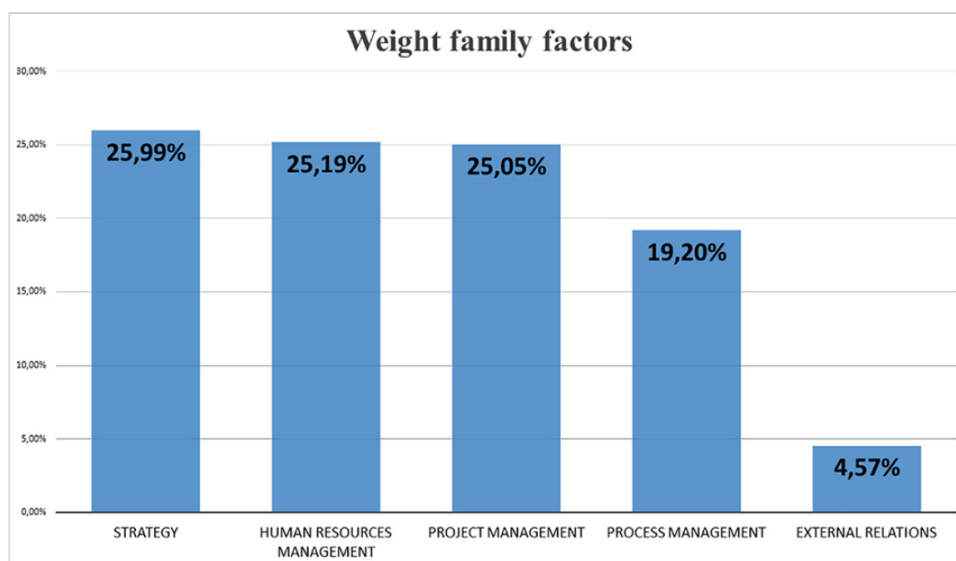




Figure 2:

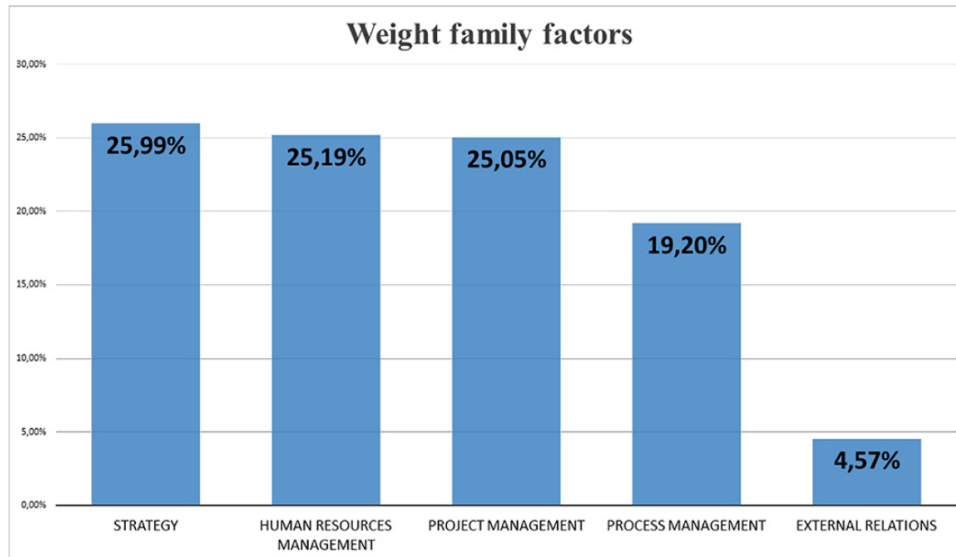


Figure 2. Weight obtained by family factors

### 3.4.3 Calculation of the indicator: The Lean Six Sigma Global Index (LSSGI) and classification of companies

Thanks to the weights obtained in the previous section, the evaluations of maturity grid and the aggregation method of AHP (weighted average), it is possible to build the model of the proposed index, which is called Lean Six Sigma Global Index (LSSGI) and has a minimum value of zero and a maximum of three (according to the values associated with the levels of maturity grid, section 3.3.2). One of objectives of the LSSGI is to categorize the companies in one of the categories presented in Figure 3, according to the value obtained.

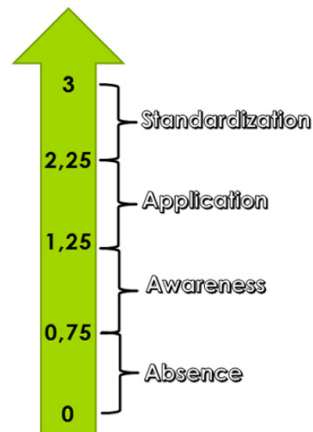


Figure 3. Categories and limit values for the LSSGI

These categories are based on the AIDA model (Petit et al. 2011; Rawal 2013; Enjolras et al. 2015), typically used in the context of sales and marketing. This model proposes a progressive scale of four levels that expose the cognitive phases that a client experiences before a new product or idea. The scale of 4 levels is: attention (A), then interest (I), desire (D) and action (A) (Hassan et al. 2015).

