
Diagnostic framework of operational performance

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PREFACE

This master's thesis was conducted during the spring of 2019 and represents the final part of my master's degree in Industrial Engineering which was equally realized through the Polytechnic University of Valencia (UPV) and through the Faculty of Engineering, Lund University and thus, of my six years of study as an industrial engineer.

I am grateful for the present project to my tutor Bertil, for all the help, dedication and motivation provided. I also thank all the interviewees, Johan Valette, Johan Wiesel and Fredrik Clausson, the treatment and the great contribution they have made to this master thesis.

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Lund, June 2019

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ABSTRACT

Title	Diagnostic framework of operational performance
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Problem definition	All organizations need to continuously scrutinize and analyse their facilities, operations, quality and cooperation along the Supply Chain. When analysing their facilities, it is necessary not only to recognize and review how well the operations are running by estimating the current state but also to recognize potential problems and improvements. Once the current situation is known, it is also needed to compare/benchmark the situation in one work-shop today with other work-shops, to evaluate the supplier's capability or capacity and other potential gaps of technical nature.
Purpose	The purpose of this master thesis is to develop an integrated diagnostic framework including the strategic, tactical and operational levels of planning, describing briefly applicable tools and programs and test it on a few companies.
Methodology	<p>This master thesis can be classified as an Action Research since its main objective is to produce guidelines for best practice.</p> <p>Different research methods are used: first, documentary research for the knowledge of all the concepts, methodologies and tools involved in the development of the framework; second, interviews to managers from different companies are carried out to obtain information about current practice in the field and with the objective of verifying if the framework developed is useful, knowing its limitations and trying to perfect it. In addition, when carrying out interviews, observation can be used as an auxiliary method.</p>
Results and conclusion	<p>A diagnostic framework is constructed and validated by the managers of three different companies in Skåne which give empirical support for the reliability and validity of its contents.</p> <p>The framework is defined as a three steps guide that includes a set of tools classified into the three levels of planning, used to prevent operational performance problems or improvements and whose importance increases in small and medium companies without Lean or Six Sigma.</p>
Key words	Integrated framework; Problem identification; Improvement identification; Planning levels; Operational performance problem; Current state; Benchmarking; Supplier's evaluation; Quality;

GLOSSARY AND ACRONYMS

Benchmarking	The search for industry best practices that lead to superior performance.
Current State Analysis	A report indicating how an organization is running its operations today.
Framework	A system of rules, ideas or, in this case, tools and methodologies that is used to plan or decide something.
Improvement process	The proactive task of identifying, analysing and improving upon existing business processes within an organization for optimization and to meet new quotas or standards of quality.
Levels of business	Levels in which business strategies can be classified. In the present work they are called: strategic, tactical and operational.
Operations performance	Firm's performance measured against standard or prescribed indicators of effectiveness, efficiency, and environmental responsibility such as, cycle time, productivity, waste reduction, and regulatory compliance.
Operations strategy	Set of decisions concerned with how operations configure and change their overall capacity in order to achieve a particular level of output potential.
Self-assessment	Assessment or evaluation of one's actions, processes, or performance.
SC	Supply Chain, a systems-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers.

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1. INTRODUCTION

This first chapter allows the reader to know the context in which this master's thesis is developed. Then, the problem description, the purpose and the project objective are presented. Finally, there is a brief description of the chapters and structure of the thesis.

1.1. Context

In a Supply Chain, a high requirement to avoid misunderstanding, quality deviations, additional work and delays exists. A balanced full Supply Chain is as important as a balanced assembly line for complex products. All type of non-compliance, not appropriate or misassignment resources are pitfalls in strategic terms and will decrease the organization's competitiveness and profit, from the best practices point of view. (Croxtton, 2001)

Along this lines, an audition of the complete chain is needed to avoid risks for lack of full fitness. In addition, this audition must provide valid and realistic data since according to the Standard ISO 9001:2015 (International Organization for Standardization, 2015), all the decisions are required to be based on facts.

In order to carry out the said audition, companies and other type of organisations are required to determine criteria and apply methods to ensure effective operation and control of their processes (Chibba, 2017), they need to continuously scrutinize and analyse their facilities, operations, quality and cooperation along the Supply Chain.

1.2. Problem description

As it has been explained above, it is necessary to scrutinize, analyse and evaluate on different levels of the business – from the operational level up to strategic level – a company facilities, operations, quality and cooperation between suppliers.

When analysing its facilities, it is necessary not only to recognize and review how well the operations are running, how well instructions and procedures are used and fitted in to the business by estimating the current state but also to recognize potential problems to prohibit delays, future emergency stops and repair or even loss of customer orders.

Once the current state is known, it is also needed to compare/benchmark the situation in one work-shop today with other work-shops, to evaluate the supplier's capability or capacity and other potential gaps of technology nature, to plan, for example, investments or outsourcing.

