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A LEAN SIX SIGMA IMPLEMENTATION MODEL BASED ON CRITICAL SUCCESS FACTORS

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Abstract. Maintenance of continuous improvement culture and methodologies, such as Lean Six Sigma (LSS), is a recurrent challenge to practitioners and researchers. The Critical Success Factors (CSFs) for LSS are pointed as an important subject to understand LSS implementation process. In this scenario, this work aims to develop an LSS implementation theoretical model for small and medium enterprises (SMEs) using as a framework the CSFs for LSS. To develop the model, a systematic review was conducted in order to find out the state of the art in LSS CSFs and LSS in SMEs. The results showed that many researches studied the CSFs for LSS, but none of them has suggested the use of CSF to ensure LSS implementation. In addition, many authors have studied the deficiencies and barriers in SMEs to implement LSS, but just a few have proposed models to LSS implementation in SMEs, considering their own conditions. To fill this gap, this work proposes a model to pursue a successful implementation of LSS methodology using the CSFs as guidance, focusing on SMEs deficiencies, and ensuring improvements sustainability. As a limitation, this theoretical model needs implementation for validation and refinement.

Keywords: Lean Six Sigma, Critical Success Factors, Small and Medium Enterprises, Continuous Improvement.

1. INTRODUCTION

Enterprises are always looking forward to improving their results. In order to achieve better performance, Lean Six Sigma (LSS) methodology became highly desired due to its efficiency and major results in the industry. Gathering Lean principles – waste reduction and adding value – with Six Sigma objectives – process controlling and variance reducing – turns LSS into a powerful tool to implement continuous improvement (CI) culture (Snee, 2010; Albliwi *et al.*, 2015).

LSS studies have been increasing every year. However, there are many opportunities to explore this methodology and make it even more accessible yet. Considering this, we conducted an initial search to find out what are the latest issues and gaps in LSS.

The recurrent challenge in LSS subject is the maintenance of improvement and culture sustainability. From the initial search, we noted that researches are seeking for patterns and imperative characteristics to the successful implementation of LSS, exploring the Critical Success Factors (CSFs) for LSS (Abu Bakar *et al.*, 2015). Although many of them have explored different scenarios, the use of CSFs to develop a LSS implementation framework is a topic not yet fully explored (Yadav and Desai, 2016).

On the other hand, literature shows that small and medium enterprises (SMEs) have been struggling to apply CI methodologies such as LSS (Gnanaraj *et al.*, 2010). The fact that LSS was born in larger companies and, therefore, has its structure geared towards them, is pointed out as the main reason. Also, considerable limitations, such as little financial resources, affects the SMEs' capability to implement LSS. Finally, the lack of a concrete model to overcome the deficiencies of SMEs and guide them through the initial steps, along with high investments needs in training and changes, discourage these companies to start a LSS journey.

1.1 Objectives

Considering the initial findings, this work aims to develop a LSS implementation model to SMEs based on CSFs to increase chances of success. We define success as (a) orientation in initial steps, (b) achieve desired results, (c) sustain improvements through time, (d) create CI culture and (e) enhance business competitiveness.

1.2 Procedure

Initially, we made an exploratory search to identify potential issues to work on and define this work's goals. In literature review, we conducted two systematic searches, following the Systematic Search Flow (SSF) method from Ferenhof and Fernandes (2016). One on CSFs for LSS and the other on LSS in SMEs. Findings were filtered according to subject adherence and relevance. Finally, we made further exploratory searches to seek detailed information.

From literature review, we analyzed the findings to define the model requirements. In order to do that, we used the current reality tree (CRT) from theory of constraints (Goldratt and Cox, 1990) to understand the relationship between CSFs. Based on the requirements stated, we designed the model with the support of flowchart and an input-process-output chart.

2. LITERATURE REVIEW

To conduct the literature review, we made two different systematic literature searches. One dedicated to CSFs for LSS and other related to LSS in SMEs.

2.1 Critical Success Factors for Lean Six Sigma

According to Rockart (1979), CSFs are those factors essential to the success of any program or technique, in the sense that, if objectives associated with the factors are not achieved, the application of the technique will fail – perhaps catastrophically. Brotherton and Shaw (1996) emphasize that CSFs are not major objectives, but the actions and processes that can be controlled by the management to achieve the organization's goals. Thus, we can assume that the CSFs for LSS are the essential areas to achieve the expected results of quality and productivity improvement.

To explore the Critical Success Factors for Lean Six Sigma, we conducted a systematic search, following the SSF method from Ferenhof and Fernandes (2016), on August 8th, 2016. The search was performed in the Compendex, Scopus and Web of Science databases with the query string ("*lean six sigma*") AND ("*critical success factor*" OR *barrier* OR *csf*), resulting 36 non-repeated papers of which 24 were available for full reading. Following the SSF method, those available were read the title and abstract, remaining 18 papers, aligned with the research. In the sequence, the full text reading where applied, resulting on five papers aligned to this research.

Regarding the inclusion and exclusion criteria, to be included, the works must have made their own research on CSFs, through literature review and/or evaluation in a specific context or if they have used the CSFs to develop a LSS implementation framework. The papers must be written in English or Portuguese language. The articles were available with full text access through CAPES (Coordination of Improvement of Higher Education), Google®, Google Scholar®, Microsoft Academic Search® or sent by email to the authors.