On the other hand, some research proposes adaptations of the AIDA model to other contexts than marketing and sales. Enjolras et al. (2015) (Enjolras et al. 2015) propose an adaptation for the assessment of the intellectual property in SMEs. Analogically, an adaptation of the AIDA model was made for the LSS in SMEs, proposing the following scale of categories:

- (1) *Absence*: The Company has no tools or skills that facilitate the implementation of LSS, thus the company has an unfavourable context that increases the probability of failure of implementation.
- (2) *Awareness*: The Company has some advantageous tools or contexts, but they are sporadic and not shared by the entire company.
- (3) *Application*: The Company knows present tools that support the implementation of LSS but these are not standardized. The probability of success is higher than in the previous categories.
- (4) *Standardization*: This Company usually standardizes its processes and activities. Therefore, the company has potential and favourable conditions that help increase the probability of success in the implementation of LSS.

Although no scales were found to categorize companies with respect to the potential to deploy LSS, another example of categorization is the four-level scale used by Galvez et al. (2013) to evaluate the potential of a company to innovate. The four levels proposed are “passive”, “reactive”, “preactive” and “proactive”. The first level corresponds to companies that have a defensive attitude and only think about surviving. The second is companies that only react to market demands. The third level is companies which do not initiate changes in the market, but have a good response through active technology watch. Finally, at the fourth level are the companies that generate changes in the market and work with a long-term vision.

#### ***4. Application of the LSSGI Tool in SMEs***

After presenting the LSSGI, the proposed methodology was applied to companies in different contexts. Two representative SME companies: a Chilean and a French company are presented in this section.

These companies were chosen because:

- being SMEs (fewer than 250 employees);
- not prior experience of Lean-Six sigma (LSS);
- managers’ motivation to start a program of LSS implementation; and
- availability of the required data and information.

Moreover, the choice was also to compare the assessment robustness in different contexts in France and Chile, where the research teams have direct contact with firms.

##### ***4.1.1 Case 1: Chilean company***

The first case is a Chilean SME that is dedicated to commercialize agricultural machinery and maintenance services. This company have a factory where they receive the disassembled

machines from Asia and later, they assemble and distribute the product, also offering the after-sale and maintenance services. In addition, this SME is in his first years of operation, so its efforts are focused on gaining market share. It has a workforce of 24 employees whom are composed by mechanical employees, technicians and managers. In this case, the evaluation was realized through a field visit to the company and interview with the manager.

The company obtained an IGLSS score of 1.51 out of 3 (maximum score), which ranks in the category of *Application* (see. Section 3.4.3). This means that the company has advantageous tools for the implementation of LSS, but it is necessary to standardize some of its processes to improve the context of business and increase the probability of success in the implementation of LSS. Furthermore, the analysis of the family factors' performance allows us to identify the strengths and weaknesses of the company. In this case, External

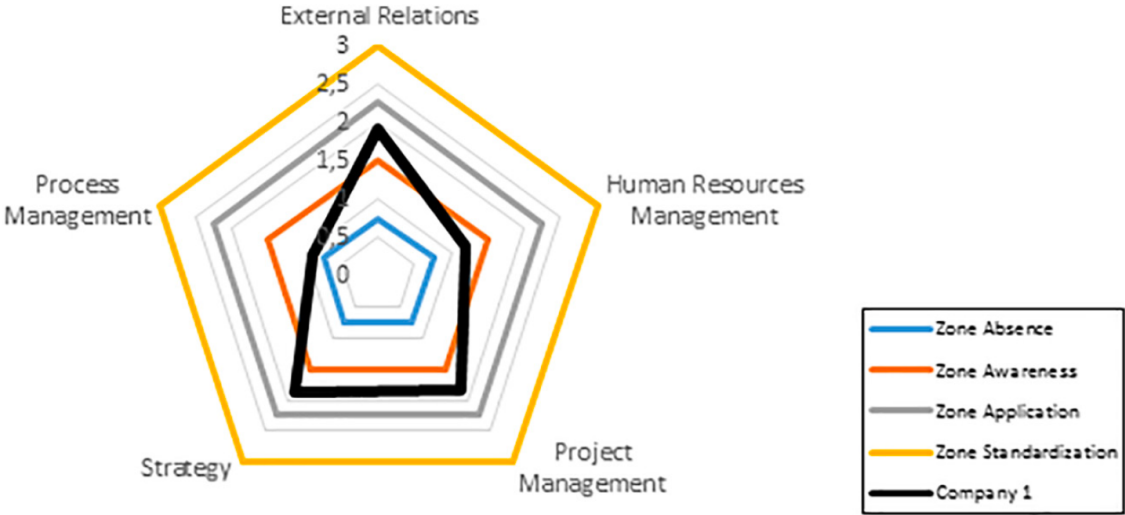


Figure 4).