All these activities can be used to help companies or plants carry out a problem or improvement identification process to not only continuously measure their current state but also solve operational performance problems. No organization is immune to these types of problems and although they are focused at the operational level, they influence further up to the strategic level. For that purpose, a wider toolbox for all these activities is required; maybe not only simple tools but also parts of quality review programs including traditional audition and critical reviews.

1.3. Purpose

The purpose of this master thesis is to develop an integrated framework to identify and define operational performance problems and improvements. It includes the strategic, tactical and operational levels of planning and describes briefly applicable tools and programs classified into three steps. Finally, the framework is verified on three different companies.

Although this framework focuses on operational performance, the operational level is not the only one analyzed, since although the problem manifests itself at this level, in many cases it is necessary to analyze the higher levels in order to find an improvement. (Schmidt et al., 2000)

Through an exhaustive search in the existing literature by both the author and the tutor of the project, it has been determined that there is no guide or framework that collects all the steps and tools to be used with this objective beyond general processes of improvement. However, this framework can be strongly compared to those general improvement processes that pursue a much more ambitious goal and can be used with the same objective as the present framework.

1.3.1. Research questions

The questions that drive the research of this paper are presented in this subsection:

RQ1: How can this framework support companies with operational performance improvements or problems?

RQ2: How do companies currently solve or prevent operational performance improvements or problems?

RQ3: What are the advantages and disadvantages of the present framework with respect to other improvement or problem-solving processes?

The answer to these questions can be found as follows: RQ1 partly in chapter 4 and partly in chapter 6; RQ2 in chapter 5; and RQ3 in chapter 6.2.1.

1.3.2. Delimitations

Being a Master Thesis, the timeframe for this project is about 20 weeks. This has impacted the choice of project scope and research questions. Due to this limitation, this paper does not include more than three interviews with managers of different companies or the evaluation of some of the possible alternatives of solution.

In addition, the tools necessary for the creation and evaluation of alternatives at the long term or strategic level are considered to be encompassed in subjects that do not correspond with the department where this project is carried out and for this reason, they are not included. However, there are some concepts or actions that involve more than one level of planning, including the strategic one, which are going to be added and briefly explained.

1.4. Project objective

The main objective of this project is the development of a framework to support companies scrutinize, analyse and evaluate their operations on different levels of the business and with it, build up competence in the best possible way.

From the description of basic concepts such as total quality management or performance measures to the development of a particular set of rules, ideas, or beliefs which can be used in order to deal with a need for improvement. In between, all the methods and techniques used to recognize a need for improvement, to evaluate the current state of an organization or a plant and to create and evaluate alternatives.

1.5. Structure of the report

The thesis is structured in the following way:

Chapter 1: Introduction

The first chapter gives a context for the thesis, the problem description, the purpose and objectives of the thesis and its delimitations.

Chapter 2: Methodology

This chapter explains the research methodology, the data collections methods and the criteria for the quality of this research.

Chapter 3: Theoretical references

The third chapter introduces some concepts that need to be explained in order to understand the tools and techniques proposed to the different steps of the framework developed. It gives a basic knowledge about Total Quality Management, Lean and Six Sigma, Performance measures, Supply Chain Management, Best Practices, Benchmarking and Business Excellence Models.

Chapter 4: Development

The development chapter explains elaborately the three steps of the present framework: (1) How does a company know it has a need for improvement, (2) Current State Analysis and (3) Create and evaluate alternatives.

Each of these steps include a set of tools to use in order to achieve the main objective of the step. While the tools of the first step are classified according to its purpose (recognize a need for improvement, find root causes and analyse hazards), the tools of the other two steps are classified according to the level of planning (strategic, tactical and operational) that has been deduced as starting point from the first step.

Chapter 5: Empirics

In this chapter, the insights from the three cases, made from interviews with three managers of different companies, are shown. The cases show the way companies currently work and face operational performance improvements or problems.

Chapter 6: Analysis

The sixth chapter includes the comparison between the already developed framework and the companies' insights which are extracted from the interviews. In addition, this chapter includes the interviewees comments about the framework. Then, the limitations of the framework arise and also the necessary corrections for the development of the final framework.

Chapter 7: Reflections

The reflections chapter includes the discussion of the used methodology, the academic contribution of the author with this thesis and the further research.

Appendices:

A1. Evaluate manufacturing capability

This appendix includes two tables that are used to evaluate the manufacturing capability using the methodology proposed by (Lekurwale et al., 2014).

A2. Benchmarking: Integrated strategic benchmarking framework

This appendix contains the table that groups the four areas and the elements that are evaluated in the questionnaire-based survey which conforms the integrated strategic benchmarking framework proposed by (Meybodi, 2006).