Two papers assessed the CSFs through literature review and three evaluated in specific context. None has used the CSFs for LSS as framework. We discuss meaningful findings in the following paragraphs.

Abu Bakar *et al.* (2015) reviewed and gathered the latest literature, starting 2010 onwards. They listed nine groups out of the initially 97 CSFs, in clustering analysis using Affinity Diagram tool. Laureani and Antony (2012) have made a comprehensive review on current literature resulting in a list of 19 CSFs.

Lande *et al.* (2016) evaluated the CSFs affecting quality and performance of SMEs in the Indian context through a systematic literature review. The CSFs found were grouped by similarity and a Pareto analysis was used to evaluate their frequency. The findings show 8 to 12 most relevant CSFs and that the CSFs of various countries are more or less the same as India.

Manville *et al.* (2012) evaluated the CSFs for LSS from a middle managers' perspective through a structured survey answered by 99 managers from one company to identify the top six CSFs of LSS. Although this study concludes its results are limited due to analysis of only one case, they seem to converge with the other papers.

Timans *et al.* (2012) analyzed LSS in Dutch SMEs, identifying and analyzing the CSFs. Questionnaire and statistical testing were applied to validate the result, which consists in 12 CSFs.

The results from the CSFs search shows similarity between factors from different researches. This confirms the findings from Timans *et al.* (2012) and Lande *et al.* (2016), who pointed to a high similarity between CSFs from different countries, appearing to be no evidence that cultural and geopolitical factors are dominant in the CSFs for LSS definition.

There are a few differences only in the prioritization order depending on the method or emphasis. Because of high similarity between researches, we organized the CSFs found in literature in 12 groups summarized in Tab. 1. Thus, for the matter of this research, we will use the groups from Tab.1 as CSFs from now on.

Table 1 – Summary of Critical Success Factors from literature. Source: Authors.

Critical Success Factors	Authors
Communication	
Communication	Laureani and Antony (2012) and Timans <i>et al.</i> (2012)
Linking LSS to business strategy	
Linking LSS to business strategy	Abu Bakar <i>et al.</i> (2015), Laureani and Antony (2012), Manville <i>et al.</i> (2012) and Timans <i>et al.</i> (2012)
Strategic quality planning	Lande <i>et al.</i> (2016)
Vision and plan statement	Timans <i>et al.</i> (2012)
Linking LSS to suppliers	
Extending LSS to supply chain	Laureani and Antony (2012)
Linking to suppliers	Timans <i>et al.</i> (2012)
Linking LSS to the customers	
Customer satisfaction	Lande <i>et al.</i> (2016)
Linking LSS to customers	Abu Bakar <i>et al.</i> (2015), Laureani and Antony (2012), Manville <i>et al.</i> (2012) and Timans <i>et al.</i> (2012)
LSS competency	
Data based approach	Laureani and Antony (2012)
LSS competency	Abu Bakar <i>et al.</i> (2015)
LSS tools and techniques	Laureani and Antony (2012)
Understanding LSS methodology	Lande <i>et al.</i> (2016)
Understanding of LSS	Timans <i>et al.</i> (2012)
Understanding the tools and techniques	Manville <i>et al.</i> (2012)
Management commitment and leadership	
Leadership	Lande <i>et al.</i> (2016)
Leadership style	Laureani and Antony (2012)
Management commitment	Laureani and Antony (2012)
Management commitment and leadership	Abu Bakar <i>et al.</i> (2015)
Management involvement and commitment	Lande <i>et al.</i> (2016)
Managers involvement and participation	Timans <i>et al.</i> (2012)
Senior management commitment	Manville <i>et al.</i> (2012)
Organizational culture	
Awareness	Laureani and Antony (2012)
Cultural change	Lande <i>et al.</i> (2016) and Timans <i>et al.</i> (2012)
Organizational culture	Laureani and Antony (2012)
Project management skills	
Project management skills	Abu Bakar <i>et al.</i> (2015), Laureani and Antony (2012) and Timans <i>et al.</i> (2012)
Project selection and prioritization	
LSS projects tracking and review	Laureani and Antony (2012)
Project selection and prioritization	Abu Bakar <i>et al.</i> (2015), Lande <i>et al.</i> (2016), Laureani and Antony (2012), Manville <i>et al.</i> (2012) and Timans <i>et al.</i> (2012)
Proper infrastructure	
LSS financial accountability	Laureani and Antony (2012)

Organizational infrastructure	Abu Bakar <i>et al.</i> (2015), Laureani and Antony (2012) and Timans <i>et al.</i> (2012)
Resources for LSS staff	Laureani and Antony (2012)
Selection of LSS staff	Laureani and Antony (2012)
Reward and recognition system	
Linking LSS to HR rewards	Laureani and Antony (2012)
Reward and recognition system	Abu Bakar <i>et al.</i> (2015)
Training and education	
Training	Lande <i>et al.</i> (2016) and Laureani and Antony (2012)
Training and education	Abu Bakar <i>et al.</i> (2015), Manville <i>et al.</i> (2012) and Timans <i>et al.</i> (2012)

As it can be seen, Lande *et al.* (2016) and Laureani and Antony (2012) discriminated management commitment and leadership, while Abu Bakar *et al.* (2015) considered as just one factor. For the matter of this research, we will consider as just one factor. Since the meaning of “proper infrastructure” is not clear in literature, we will define it as the range of resources such as financial, physical and human.