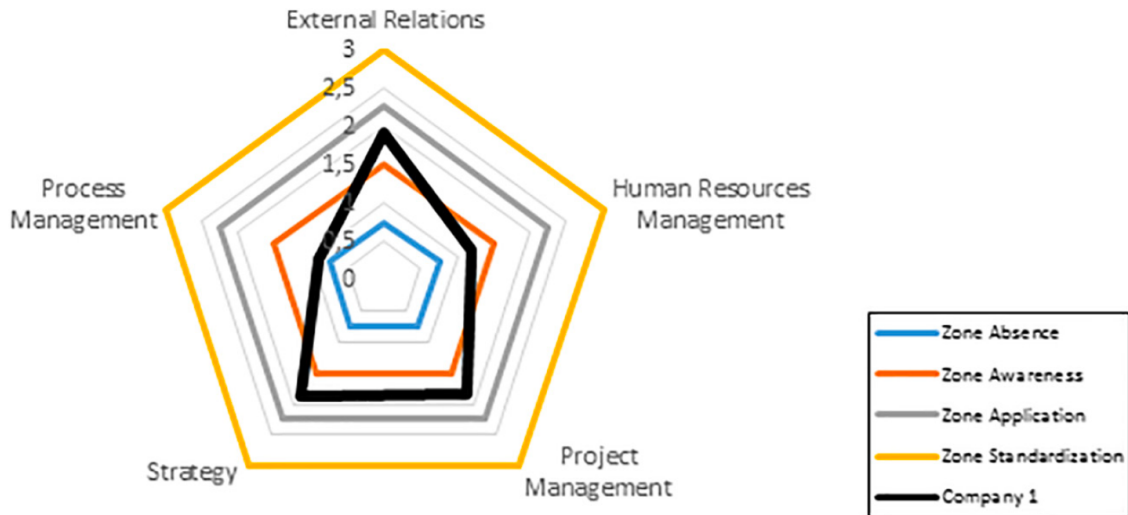


Figure 4. Performance for family factors Chilean company

Furthermore, it is also possible to identify two weaknesses: Process Management and Human Resources Management. To deepen the analysis, it is necessary to review the third level to identify the observable phenomena related to weak factors because they represent a barrier to successfully implement an LSS project.



Figure 5. Performance and expected value for each factor of weak families

In *Figure 5*, a comparison is made between the performance obtained and the expected score (final score) for each factor of the weak families. The gap between the two values is the magnitude that the company must improve to have an acceptable level in each factor.



Figure 6. Performance and expected value for observable phenomena of weak factors

Figure 6 shows the observable phenomena of two factors, both belonging to the Human Resource Management family. This analysis is deeper and allows identifying the gap for each phenomenon. In the case of skills and expertise, all phenomena were evaluated with the minimum value, therefore, the company must fully develop these processes or activities. On the other hand, in the case of commitment of employee, Redistribution or Gain Sharing is a phenomenon that must be improved to reach the expected value, while for Employee Empowerment resources should not be allocated because their evaluation is higher than the expected value.

For achieve the improvement of the phenomena, it is recommended to follow the proposed upper levels for each maturity grids. For example, to improve Process Management, it is necessary start initiatives to obtain certifications type ISO 9001 or similar to ignite formalization processes. Also, it is important integrate within the company routines the use of indicators of type TRS or OEE that allow to generate actions to improve the performance. In addition, it is necessary to establish and exhibit visual indicators that help to direct the activities and the integration of a metrology system. For this integration it is possible to begin an external system and ending with an internal service, competent and with periodic review. In relation to the second weakness of the company, to improve the evaluation of Human Resources Management, improvement actions should be oriented mainly to the training of employees in technical and human skills, in addition to promoting learning about the LSS methodology. For employees training, a policy of training must exist in order that the

workers periodically receive new knowledge and obtain certifications in different aspects that favour the achievement of the objectives of the company.

In the same way, all weak points must be analysed to see which observable phenomena are related and later, through the maturity grid, generate the action plan to achieve the improvement of the process or activity. It is important to note that the action plan must be associated with the company's strategy and must be shared by all members.