A3. Rapid Plant Assessment

The tables needed to implement the Rapid Plant Assessment (RPA) are included in the fourth appendix

A4. Interview guide

The fifth appendix includes the interview guide that is followed during the realization of the interviews to the three managers of three different companies.

A5. Briefly explanation of the tools mentioned in the interviews

This appendix includes a briefly explanation of the tools that are mentioned in chapter five.

2. METHODOLOGY

This second chapter explains the research methodology. Firstly, the approach used to perform the research and the research design are explained. Then, there is an explanation of how the data has been collected, and finally, the general criteria for assuring the quality of this thesis is explained.

2.1. Research strategy

A research strategy requires an overview of the whole project, a carefully constructed plan of action and a specific goal that can be achieved and which is clearly identified.

To decide which strategy is likely to work best, different factors need to be considered such as suitability, feasibility and ethics. According to Denscombe (2010), the project to be carried out should be classified into Action Research because of its purpose of research, i.e. because its main objective is to “produce guidelines for best practice”.

The action research characteristics are a practical nature since it is aimed at dealing with real-world problems; change because it is a way of dealing with practical problems and a means of discovering more about the theory involved; cyclic process since involves a feedback loop; and active participation.

In addition, the research methods, which can be classified into quantitative, qualitative and mixed, have to be also decided. This thesis research is qualitative since it is a subjective research that focuses on the meaning of things. According to this, the data collection methods used are qualitative and the criteria for the quality of this research are, from (Bryman et al., 2007), authenticity, credibility, transferability, dependability and confirmability.

2.1.1. Research approach

In this master thesis, it is necessary to acquire a good knowledge about very diverse concepts, but all encompassed within the main topic of operational performance. For this matter, several books and articles, cited in the following sections, were reviewed not only to acquire a base of key knowledge, but also to look for tools, methodologies and frameworks that could be part of this project.

Moreover, the author considered very important to have empirical knowledge in order to test and validate the framework with some managers of companies. Along these lines, face-to-face or online interviews have been used as the main method for doing the case studies.

2.2. Research design

The research design followed in this thesis is, roughly, the one shown in the following figure:

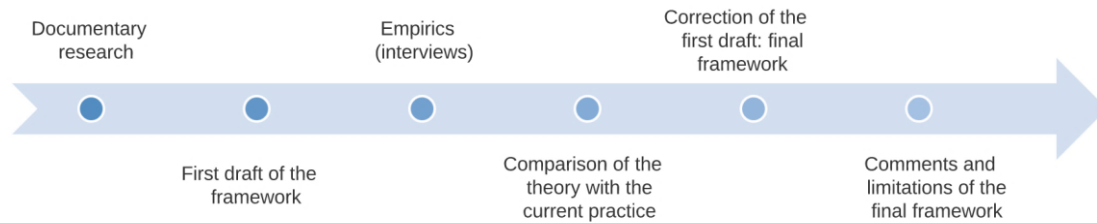


Figure 1. Methodology. Source: Own elaboration

As it can be seen in the above figure, the first step is to collect information about all the concepts involved in the development of the framework as well as for the knowledge of existing methods or techniques for the resolution of the different questions. Afterwards, the first draft of the framework should be developed.

Secondly, the theory needs to be compared with the current practice. This practice is extracted from interviews to some companies' managers that have shown interest in collaborating with the realization of this master thesis.

Once the data is collected, it should be analysed. In this way, the interviews responses are translated into companies' insights in order to make the comparison with the theory possible.

With the comparison, the corrections of the framework as well as its limitations arise and with its correction and complete definition, the final proposal of the framework is developed.

2.3. Data collection methods

In order to carry out this project and collect information, different research methods are used. In the first place, documentary research is used for the knowledge of all the concepts, tools and methods involved in the development of the framework. When defining all the concepts, methods and techniques, their utility for the development of the framework is commented in order to explain why they are included in this project.

The documentary research is based on books focused mainly on Operations Strategy such as (Foster, 2012), (Krajewski et al., 2019) and (Slack et al., 2017) and articles that, although all are encompassed with the same field, deal with varied topics as the ones that follow:

- Strategic, tactical and operational decisions
- Assessing organizational performance
- Supply Chain integration and management
- Benchmarking business performance
- Strategic sourcing
- Managing quality
- Lean and Six Sigma

All these articles are collected using two information search engines: Google Scholar and LUB Search.

Secondly, interviews with managers of companies are carried out to obtain information about the current practice in the field and with the objective of verifying if the framework developed is useful, knowing its limitations and trying to perfect it. These interviews are held in English, a language in which both the interviewer and the interviewee are comfortable. In addition, when carrying out the interviews, observation can be used as an auxiliary method.

An interview question guide is created with the objective of having a reference at the time of conducting the interviews. It should be mentioned that during the realization of these, it is not strictly necessary to follow the guide if it is considered that, for example, there is great interest in an area in which it is not deepened with the guide. In addition, the guide does include not only questions but also explanations about the framework.