These results from this search corroborates with the initial assumptions. Recent studies evaluated the CSFs to better ensure LSS efficiency and avoid failing programs. Many consider the importance of attending these factors and suggest a list of CSFs, but none of them has used the CSFs as a tool to improve the chances of a successful LSS implementation. Yadav and Desai (2016) also confirmed this finding.

2.2 Lean Six Sigma in Small and Medium Enterprises

Literature have been reporting that practitioners are struggling to apply LSS in SMEs (Gnanaraj *et al.*, 2010). Usually, lack of orientation through the initial steps and high investment discourage their efforts to implement LSS (Grudowski *et al.*, 2014). In addition, LSS implementation in SMEs has two major issues to be considered: they have common deficiencies and barriers (Gnanaraj *et al.*, 2010), but their nature is so diverse that researchers and practitioners find hard to propose a framework easily applicable in all kinds of enterprises (Thomas *et al.*, 2009). Thus, before the implementation of scientifically developed approaches like LSS, SMEs must take essential steps to overcome these deficiencies (Prasanna and Vinodh, 2013).

Considering these initial findings, we conducted a systematic search, following the SSF method from Ferenhof and Fernandes (2016), on December 7th, 2016, intending to explore the deficiencies, barriers, guidelines, frameworks and tools for SMEs to implement LSS. The search was performed in the Compendex, Scopus and Web of Science databases with the query string ("*lean six sigma*") AND ("*small and medium enterprise*" OR *sme*), resulting 24 non-repeated papers of which 20 were available for full reading. Following the SSF method, those available were read the title and abstract, remaining 11 papers, aligned with the research. In the sequence, the full text reading where applied, resulting on seven papers aligned to this research.

Regarding the inclusion and exclusion criteria, to be included, the works must have made their own research on deficiencies of SMEs, through literature review and/or evaluation in a specific context or if they have developed guidelines, frameworks and tools for SMEs to implement LSS. The papers must be written in English or Portuguese language. The articles were available with full text access through CAPES (Coordination of Improvement of Higher Education), Google®, Google Scholar®, Microsoft Academic Search® or sent by email to the authors.

Five papers assessed common deficiencies and barriers to LSS deployment, one developed useful tools and another one assessed common deficiencies and barriers, and developed a useful tool. We discuss the relevant findings in the following paragraphs.

Deficiencies, barriers and challenges to implement LSS in SMEs

Thomas *et al.* (2009) identified the lack of financial and intellectual capacity as the main barrier to implement systems such as LSS in SMEs. Also, their complexity and singularity turns difficult to develop a model suitable to all SMEs but not too generic to fail in guiding the company.

Grudowski *et al.* (2014) identified that insufficient financial resources and unavailability of qualified staff are the main reason why SMEs have difficult to apply Lean and SS tools correctly. Despite that, good internal communication and simplified decision-making process – due to the small size of the company – make some LSS tools unnecessary.

Shokri *et al.* (2016) focused on the relation of human behavior in readiness to initiate LSS projects, such as personal skills, strategic vision and organizational culture. They found out that improving education, vision and team values increase staff readiness to apply LSS.

Timans *et al.* (2012) evaluated the impeding factors for LSS implementation in Dutch SMEs. Prasanna and Vinodh (2013) and Gnanaraj *et al.* (2010) identified deficient characteristics of SMEs through a comprehensive literature review.

We considered some of these 39 deficiencies equivalent, therefore we combined them as follows: “Inadequate training impaired to the employees” to “Poor training/coaching”; “Lack of financial capacity” and “Insufficient financial resources” to “Poor availability of funds”; “Lack of intellectual capacity” and “Unavailability of qualified staff” to “Poor educational level of employees”; “High labor turnover” to “Low employee retention”; and “Lack of leadership” to “Poor leadership”. We summarized the 32 final deficiencies in Tab. 2.

Table 2 – Summary of deficiencies and barriers for LSS implementation in SMEs. Source: Authors.