4.1.2 Case 2: French company

Case 2 is a company located in France that specializes in processing of plastic materials and has a workforce of 150 employees. For this company, the questionnaire was sent by email to Manager of Quality/Supply Chain.

In this case, the LSSGI obtained is 2.1 out of 3; therefore, the company is classified in the category of *Application*. However, despite being classified in the same category as company 1, there are marked differences in performance by family practices. As shown in figure 7, a strong point is Process Management and a low point is Human Resources Management.

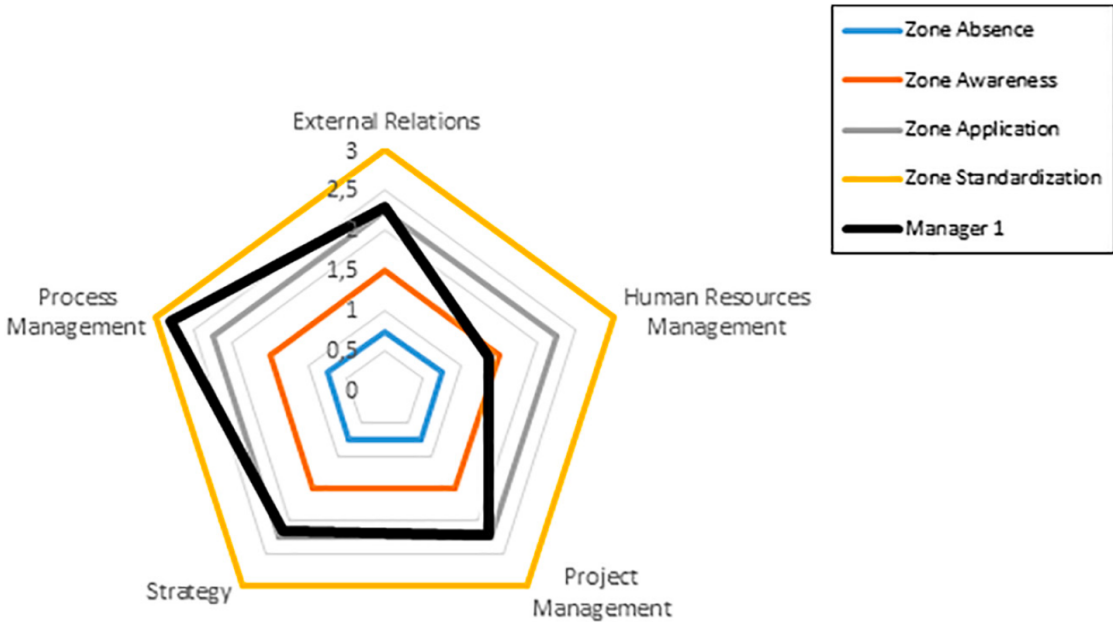


Figure 7. Performance for family factors of French company

Reviewing the answer given by the quality/supply chain manager, Process Management is a strong point of the company because six of the eight observable phenomena were evaluated

with the maximum score. The two phenomena that scored lower are “Existence of LSS tools” and “An active measuring system”.

As in the first case, training of the employees is a weak point and must be improved through effective training policies in technical, human and LSS aspects. In addition, the versatility of workers should be promoted, that is to say, that they are able to move without difficulties. This includes that each post of job must be defined and standardized. A reward system should be created that favours the generation of good ideas and employee actions. Rewards should not only be economical and can be individual or collective.

Comparing the first and second cases, it is possible to show some similarities in the performance of companies related to three families of factors: Strategy, Project Management and External Relations. The main differences are between Process Management and Human Resources Management. While a family factor is an strength for one company, but a weakness for the other.

## **5. Discussion**

In this paper, a review of the literature identified a group of critical factors that were validated and weighted by experts. These factors are important because they make it possible to increase the probability of success in a LSS project in SMEs. Our methodology leads us to highlight five main family factors, four of which are of similar weight: strategy (26 per cent), human resources management (25 per cent), project management (25 per cent) and Process management (19 per cent). The remaining family is external relations (5 per cent). Analyzing the hierarchical level of the factors, this paper shows that the most important factors are organizational culture, strategy and objectives, employee commitment, financial capacity, quality management and measurement and control.

Several articles consulted propose a ranking of critical factors based on their frequency of appearance in the literature. In this case, the weighting of the factors was done with the opinion of a group of LSS experts; all of them certified Black Belt or Master Black Belt.

Comparing the results obtained with other works, there are clear differences in the ranking order: while for us the most important factor is the “organizational culture”, for Timans et al. (2012) the most important factor is “linking to customer”, for Abu Bakar et al. (2015) it is “organizational infrastructure and Project management”, for Lande et al. (2016) the most



important is “training (employee involvement)” and for Stankalla et al. (2018) it is “topmanagement commitment”. Despite these differences in ranking of factor, several of them are common to all research work.