This question guide is structured in sections as follows:

(1) Understanding the interviewee and the company, (2) Define: Identify a need for improvement, (3) Measure: Current State, (4) Analyse: Talking about solutions and (5) Comments about the presented framework.

2.4. Criteria for the quality of this research

In order to assess the quality of this research authenticity, credibility, transferability, dependability and confirmability are concepts that need to be considered. All the information of this section is extracted from (Bryman et al., 2007).

2.4.1. Authenticity

Authenticity refers to whether the research fairly represents different observed points of view, whether it help individuals to show signs of comprehension improvement of their social environment or encourages them appreciate the perspectives of other individuals. Likewise, it alludes to if the research has been an incentive to individuals to participate in action and if it has empowered individuals to find a way to change their circumstances.

To ensure authenticity of this project, different managers were interviewed regarding similar issues and different sources for the same area of information were cited. In addition, since the interviews were conducted temporarily separately, some of the insights extracted from an interview could be shared with other interviewees. Lastly, two tutorials per month were carried out to corroborate the good path of the project.

2.4.2. Credibility

Credibility concerns whether there is a decent match between the researcher perceptions and the theoretical ideas created and whether the conclusions that link two or more concepts are firm and sound.

In order to ensure credibility, multiple sources were used to obtain similar information. This was utilized for the written sources, interviews and observations.

2.4.3. Transferability

Transferability refers to which results can be generalized. In order to provide the reader with enough information for making judgements about transferability to other cases, it is important to provide a detailed description of the underlying concepts.

To guarantee transferability, this project includes a description of all the proposed tools and the steps of which the framework is composed, as well as a complete description of its usefulness.

2.4.4. Dependability

Dependability is concerned with the question of whether the results of a study are repeatable, or in other words, how stable the measurement of a concept is.

In order to provide a repeatable result, the methodology for the realization of this project was clearly explained and an interview guide is added in appendix (A4) with which comparable insights to those obtained could be elicited.

2.4.5. Confirmability

Confirmability is concerned with guaranteeing that the researcher has not enabled personal values or influences to modify the conduct of the research and the findings derived from it.

To ensure confirmability and thus, objectivity, the first-hand information of the interviewees was collected, and the information extracted from different written sources was not modified adding any subjectivity.

3. THEORETICAL REFERENCES

Some theoretical concepts need to be introduced in order to understand the tools and techniques proposed to the different steps of the framework

3.1. Total Quality Management (TQM)

Total quality management (TQM) is a total, company-wide effort, though full involvement of the entire workforce and a focus on continuous improvement, that companies use to achieve customer satisfaction. (Lakhe et al., 1993)

TQM has been developed around critical factors such as leadership, quality planning, human resources management, process management, cooperation with customers and suppliers, and continuous improvement. It includes not only a number of critical factors, but also other components such as tools and techniques for quality improvement which are vital to support and develop the quality improvement process.

3.2. Lean and Six Sigma

Lean and Six Sigma are both business process improvement methodologies and their end goals are better process performance but focusing on different elements of a process.

Ian Wedgwood (2016) defines these concepts as follows: Six Sigma is “a systematic methodology to home in on the key factors that drive the performance of a process, set them at the best levels, and hold them there for all time” while Lean is “a systematic methodology to reduce the complexity and streamline a process by identifying and eliminating sources of waste in the process, which typically causes lack of flow”.

Lean and Six Sigma have been positioned as competitors when, in fact, they are complementary. Lean accelerates Six Sigma, delivering greater results than what would typically be achieved by Lean or Six Sigma individually. (Go Lean Six Sigma, 2012)

According to this, several tools that are part of the Lean Sigma toolbox are included in the presented framework.

3.3. Performance measures

Matthews (2011) defines a performance measurement as a metric used to quantify the efficiency or effectiveness of an activity. Its real value is when an organization goes through a planning process that identifies performance measures that are linked to that organization’s vision, goals and objectives.

In order to set good performance measures, they must be balanced, aligned to the organization's strategies, flexible, timely and accurate, simple to understand and focused on improvement. They can be defined also using the SMART rule: Specific purpose, Measurable, Achievable, Relevant and Time phased.

While performance measures can stand alone, they can also be combined with other management techniques to create more useful organization tools. These management techniques can be Dashboards, Key Performance Indicators (KPI), Critical Success Factors (CSF), Process Improvement Initiatives, Self-Assessment Award Models, etc. (Matthews, 2011)

Measurement is important, as it affects behaviour that impacts supply chain performance. As such, performance measurement provides the means by which a company can assess whether its SC has improved or degraded.