Deficiencies	Authors
Change of management	Timans <i>et al.</i> (2012)
Changing business focus	Timans <i>et al.</i> (2012)
Competing projects	Timans <i>et al.</i> (2012)
Fewer human resources	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
High cost and complexity of implementing quality models	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Inadequate knowledge about foreign sales practices and market contacts	Gnanaraj <i>et al.</i> (2010)
Insufficient new initiatives and technology	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Insufficient usage of IT	Gnanaraj <i>et al.</i> (2010)
Internal resistance	Timans <i>et al.</i> (2012)
Lack of planning	Gnanaraj <i>et al.</i> (2010)
Lack of tangible results	Timans <i>et al.</i> (2012)
Lack of timely data for further investigation	Gnanaraj <i>et al.</i> (2010)
Low degree of standardization and formalization	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Low employee retention	Gnanaraj <i>et al.</i> (2010), Prasanna and Vinodh (2013) and Timans <i>et al.</i> (2012)
No scientific decisions/data	Gnanaraj <i>et al.</i> (2010)
Poor availability of funds	Gnanaraj <i>et al.</i> (2010), Grudowski <i>et al.</i> (2014), Thomas <i>et al.</i> (2009) and Timans <i>et al.</i> (2012)
Poor communication	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor cost control and safety management system	Gnanaraj <i>et al.</i> (2010)
Poor educational level of employees	Gnanaraj <i>et al.</i> (2010), Grudowski <i>et al.</i> (2014), Prasanna and Vinodh (2013) and Thomas <i>et al.</i> (2009)
Poor global competitive power	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor infrastructure	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor leadership	Gnanaraj <i>et al.</i> (2010), Prasanna and Vinodh (2013) and Timans <i>et al.</i> (2012)
Poor management commitment	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor management skills	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor meeting of customer expectations and demands	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor process improvement	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor product quality and logistics	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor productivity improvement	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor project selection	Timans <i>et al.</i> (2012)
Poor skills and experience	Gnanaraj <i>et al.</i> (2010) and Prasanna and Vinodh (2013)
Poor training/coaching	Gnanaraj <i>et al.</i> (2010), Prasanna and Vinodh (2013) and Timans <i>et al.</i> (2012)
Unmanaged expectations	Timans <i>et al.</i> (2012)

Models, techniques and tools for LSS implementation in SMEs

Despite the high amount of techniques and tools available from Lean and SS, these are not enough to generate meaningful impact in SMEs (Gnanaraj *et al.*, 2010). According to Grudowski *et al.* (2014), while most tools from Lean are easily understandable and applicable in SMEs, a large number of techniques from SS are considered too complex and therefore usually rejected. Considering these statements, the search also focused on complementary tools, techniques and models that could help LSS implementation in SMEs.

Grudowski *et al.* (2014) developed maturity criteria to evaluate the preparedness to LSS projects in SMEs considering their needs, expectations, concerns and experience. The responses to these criteria define small or great

need for improvement and their capability to pursue improvements. The results define if an organization should implement LSS at the primary level (Zone 1) or the advanced one (Zone2).

As a general rule, small needs and small capabilities to improve place a company in Zone 1, where the LSS project is executed at a basic level. High needs and big capabilities of improvement place a company in Zone 2, which indicates that the LSS project will be implemented using methods, techniques, tools and indicators. It is worth noting that when the demand for improvement is insignificant in a company, and its organizational potential is considerable, therefore the LSS project should be run at the basic level.

In situations where a company has a high or moderate need for improvement, but the capabilities of its implementation are modest, basic improvements corresponding to the scope of Zone 1 are recommended. When the demand for improvement is high and the resources are few, carrying out the LSS project at the basic level is the basis for introducing better solutions, which could be a preparation for the implementation of more advanced projects in the future. An alternative solution in this situation is to postpone the launch of the LSS project in the scope of Zone 2 until the capabilities of a company are significantly increased.

Arcidiacono *et al.* (2016) developed a model named AMSE (which stands for Assessment, Monitoring, Sustainability, Expansion) aiming the sustainability of an LSS program, ensuring projects' savings over time. Relevant contributions from these authors are (1) the definition of KPIs (Key Performance Indicators) – in the monitoring phase – to evaluate the progress of the organization in terms of CI culture periodically, and (2) a project prioritization tool – in the sustainability phase – with weighted criteria to help selecting the best improvements and foster the CI culture.

3. MODEL REQUIREMENTS

This section aims to define the requirements of the proposed model based on the 12 CSFs for LSS and the 32 common deficiencies of SMEs found in literature. In order to do that, we analyzed the relationship of deficiencies with CSFs and the goals of the SMEs, LSS and the model.

Table 3 – Deficiencies relation with Critical Success Factors. Source: Authors.

Critical Success Factors	Linked Deficiencies	
Communication	Poor communication	
Linking LSS to business strategy	Changing business focus Lack of planning	
Linking LSS to suppliers	Poor leadership ^(a) Poor management skills ^(a)	
Linking LSS to the customers	Insufficient knowledge about its own market ^(a) Poor competitive power	Poor meeting of customer expectations and demands
LSS competency	Poor skills and experience ^(a)	Poor training/coaching ^(a)
Management commitment and leadership	Change of management Insufficient new initiatives ^(a) Poor leadership ^(a)	Poor management commitment Poor management skills ^(a) Unmanaged expectations
Organizational culture	Internal resistance	
Project management skills	Poor educational level of employees ^(a) Poor management skills ^(a) Poor project selection ^(a)	Poor skills and experience ^(a) Poor training/coaching ^(a)
Project selection and prioritization	Competing projects Poor project selection ^(a)	
Proper infrastructure	Fewer human resources Insufficient technology	Poor availability of funds Poor infrastructure
Rewards and recognition system	Insufficient new initiatives ^(a) Low employee retention	
Training and education	Insufficient knowledge about its own market ^(a) Poor educational level of employees ^(a) Poor management skills ^(a)	Poor skills and experience ^(a) Poor training/coaching ^(a)
^(a) Repeated deficiencies		

First, we made some changes in the deficiencies. We divided the deficiency “insufficient new initiatives and technology” in two, naming “insufficient new initiatives” and “insufficient technology”, and managed as different subjects. As information technology is a kind of technology, we merged “insufficient usage of IT” with “insufficient new technologies”. We also simplified “inadequate knowledge about foreign sales practices and market contacts” to “insufficient knowledge about its own market” and “poor global competitive power” to “poor competitive power”, considering that not every SME outsources its supplies or aims to export its goods.