The fact that four factors have the same weight explains the difficulty for SMEs to develop LSS projects, because the company has to perform simultaneously in all four factors to increase the probability of success. The low weight of external relations (including customer focus) may seem surprising but can be explained by the customer-based approach already included in the LSS methodology, through tools such as voice of customer, critical to quality or takt time. It is therefore not necessary to make customer focus a prerequisite of the success of an LSS project.

From a conceptual point of view, the traditional representation of the Lean system as the Lean house with two pillars and a foundation could be completed for an LSS project as shown in Figure 8. We added a new foundation assessed by the LSSGI, which aim to evaluate its solidity. This represents our main conceptual contribution. In addition, assessment tools in the literature let you know the level of Lean maturity or the effectiveness of Lean implementation in the performance of a company (Khadem et al., 2008; Maasouman and Demirli, 2015; Pakdil and Leonard, 2014). But none helps to know the initial state of a company, prior to any LSS implementation project.

Timans et al. (2016) propose a support framework for the implementation of LSS in SMEs, based on four phases and a sequence of steps. While it is a framework that focuses on SMEs, it does not provide a metric of the potential for a company to deploy LSS prior to implementation.

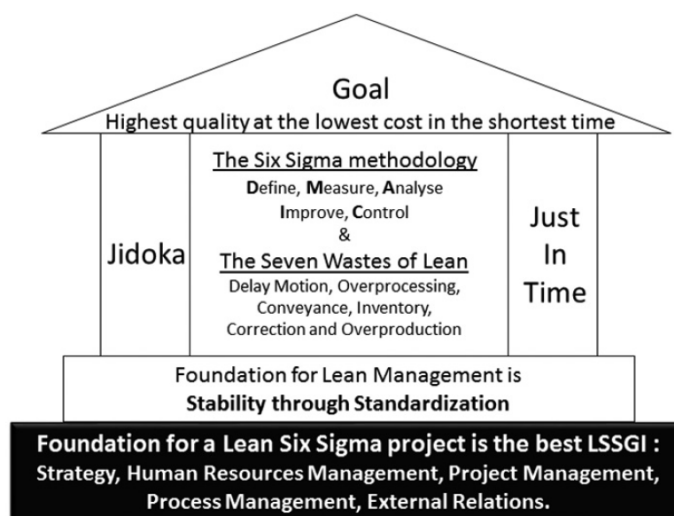


Figure 8. The Lean Six Sigma house(Bicheno & Holweg 2016)

## **6. Managerial implications**

The LSSGI proposed in this paper can be used by managers or consultants as a diagnostic tool, prior to the implementation of LSS as described in the application cases in Section 4. It has several advantages: it provides a simple and global indicator on four levels giving the maturity level of the organization; it gives a rating of five families of practices based on 13 CSFs of LSS; finally, it allows to identify the basic practices which should evolve to improve the maturity level of the company.

The diagnosis is simple and efficient. It consists in answering 30 questions about observable practices in the company. This questionnaire and the research method thus aim to reduce the subjectivity of the LSSGI. The LSSGI is actually a useful tool to support decision making because it helps us measure the difficulties that SMEs could have in an LSS implementation project, identifying weaknesses and forces in a series of factors, allowing managers to determine what factors need to be allocated more resources to improve the probability of success. The index is useful for comparing the state of a company at different times to identify progressions made. If a company has a low LSSGI value, it does not mean that it cannot develop an LSS project, but it will have to face a set of difficulties to achieve the objective, unlike a company with a higher LSSGI value.

## **7. Conclusions, limitations and future research**

This paper proposes an assessment tool to determine the SMEs' capabilities to implement an LSS project. Through maturity grids, this tool can evaluate a series of observable phenomena that reflect the current state of a company. This framework feeds the growing knowledge base of LSS in SMEs. In fact, it responds to a need for specific LSS deployment frameworks for SMEs that address the particular context of the participant companies (Timans et al., 2016). Regarding some limits and perspectives of the proposed tool to assess the capacity of SMEs to deploy the LSS, we could mention that although it identifies the main characteristics of companies that lead to successful implementation, it is not yet able to give companies a strategy or prioritized plan to improve these characteristics. One of the perspectives is to create a tool that determines the key actions necessary for companies to improve their LSSGI value.

As mentioned in previous sections, even if the set of main factors is clearly identified, there is not yet a consensus within the scientific literature about the ranking of the most important of them. It could be explained by the action of synergistic effects between factors.

As a consequence, further research must focus on using multi-criteria decision aid techniques enabling the evaluation of those effects, such as ANP, DEMATEL or the Choquet Integral.