For any business activity, such as Supply Chain Management (SCM), identifying the required performance measures on most of the criteria is essential and it should be an integral part of any business strategy. In order to measure and evaluate complex supply chains, measurement goals must consider the overall scenario and the metrics to be used. These should represent a balanced approach and should be classified at strategic, tactical and operational levels, and be financial and non-financial measures, as well. (Bhagwat et al., 2007)

3.4. Supply Chain Management

Foster (2012) defines the Supply Chain (SC) as “a systems-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers”. It is a sequence of activities and organizations involved in producing and delivering a good or service.

When talking about its management, Stadler (2005) defines the SCM as the task of integrating organizational units along a SC and coordinating material, information and financial flows in order to fulfil customer demands with the aim of improving competitiveness of the SC as whole.

However, there are a lot of different definition of the SCM. From (SCRC SME, 2017), the Supply Chain Management (SCM) is defined as the active management of supply chain activities to maximize customer value and achieve a sustainable competitive advantage. It represents a conscious effort by the SC firms to develop and run supply chains in the most effective and efficient ways possible. SC activities cover everything from product development, sourcing, production, and logistics, as well as the information systems needed to coordinate these activities. (SCRC SME, 2017)

This concept is based on two ideas. The first is that “practically every product that reaches an end user represents the cumulative effort of multiple organizations” (Kleab, 2017). The second idea is that while supply chains have existed for quite a while, most associations have just focused on what was going on inside their own business. Few organizations understood, and fewer managed, the whole chain of activities that ultimately delivered items to the last customer. The outcome was disjointed and frequently useless supply chains.

The associations that make up the SC are "connected" together through physical and data flows. While physical flows include the transformation, movement, and storage of goods and materials and are the most noticeable part of the supply chain, data flows permit the different SC accomplices to facilitate their long-term plans, and to control the everyday flow of goods and materials up and down the SC. (Kleab, 2017)

An important issue in performance measurement is how company can use measures to gauge its SC's performance. To do this effectively, a target for each measure needs to be established, providing the framework for determining if the metric has improved from the last time it was reviewed, by how much and how close is the metric to where it should be.

3.5. Best practices

(Angulo Cuentas et al., 2015) is the article used to describe and get a better knowledge about best practices. A best practice can be defined as a process that is better at delivering a particular result than any other and can be identified and learned from many sources such as industrial experiences, consulting experiences, advanced information systems and knowledge base.

This practices can be identified by studying both the excellent organizations processes and activities and studying and each organization's processes and activities and approaching them in context and determining the cause and effect relationship with organizational performance. (Angulo Cuentas et al., 2015)

3.6. Comparative analysis

Comparative analysis (CA) is an analysis that allows an organization to contrast against others or against itself. This comparison can be made in several ways: by industry, revenue, employee base of similar organizations, comparing the organization to those considered "best in class", comparing functional departments, processes, and facilities within the organization, etc.

Benchmarking is considered in this section as a tool or process to carry out comparative analyses in a more specific way. Along these lines, this section describes the Benchmarking process and its utility in this framework.

Benchmarking, as a part of total quality process, is the search for industry best practices that lead to superior performance (Shen et al., 2000). It helps organizations identify current best-in-class designs and identify strengths and weaknesses. It can thus be used to identify the areas on which to focus the company's efforts for obtaining a competitive advantage and it may lead to creative, cost-effective innovations. (Foster, 2012)

Benchmarking has proven to be an effective quality improvement tool, as it has been said above. It can be used to effectively guide the direction of incremental continuous improvement as well as for major changes of process engineering. Learn from the best-in-class organization and utilizing the best practices is a good means to achieve superior performance.

In order for the benchmarking process to be considered effective, it needs to be integrated into organizational strategy and those activities that are critical to organizational success. Along these lines, auditing inner manufacturing strategy, as (Meybodi, 2006) proposes, is necessary to the adequacy of the benchmarking process by accomplishing strategic alignment between different levels in the organization.

From the International Organization for Standardization (2018) is known that the organization should consider the different types of benchmarking practices such as internal benchmarking of activities and processes within the organization, competitive benchmarking of performance or processes with competitors and generic benchmarking, by comparing strategies, operations or processes with unrelated organizations.

3.7. Business Excellence Models

Business Excellence Models (BEMs) have played a major role in improving the performance of organizations. Based on total quality management principles, BEMs have evolved to support strategic planning and decision-making processes and also to measure overall organizational performance. (Meza-Ruiz et al., 2017)

3.7.1. The Malcolm Baldrige National Quality Award

The Malcolm Baldrige Quality Award (MBNQA) was established by Congress in 1987 to improve the competitiveness of American organizations. After that, the principles of the MBNQA were introduced as a promising framework for assessing and improving organizational performance. (Shields et al., 2012)

The Baldrige Excellence Builder is used to assess the organization against the most important features of organizational performance excellence, and it is based on the Baldrige Excellence Framework and its Criteria for Performance Excellence.