The second step was grouping the deficiencies with CSFs to understand the objective of each CSF. There are repeated deficiencies, as they could fit more than one factor. We summarized the list of deficiencies linkage to CSFs in Tab. 3.

As we can see from Tab. 3, the large amount of deficiencies repeated in different CSFs shows that the CSFs also are linked between each other. For instance, “LSS competency”, “Project management skills” and “Training and education” have common deficiencies related, such as “Poor training/coaching” and “Poor skills and experience”. This means that if a company does not have a formal plan for training its employees, they will not have adequate skills to execute their jobs such as project management and/or improvements through LSS technique.

Table 4 presents the remaining deficiencies related to the goals of SMEs, LSS and the model. From Tab. 4, we can observe that “Poor competitive power” is linked to companies’ goals. This means that, although this is a common deficiency from SMEs, this is also their main goal, and so it is the final goal of CI programs such as LSS. We can also see that this deficiency directly relates to the success goal defined in section 1.1, “Enhance business competitiveness”. In this way, from now on we will consider “Poor competitive power” as an undesired effect that must be solved by the model.

From the eight deficiencies linked to LSS goals, we can see that many deficiencies relate to lack of capacity to make improvements. Therefore, we will consider these deficiencies circumstantial, that is, overcoming other deficiencies will end up overcoming these deficiencies and achieving the company’s main goal.

The deficiency “High cost and complexity of implementing quality models” is linked to the model main goal improve chances of success in the LSS implementation, which means solving the following issues: (1) lack of orientation in LSS initial steps, (2) sustain improvements results and practices and (3) failing in LSS implementation. In this way, we will consider these issues undesired effects to be solved by the model.

Table 4 – Deficiencies relation with goals from companies, LSS and the model proposed. Source: Authors.

SMEs main goal (Competitiveness)	Poor competitive power ^(a)
LSS goals (Waste and cost reduction, quality improvement, consumer satisfaction, etc.)	Lack of timely data for further investigation
	Lack of tangible results
	Low degree of standardization and formalization
	No scientific decisions/data
	Poor cost control and safety management system
	Poor process improvement
	Poor product quality and logistics
	Poor productivity improvement
Model goals (facilitate LSS implementation)	High cost and complexity of implementing quality models
^(a) Repeated in Tab. 3	

Finally, to better understand the relationship between CSFs, their relation to the undesired effects stated, and to find the root causes of these undesired effects, we made a cause-effect analysis through the Current Reality Tree (CRT) from Goldratt and Cox (1990). In this analysis, we translated the CSFs in deficiencies, for instance, “Management commitment and leadership” becomes “Lack of management commitment and leadership”, and so on. The CRT follows in Fig. 1.

The analysis in Fig. 1 to find the relation between CSFs and undesired effects led to two root causes: (1) unknowing LSS potential and (2) ineffective training and recruiting policy. This means that solving these root causes will create a framework to achieve the CSFs’ goals.

While “unknowing LSS potential” leaves managers trustless about its effectiveness, compromising their commitment and leadership to LSS implementation, “ineffective training and recruiting policy” leads to a poor skilled staff – including managers with no leadership skills. Without the support of managers, it becomes difficult to get the needed resources to make LSS – or any CI program – feasible. Lack of leadership leaves the staff rudderless. Poor skilled staff means not having the expertise needed to execute their jobs, that is, lack of leadership, “poor LSS competency” and “poor project management skills”. Without competency in LSS, initiatives to implement LSS are