Furthermore, the current survey should be applied under the supervision of a consultant to ensure the accuracy of the answers and avoid errors in the evaluation because of problems of subjectivity or understanding maturity grids. For this reason, another perspective to improve the robustness of the tool is to continuously review the maturity grids of the questionnaire for companies, with the aim of decreasing subjectivity each time and ensuring that everyone understands the same when they read the questionnaire. A comparison of both case studies reveals that there are similarities and differences that can be explained by the business culture of each country. That is, the cultural configuration of each country can influence the way companies are organized and managed. It is thus important to carry out numerous case studies to find out if the results obtained in two companies are repeated in other organizations of the same country, generating a company profile for each country.

Another aspect to consider in the future is the integration of new CSFs that may appear in the literature. It is necessary to periodically review the list of factors considered to keep the tool up to date. In addition, a group of French experts was consulted in this research for the validation and weighting of critical factors. In future research, it is advisable to integrate a greater number of experts to strengthen the results obtained. Although the literature shows that the critical factors of LSS are shared by multiple markets, the incorporation of professionals from other markets is suggested to validate the proposed framework at the international scale. Finally, it is possible to consider the use of another multi-criteria method that gives more robustness to the computation of the index and that helps to reduce the subjectivity in the weighting of the criteria.

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## References

- Achanga, P. et al., 2006. Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management*, 17(4), pp.460–471.
- Ali Maasouman, M. & Demirli, K., 2015. Assessment of lean maturity level in manufacturing cells. *IFAC Proceedings Volumes (IFAC-PapersOnline)*, 48(3), pp.1876–1881. Available at: <http://dx.doi.org/10.1016/j.ifacol.2015.06.360>.
- Antony, J. & Banuelas, R., 2002. Key ingredients for the effective implementation of Six Sigma program. *Measuring Business Excellence*, 6(4), pp.20–27.
- Antony, J., Kumar, M. & Madu, C., 2005. Six sigma in small- and medium-sized UK manufacturing enterprises. *International Journal of Quality & Reliability Management*, 22(8), pp.860–874. Available at: <http://dx.doi.org/10.1108/02656710510617265>.
- Arnheiter, E.D. & Maleyeff, J., 2005. The integration of lean management and Six Sigma. *The TQM Magazine*, 17(1), pp.5–18. Available at: <http://www.emeraldinsight.com/doi/10.1108/09544780510573020>.
- Arslankaya, S. & Atay, H., 2015. Maintenance Management and Lean Manufacturing Practices in a Firm Which Produces Dairy Products. *Procedia - Social and Behavioral Sciences*, 207, pp.214–224. Available at: <http://www.sciencedirect.com/science/article/pii/S1877042815052234>.
- Bakås, O., Givaert, T. & Van Landeghem, H., 2011. Challenges and Success Factors for Implementation of Lean Manufacturing in European Smes. In *Mitip 2011*. Trondheim, Norway: Norwegian University of Science and Technology, p. 11. Available at: <https://biblio.ugent.be/publication/1929995>.
- Barbosa, E.A., Villar, S.G. & Dzul, L.A., 2013. Propuesta de metodología Lean Seis Sigma en empresas Pimes: un enfoque participativo con la academia. *Ridtec*, 9(1), pp.10–20.
- Bicheno, J. & Holweg, M., 2016. *The Lean Toolbox, A handbook for lean transformation* 5th Editio., Buckingham, England: PICSIE Books.
- Boly, V. et al., 2014. Evaluating innovative processes in french firms: Methodological proposition for firm innovation capacity evaluation. *Research Policy*, 43(3), pp.608–622. Available at: <http://dx.doi.org/10.1016/j.respol.2013.09.005>.
- Boly, V., 2008. *Ingénierie de l'innovation : Organisation et méthodologies des entreprises innovantes* H.- Lavoisier, ed., Hermes Science Publications.
- Boynton, A.C. & Zmud, R.W., 1986. An Assessment of Critical Success Factors. *Sloan Management Review*, 25(4), pp.17–27.
- Chan, J. et al., 2014. Implementing the Lean Six Sigma Framework in a Small Medium Enterprise (SME) – A Case Study in a Printing Company. In *2014 International Conference on Industrial Engineering and Operations Management Bali*. Indonesia, pp. 387–396.
- Chiesa, V., 1996. Development of a technical innovation audit. *Journal of Product Innovation Management*, 13(2), pp.105–136. Available at:

[http://doi.wiley.com/10.1016/0737-6782\(95\)00109-3](http://doi.wiley.com/10.1016/0737-6782(95)00109-3).