3.7.2. The European Foundation for Quality Management

The European Foundation for Quality Management (EFQM) Excellence Model was introduced at the beginning of 1992 as the framework for assessing applications or the European Quality Award. The EFQM model is used as a management system that encourages the discipline of organizational self-assessment. (EFQM, 2016)

The EFQM Excellence Model is a practical tool to help organizations by measuring where they are on the path to Excellence; helping them understand the gaps; and simulating solutions. It is applicable to any organization irrespective of size and structure, and sector. (Michalska, 2008)

3.7.3. The international Organization for Standardization series

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. Two of these standards are of interest for the present project: ISO 9001:2015 and ISO 9004:2018.

While ISO 9001:2015 focuses on providing confidence in an organization's products and services, the ISO 9004:2018 focuses on providing confidence in the organization's ability to achieve sustained success. All the information about the different standards is extracted from each specific standard: (International Organization for Standardization, 2015) and (International Organization for Standardization, 2018).

3.7.3.1. ISO 9001:2015

The selection of a quality management system is a key choice for an association that can improve its general performance and give a sound premise to sustainable development initiatives.

The potential benefits to an organization of implementing a quality management system based on the ISO 9001:2015 are the ability to meet customers and regulatory requirements, facilitating opportunities to enhance customer satisfaction, addressing risks and opportunities and the ability to demonstrate conformity to specified quality management system requirements.

This International Standard employs the process approach, which incorporates the Plan-Do-Check-Act (PDCA) cycle and risk-based thinking.

3.7.3.2. ISO 9004:2018

The ISO 9004:2018 provides guidance for organizations to achieve sustained success in a complex, demanding and ever-changing environment, with reference to the quality management principles. It addresses the systematic improvement of the organization's overall performance and includes the planning, implementation, analysis, evaluation and improvement of an effective and efficient management system.

This International Standard promotes self-assessment and provides tool for reviewing the extent to which the organization has adopted the concepts in the document.

4. DEVELOPMENT

This chapter describes the development of the framework, as well as the three steps and all the tools included in it.

4.1. Introduction

In this chapter, the development of the Diagnostic Framework of Operational Performance is explained. Along these lines, this chapter is composed of three sections in addition to the introduction and the final complete framework structure section that represent the three steps of the framework as follows:

First, the existence of improvement requirement needs to be detected and thus, the level of planning is deduced according to the fault or improvement detected. Secondly, the current state of the company should be known with the aim of increasing knowledge about the company itself and about the problem or need detected. And finally, the evaluation of some alternatives to find a solution. It worth nothing to say that most of the tools to carry out this process and thus, these three steps are classified in the three different levels of planning which are explained below.

According to this, the steps of the framework are:

1. How does a company know it has a need for improvement?
2. Current State Analysis
3. Create and evaluate alternatives

These steps were chosen after several hours of brainstorming between the author and the tutor and the reading of articles and books related to the resolution of operational problems and improvement processes such as (Pal et al., 2017) or (Krajewski et al., 2019).

In order to answer the research question RQ1 (“How can this framework support companies with operational performance improvements or problems?”), some information is added in this chapter and some in the analysis chapter. It worth nothing to say that chapter four in full responds, indirectly, to that question.

As the main aim of the present framework is to provide a series of tools and methodologies to identify a need for improvement and get more information about the company or the plant by measuring its current state, can be considered as a problem or improvement identification process used to prevent operational problems. Moreover, it gives some hints to solve or find solutions.

Some of the proposed tools belong to the Lean Six Sigma toolbox. However, they are considered the simplest ones, so any company, even if they do not use Lean or Six Sigma, can apply them.

In this way, this framework proposes examples of tools and methods than can be used but when selecting or using them, there are two factors which organizations should keep in mind. First, all the tools or techniques need to be accompanied by a plan to be effective and by an appropriate behaviour and attitudes of the employees and thus, make affective improvements. Second, no one technique is better than another and they all play an indispensable role in the improvement process. (Dale et al., 2007)

In addition, it should be noted that all this process must be accompanied by a feasibility study to know, at each step of the process, whether it is economically profitable to continue with the search for a solution or improvement.

Before beginning any process improvement project, it's vital that good candidates for improvement are chosen as projects. Those candidates have to have the potential to result in increased revenue, reduced cost or improved efficiency and also, collectable data. (Go Lean Six Sigma, 2012)

To make this project completely understandable, some concepts are explained such as the differences between capacity, capability and performance, the decision making process and the different planning levels.

The words capacity, capability and performance are often used as synonyms when applied to the problem of strengthening organizations, businesses and governments. However, there are differences in their definitions: Capacity is the ability that exists at present while capability refers to the higher level of ability that can be achieved or improved to and performance refers to how the execution of an action or the fulfilment of a claim, promise or request is being carried out. (BusinessDictionary, 2019)

Talking about managerial activities, decision making is central to all the them, be it planning, organizing, staffing, directing and controlling. It is a process of making choices from alternative courses of action with the intention of moving towards a desired state of affairs.