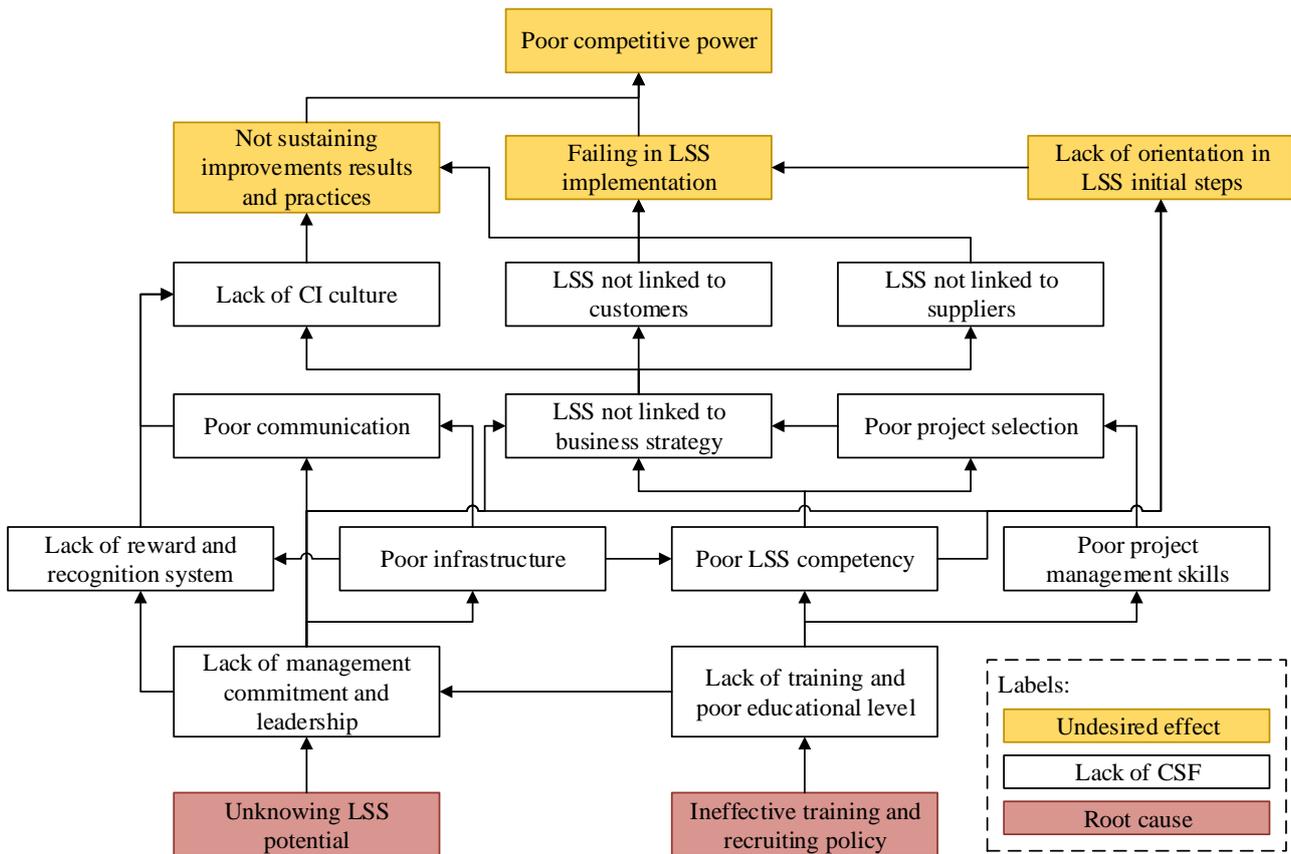


Figure 1 – Current Reality Tree of Critical Success Factors, undesired effects and root causes. Source: Authors.

likely to fail. Combining “poor LSS competency” with “poor project management skills”, the company might take actions with meaningless results and/or misaligned with their strategy.

Gathering all these analysis, we can finally state the requirements of the model, as follows:

- Provide clear guidance for LSS implementation, especially in initial steps;
- Ensure enough capability to start LSS implementation, which means commitment from managers and minimum knowledge in LSS;
- Understand the capability of the company to adequate and gradually increase LSS implementation complexity;
- Understand the needs of the company to adequate the LSS implementation strategy, lining up with the company’s strategy and customers’ requirements;
- Help selecting proper projects according to needs and capability;
- Emphasize the continuity factor to increase chances of sustaining results and practices and keep up developing new improvements projects.

4. LEAN SIX SIGMA IMPLEMENTATION MODEL

This section describes the LSS implementation model to SMEs based on CSFs. We established the following characteristics in order to reflect the previously requirements stated:

- A step-by-step approach to guide the enterprise through the implementation;
- An evaluation of capability in the initial steps to create a framework, achieving minimum skills;
- An evaluation of needs to link LSS to business strategy and increase chances of meaningful achievements;
- A strategy definition step to adequate the usage of LSS tools and techniques to the company’s capability;
- A project selection step to increase chances of meaningful achievements;
- A feedback step to ensure projects achieve its targets;
- A final step to consolidate the improvements and increase chances of sustainability;
- A cyclical process to increase complexity gradually.

Considering these characteristics, we designed the model as an input-process-output diagram, following in Fig 2. This diagram is similar to the SIPOC chart. However, since suppliers and customers are the company itself, there is no need to add these columns.