- Dora, M. et al., 2013. Operational performance and critical success factors of lean manufacturing in European food processing SMEs. *Trends in Food Science & Technology*, 31(2), pp.156–164. Available at: <http://www.sciencedirect.com/science/article/pii/S0924224413000496> [Accessed January 12, 2015].
- Elmoselhy, S.A.M., 2013. Hybrid lean-agile manufacturing system technical facet, in automotive sector. *Journal of Manufacturing Systems*, 32(4), pp.598–619. Available at: <http://dx.doi.org/10.1016/j.jmsy.2013.05.011>.
- Enjolras, M. et al., 2015. Supporting SMEs' IP capabilities: Impact study of INPI pre-diagnosis through the use of the AIDA approach. *World Patent Information*, 40, pp.21–29. Available at: <http://dx.doi.org/10.1016/j.wpi.2014.11.001>.
- Etemad, H., 2009. Internationalization of Small and Medium-sized Enterprises: A Grounded Theoretical Framework and an Overview. *Canadian Journal of Administrative Sciences / Revue Canadienne des Sciences de l'Administration*, 21(1), pp.1–21. Available at: <http://doi.wiley.com/10.1111/j.1936-4490.2004.tb00319.x>.
- Felizzola, H. & Luna, C., 2014. Lean Six Sigma en pequeñas y medianas empresas: un enfoque metodológico. *Ingeniare. Revista chilena de ingeniería*, 22(2), pp.263–277. Available at: [http://www.scielo.cl/scielo.php?script=sci\\_arttext&pid=S0718-33052014000200012&lng=en&nrm=iso&tlng=en](http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-33052014000200012&lng=en&nrm=iso&tlng=en).
- Grant, K.P. & Pennypacker, J.S., 2006. Project management maturity: an assessment of project management capabilities among and between selected industries. *IEEE Transactions on Engineering Management*, 53(1), pp.59–68. Available at: <http://ieeexplore.ieee.org/document/1580894/>.
- Hassan, S., Nadzim, S.Z.A. & Shiratuddin, N., 2015. Strategic Use of Social Media for Small Business Based on the AIDA Model. *Procedia - Social and Behavioral Sciences*, 172, pp.262–269. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S1877042815004000>.
- Hedelind, M. & Jackson, M., 2011. How to improve the use of industrial robots in lean manufacturing systems. *Journal of Manufacturing Technology Management*, 22(7), pp.891–905. Available at: <http://dx.doi.org/10.1108/17410381111160951>.
- Hibadullah, S.N. et al., 2014. Critical success factors of lean manufacturing practices for the Malaysian automotive manufacturers. *International Journal of Quality and Innovation*, 2(3/4), p.256. Available at: <http://www.inderscience.com/link.php?id=66382>.
- Hoerl, R.W. & Snee, R., 2010. Statistical Thinking and Methods in Quality Improvement: A Look to the Future. *Quality Engineering*, 22(3), pp.119–129. Available at: <http://www.tandfonline.com/doi/abs/10.1080/08982112.2010.481485>.
- Khadem, M., Ali, S.A. & Seifoddini, H., 2008. Efficacy of Lean Metrics in Evaluating the Performance of Manufacturing Systems. , 15(2), pp.176–184.
- Kumar, M., Antony, J. & Douglas, A., 2009. Does size matter for Six Sigma implementation? *The TQM Journal*, 21(6), pp.623–635. Available at: <http://www.emeraldinsight.com/doi/10.1108/17542730910995882>.
- Kumar, M., Khurshid, K.K. & Waddell, D., 2014. Status of Quality Management practices in manufacturing SMEs: a comparative study between Australia and the UK.