Planning is the part of management concerned with creating procedures, rules and guidelines for achieving a stated objective. Making decisions in planning activities may range from setting of goals and targets for the entire business enterprise to specific decisions regarding day-to-day activities. Some of them may have only short-term implications, while others may have long-term implications on the enterprise. (Mikoluk, 2013)

From these points of view, managerial decisions can be broadly classified into three categories, i.e. into three levels of planning, namely, strategic, tactical and operational levels.

While strategic planning is an organization's process of defining the strategy, or direction and making decisions on allocating its resources to pursuit this strategy, tactical planning is a short range planning (one year or less) emphasizing the current operations of various plants of the organization. Finally, operational planning in the process of linking the objectives and goals of the previous two. Implementing operational processes is useful to obtain the tactical policies, aims and goals as well as the strategic objectives. (Mikoluk, 2013)

4.2. STEP 1: How does a company know it has a need for improvement?

4.2.1. Introduction

The first step of the present framework is the identification of the existence of a need for improvement and the definition of this need.

The appropriate definition of the problem or improvement needed is the most important step in the search for a valid solution since without having a clear and defined objective, all the following steps can go in the wrong direction or be inefficient.

All type of activities within the Value Chain and SC are both planned, scheduled and tracked. In all these three phases deviations and gaps can be identified. Some of said deviations need immediate action while others need a series of previous phases in order to, for example, find the causes. In addition, not only visible or current problems need to be found but also hazards or risks that will imply a future problem.

Along these lines, direct problems, tools for the identification of a need for improvement, tools to find the root causes of the aforementioned deviations and tools to detect hazards are developed.

4.2.2. Direct problems

Depending on the management area where the improvement is needed or, if it is known, depending on the improvement needed, the level of planning where the analysis has to start is deduced. In this way and using (Schmidt et al., 2000), the different levels are related with different issues or needs for improvement.

The strategic level prescribes a set of locations where facilities are to be located, production technologies to be employed at each facility, and the capacity of each plant. In addition to labour and transportation costs, it must consider other issues such as the infrastructure, general business environment, closeness to markets and to suppliers, taxes and duties, strategic alliances and joint ventures. Strategic decisions thus determine the network through which production, assembly and distribution serve the marketplace and has as objective, the maximization of the total profit.

The tactical level prescribes material flow management policies, including production levels at all plants, assembly policy, inventory levels and lot sizes. It deals with material flow from suppliers to production facilities, to assembly plants, through warehouses and on to customers.

It has to be considered that some issues such as product design may affect both strategic and tactical decisions, so there are issues that may need both, strategic and tactical tools.

The operational level schedules operations to assure in-time delivery of final products to customers, coordinating the logistics network to be responsive to customers demand. The question at this level is when to perform a manufacturing task and at which facility so that due dates are met to the fullest extent possible. It must deal with the environment created by tactical decisions which may induce long throughput times, causing due dates to be violated.

To summarize the above information, the following table is created:

Table 1. Levels of planning, time horizons and issues related.
Source: (Schmidt et al., 2000) modified

Level of planning	Time horizon	Issues
Strategic	Long term	Locations of the facilities, production technologies, plants capacity, infrastructure, general business environment, closeness to markets and to suppliers, taxes and duties, strategic alliances and joint ventures
Tactical	Short term	Material flow management policies
Operational	Today and historically	In-time delivery: when to perform a manufacturing and at which facility; at estimated cost and performance/quality

4.2.3. Tools to be used

As it is said in the introduction, there are different tools to be used in this section. Each of these tools with one specific purpose.

4.2.3.1. Tools to identify a Need for Improvement (Nfi)

In table 1, different tools for the identification of a Need for Improvement (Nfi) are classified depending on the level of planning where the improvement is detected as necessary. Then, these tools are briefly explained.

Table 2. Tools for identification depending on the level of planning.
Source: Own elaboration

Tools for identification	Level of planning	Time horizon or measurement & improvements
Complaints, Stakeholder analysis	Strategic	Long term
Complaints, Long-range planning (capacity/capability vs. needs); Lead times; Backlog; Store levels	Tactical	Short term
Dash boards, Quality deviations, delays	Operational	Today and historically

Complaints can be translated directly into a problem or a fault. However, most of the time it will be necessary to carry out a root cause analysis to be able to find out the main cause of the complaint and thus define a Nfi.

Stakeholder analysis is an important technique for stakeholder identification and analysing their needs. The aim of this technique is to develop a strategic view of the human and institutional landscape, and the relationships between the different stakeholders and the issue they care about most. One of the main benefits of the Stakeholder Analysis and why it is included in this project is the identification of potential issues that could disrupt the project and ways to reduce potential negative impacts.