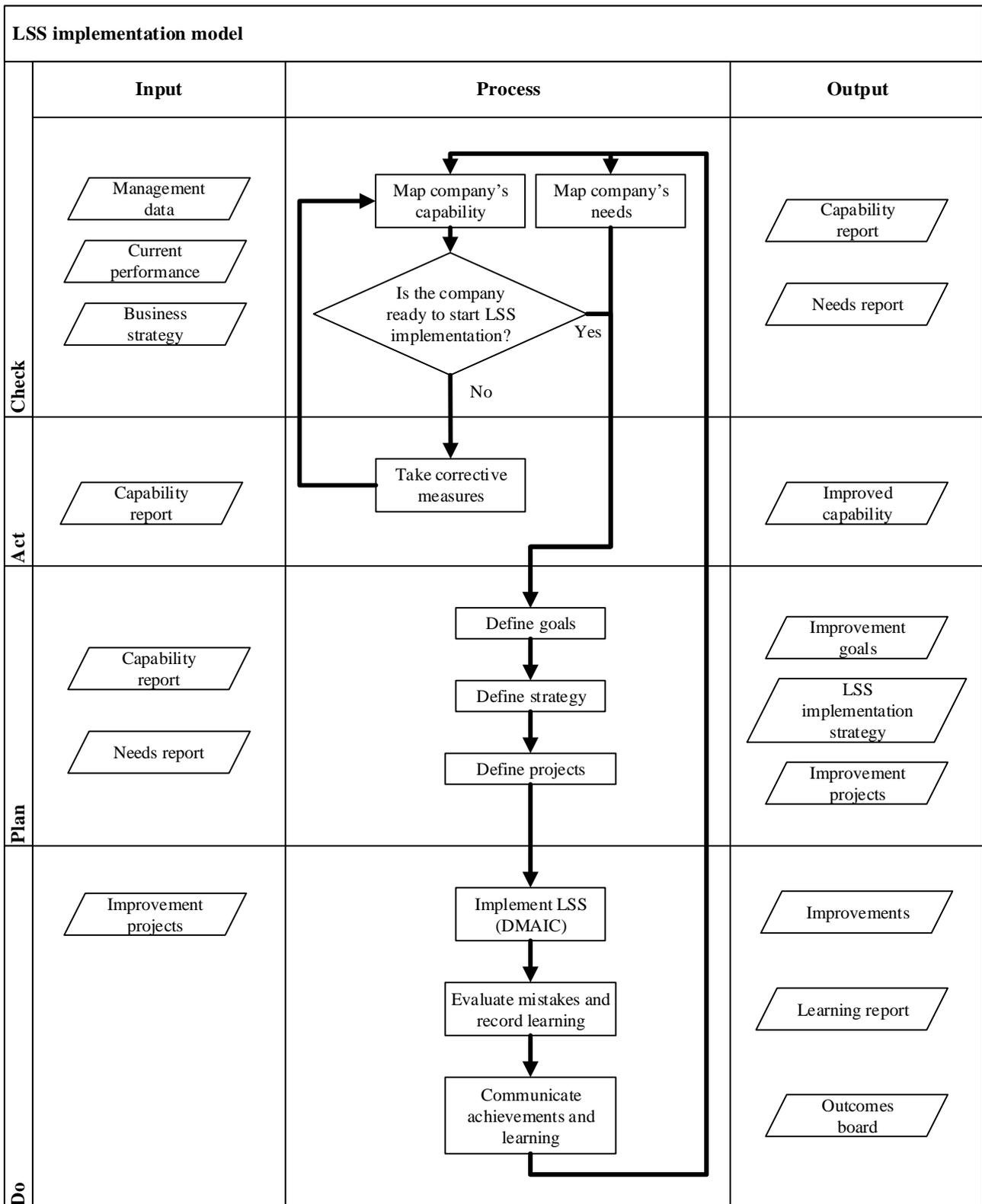


Figure 2 – Input-Process-Output chart of the model. Source: Authors.

We divided the model in four phases: Check, Act, Plan, Do (CAPD). This is necessary due to the model proposition of evaluating the company's condition before planning improvements projects. The first phase, "check", managers evaluate the current condition of the company and find out if it has minimum condition. If the company does not have these minimum conditions, corrective measures must be taken to solve them in the "act" phase. The next phase, "plan", the staff defines why (goals) and how (strategy) the improvements will be done. Finally, in the "do" phase,

improvement projects are launched to achieve the goals. In the end of the “do” phase, a new process must start. The following paragraphs will lighten up each step.

The “map company’s capability” step considers the root causes stated in the CRT analysis. This step aims to define if the managers are actually engaged in the LSS implementation and if staffs involved have minimum knowledge in LSS to begin it. After that, if the company lacks one of these basic matters, a corrective measure must be taken, otherwise, the implementation can move forward.

Simultaneously to “map company’s capability”, the company can map its needs. This step takes into account the business strategy and its actual conditions in market (“current performance”). This is necessary to define the improvement goals, which is the next step.

With the improvement goals and the capability analysis, the implementation strategy must be defined. This is an important step to avoid too difficult projects (according to the company’s capability) or low return over investment. To this step, the chart in Fig 3 presents a tool developed by Grudowski *et al.* (2014) to select the better strategy.

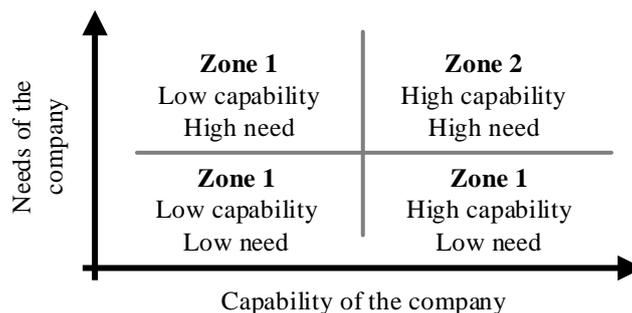


Figure 3 – Strategy chart based on needs and capability. Adapted from Grudowski *et al.* (2014).