- International Journal of Production Research*, 52(21), pp.6482–6495. Available at: <http://www.tandfonline.com/doi/abs/10.1080/00207543.2014.948574>.
- Kundu, G. & Manohar, B., 2012. Critical success factors for implementing lean practices in it support services. *International Journal for Quality research*, 6(4), pp.301–312. Available at: <http://www.ijqr.net/journal/v6-n4/1.pdf>.
- Liker, J., 2004. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*, London: McGraw-Hill Education.
- Maier, A.M., Moultrie, J. & Clarkson, P.J., 2012. Assessing organizational capabilities: Reviewing and guiding the development of maturity grids. *IEEE Transactions on Engineering Management*, 59(1), pp.138–159.
- Maleyeff, J., 2012. The continuing evolution of Lean Six Sigma. *The TQM Journal*, 24(6), pp.542–555.
- Mann, R., Adebajo, O. & Kehoe, D., 1999. An assessment of management systems and business performance in the UK food and drinks industry. *British Food Journal*, 101(1), pp.5–21. Available at: <http://www.emeraldinsight.com/doi/abs/10.1108/00070709910251432>.
- Mantilla Celis, O.L. & Sánchez García, J.M., 2012. Modelo tecnológico para el desarrollo de proyectos logísticos usando Lean Six Sigma. *Estudios Gerenciales*, 28(124), pp.23–43. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0123592312702140>.
- Mason, S.E., Nicolay, C.R. & Darzi, A., 2015. The use of Lean and Six Sigma methodologies in surgery: A systematic review. *Surgeon*, 13(2), pp.91–100. Available at: <http://dx.doi.org/10.1016/j.surge.2014.08.002>.
- Miller, G.A., 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, 63(2), pp.81–97. Available at: [papers3://publication/uuid/9D829293-04E4-4BB7-8B3B-1E868E1EC915](https://pubmed.ncbi.nlm.nih.gov/12856661/).
- Morel, L., 2007. *Vers une nouvelle forme de Génie des Procédés Complexes : intégration de la capacité à innover - innovative - pour l'évaluation des stratégies de développement produits-procédés*.
- Ohno, T., 1988. *Toyota Production System: Beyond Large-Scale Production*, Portland, Oregon: Productivity Press.
- Pakdil, F. & Leonard, K.M., 2014. Criteria for a lean organisation: development of a lean assessment tool. *International Journal of Production Research*, 52(15), pp.4587–4607. Available at: <http://www.tandfonline.com/doi/abs/10.1080/00207543.2013.879614>.
- Panat, R. et al., 2014. The application of Lean Six Sigma to the configuration control in Intel's manufacturing R&D environment. *International Journal of Lean Six Sigma*, 5(4), pp.444–459. Available at: <http://www.emeraldinsight.com/doi/abs/10.1108/IJLSS-02-2014-0004>.
- Paulk, M.C. et al., 1996. The capability maturity model: Guidelines for improving the software process. *Computers & Mathematics with Applications*, 31(7), p.143. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0898122196904617> [Accessed March 8, 2017].

- Petit, C. et al., 2011. A new, innovative and marketable IP diagnosis to evaluate, qualify and find insights for the development of SMEs IP practices and use, based on the AIDA approach. *World Patent Information*, 33(1), pp.42–50.
- Pingyu, Y. & Yu, Y., 2010. The barriers to SMEs' implementation of lean production and countermeasures - based on SMS in Wenzhou. *International Journal of Innovation, Management and Technology*, 1(2), pp.220–225.
- Raghunath, A. & Jayathirtha, R. V., 2014. Six sigma implementation by Indian manufacturing smes - an empirical study. *Academy of Strategic Management Journal*, 13(1), pp.35–56.
- Rawal, P., 2013. AIDA Marketing Communication Model: Stimulating a purchase decision in the minds of the consumers through a linear progression of steps. *International Journal of Multidisciplinary Research in Social & Management Sciences*, 1(1), pp.37–44.
- Saaty, R.W., 1987. The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, 9(3–5), pp.161–176. Available at: <http://linkinghub.elsevier.com/retrieve/pii/0270025587904738>.
- Saaty, T.L., 1990. How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, 48(1), pp.9–26.
- Smith, B., 2003. Lean and Six Sigma. A one-two punch. *Quality Progress*, 36(4), pp.37–41.
- Suárez, M.F., Castillo, I. & Miguel, J., 2011. The Implementation of Kaizen in Mexican Organizations: An Empirical Study. *GCG GERORGETOWN UNIVERSITY-UNIVERSIA*, 5(1), pp.60–74. Available at: <http://0-search.ebscohost.com.library.vu.edu.au/login.aspx?direct=true&db=bth&AN=60304870&site=eds-live>.
- Timans, W. et al., 2012. Implementation of Lean Six Sigma in small- and medium-sized manufacturing enterprises in the Netherlands. *Journal of the Operational Research Society*, 63(3), pp.339–353. Available at: <http://dx.doi.org/10.1057/jors.2011.47>.
- Vienazindiene, M. & Ciarniene, R., 2013. Lean Manufacturing Implementation and Progress Measuremet. *Economics and Management*, 18(2), pp.366–373.
- Wessel, G. & Burcher, P., 2004. Six sigma for small and medium-sized enterprises. *The TQM Magazine*, 16(4), pp.264–272. Available at: <http://www.emeraldinsight.com/10.1108/09544780410541918>.
- Womack, J. & DT, J., 2003. *Lean Thinking*, London: Simon&Schuster UK Ltd.
- Womack, J.P., Jones, D.T. & Roos, D., 1990. *That Machine that changed the World* Macmillan, ed., New York.
- Zajkowska, L., 2012. *Contribution à l'implantation de la méthode Lean Six Sigma dans les Petites et Moyennes Entreprises pour l'amélioration des processus*.