Enterprises with small needs must keep the LSS implementation process at the basic level even when they can afford making high investments. In this scenario, the improvements will not generate enough profit to justify the allocated funds. Enterprises with big capability and big needs must implement LSS with all resources available, that is, usage of advanced tools and techniques, high investments and long-term projects. Finally, enterprises with big needs and small capability are the greatest challenge. These companies must start LSS projects at the basic level to evolve their capability. In order to do that, the first projects should focus on increasing financial and human resources available. Therefore, they will be able to invest in training and then, they will be capable to execute more complex projects. In addition, these enterprises will gain experience while they implement LSS at the basic level.

It is important to state that the basic level means carrying out short-term projects with small needs of staff and funding, and usage of the tools and techniques the company already knows. While complex projects means usage of advanced tools and techniques, high investments in equipment, training and hiring, and long-term projects. Thus, these definitions are not arbitrary and depend on the enterprise’s conditions.

The next step is defining projects. This is the point where the company choses what it should do to achieve the defined goals. First, a brainstorm session to generate ideas and then, selecting the most adequate projects. The criteria to select the projects must be according to the goals defined, but the company can add other criteria depending on the situation. For instance, a company who wants to improve product quality and customer satisfaction, but needs to improve its capability, could add “learning experience” as a selecting criterion. Also, the company can add different weights to each criteria, according to its goals.

Finally, the LSS implementation itself through the DMAIC method. This is the step in which the actual changes will happen. It is important that the company keep aligned with previous definitions of goals and strategy. The “control” phase must verify carefully if the goals were achieved. In case of not achieving the planned results, the company must act to correct the deviation.

We designed the last steps “evaluate mistakes and record learning” and “communicate achievements and learnings” to consolidate the improvements and spread the CI culture. While reflecting on mistakes helps improving learning, writing down and communicating these learning and achievements foster a learning culture and motivation towards continuous improvement. When the company finishes these last steps, a new cycle must begin to keep the growth pace.

5. DISCUSSIONS

From literature review, it is noticeable that researchers have worked on LSS comprehensively, but there is some room for improvement yet. Within the gaps observed, the model proposed intends to facilitate the LSS adoption in SMEs, providing orientation in initial steps and along the process, increasing chances of achieving goals and sustaining results, promoting a CI culture and enhancing the overall business competitive power. We described below how the model works on the issues related to the successful LSS implementation:

- a. Orientation in initial steps: the use of a flowchart describing each step, along with the definition of what is the minimum required to start a LSS project in the mapping capability step, and the strategy of LSS implementation at the basic level in the strategy definition step help beginners to start the process gradually and start the LSS journey;
- b. Achieve desired results: the mapping needs step helps understanding the company's goals, and the path towards defining the improvement projects increases the chances to succeed;
- c. Sustain improvements through time: the DMAIC cycle do it already, but final steps designed, evaluate mistakes and record learning, and communicate achievements and learning, boost the likelihood of sustaining improvements;
- d. Create CI culture: the phases design foresees a cyclical implementation of the model, which is the CI culture principle, also, the two final steps foster reflecting on learning, while communicating spreads knowledge and CI culture;
- e. Enhance business competitiveness: since this is the main target of companies and therefore the model main purpose, if companies correctly follow the steps they will end up enhancing competitive power.

The model also considers the CSFs as a framework to LSS adoption process. The CRT analysis sum up the root causes of many issues in two main factors: unknowing LSS potential, which lead to a lack of commitment and guidance (leadership) from managers, and ineffective training and recruiting policy, leading to a poor skilled team. We considered these root causes the splitting point of having enough capability.

We also considered the others CSFs through the steps. Mapping needs help companies linking LSS to business strategy, customers and suppliers. The corrective measures aim to increase skills such as project management gradually, LSS and leadership. The final steps focus on improving communication, growing CI culture and, as a positive side effect, reward teams for their accomplishment. At last, we handled poor infrastructure as a secondary factor, and the development of this factor is a consequence of managers commitment and leadership –they allow more funding when committed to the cause and their leadership skill reduces employee turnover – and the deployment of improvement projects themselves. The improvements gradually increase profits, reduce costs and unleash spare resources that will increase capability to deploy new improvement projects.

6. FINAL THOUGHTS

This model helps the LSS implementation process in SMEs providing guidance through initial steps and along the process, which was the purpose of this work. As stated by Timans *et al.* (2012), using LSS in SMEs has a significantly positive result, reducing cost with product quality and warranty, reducing lead-time and improving productivity. Therefore, a model to facilitate LSS implementation in SMEs is a useful tool to improve their competitiveness.

Another meaningful contribution from this model is its ability to adapt considering the diversity of SMEs characteristics and deficiencies.

Nevertheless, this work and the model have some limitations yet. Although the model helps the LSS adoption, this process still requires great effort from managers to overcome inertia and change its fate. Thus, the model is not a solution, but a supportive tool to guide through the journey.

Another limitation is that this is a theoretical model and seeks fieldwork to validate. Further development includes an implementation to validate and refine.

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9. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.