The comparison between the existent capacity and the future need can be considered in this section. With the objective of making the comparison possible, it is necessary to make a series of forecasts of demand or, going further, a long-range or strategic planning.

Lead time analysis can help the organization or the plant to know the percentage of the total lead time of each activity or process. Then, the area of the supply chain where the efforts have to be focused is defined.

Backlog is the value of unfulfilled orders, or the number of unprocessed jobs, on a given day. It indicates the workload that is beyond the production capacity of a department or firm and it also serves as a pointer toward the firm's future sales revenue and earnings. Having a backlog could suggest the firm is unable to meet the demand so it supposes an important indicator of the capacity performance of a plant or an organization.

The goal of **store-level analysis** is to trawl for the why behind lagging stores. By checking or analysing the store-level, it can be known if the plant has enough products to supplier customers. From there it would be deduced if the material flow management policies are correct or need some kind of improvement.

The **dashboards** are one of the available tools for performance measurement. They look like electric meters or car dashboards. In the case of electric meter, each of the "gauges" shows a different metric, so that it quickly communicates performance levels. In this way, they are very useful for communication, both possibilities and problems, as they highlight what is the next step to achieve the objectives.

Quality deviation handling plays a key role in assuring quality in products and by contributing to continuous improvement. Manufacturers are expected to establish processes and define appropriate controls for measurement and analysis to identify potential nonconformities; defining when and how corrections, corrective actions, or preventive actions should be undertaken.

Potential deviations are identified and avoided by implementing risk control measures and preventive actions. Quality Risk Management is based on the identification of product attributes and operational parameters which are critical to manufacturing operations in order to identify in advance their associated risks.

When it comes to **delays**, these delays are a problem in themselves, but to find the reason why the delay has occurred and thus be able to analyse and eradicate its main cause is the most important part.

4.2.3.2. Tools to find the root causes

The root cause analysis is one of the most important elements of problem-solving in quality management since it is almost impossible to eliminate the real problem if the right target is not being aimed. There are several root cause analysis tools each of them appropriate for a different situation. In this section, some of them are briefly exposed based on (Wedgwood, 2016).

A **Pareto Chart** is a histogram or bar chart combined with a line graph that groups the frequency or cost of different problems to show their relative significance. The bars show frequency in descending order, while the line shows cumulative percentage or total as you move from left to right. It is a simple but extremely useful Lean Sigma tool which uses the Pareto's law, also called 80/20 rule.

The 5 Whys is based on the idea of keep asking "Why" (usually five times) to ensure tht the root cause(s) of the effects are fully understood. The reasoning is that the result of each time the Whys is asked gives a different answer, from Symptom, through Excuse, Blame and Cause, until Root Cause. A much stronger use of this tool is to ask "Why do I care" enough times to relate the issue back to a business-level problem.

Although the **Fishbone Diagram**, also known as a Cause and Effect Diagram, is a well-known quality tool, was dropped from the Six Sigma Process Improvement roadmap and replaced completely by the Process Variables Map and Cause and Effect Matrix combination. However, it a very useful team brainstorming tool to help identify potential root causes to problems based on the examination of the six major process-related areas (branches) which are then broken down further into sub-branches following the 5 Whys principle until some potential root causes are identified.

The **Scatter Diagram** is a quantitative method for determining relationships between variables, determining whether two variables are correlated, such as testing potential causes identified in the fishbone diagram. Its making is a as simple as plotting the independent variable (or suspected cause on the x-axis and the dependent variable or the effect on the y-axis. Then, if the pattern shows a clear line or curve, the variables are correlated.

4.2.3.3. Tools to detect hazards

It is not necessary to focus only on existing problems or easily recognizable or understandable problems, it is also necessary to carry out a risk analysis in order to detect the hazards that affect the company or the plant and thus be able to mitigate them.

Failure Mode and Effects Analysis (FMEA) is a type of risk management and focusing on the process FMEA (between four different types), it considers the risk of failure of an input to a process step. The main idea is to generate a risk priority number for each failure mode. The higher risk number, the more serious the failure could be, and the more important it is that this failure mode is addressed. In this way, the problem on which to focus and to which to seek a solution is defined. (Foster, 2012)

One of the most known tools is the **Hazard Analysis and Critical Control Point (HACCP)** which assesses hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing. Although the HACCP was created and its main use is in the food industry, its general approach can be applied to many other industries. The following information about the HACCP is extracted from (Codex Alimentarius Commission, 2003).

The HACCP system consists of the seven principles: Conduct a hazard analysis; Determine the Critical Control Points (CCP); Establish critical limits; Establish a system to monitor control of the CCP; Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control; Establish procedures for verification to confirm that the HACCP system is working effectively; and Establish documentation concerning all procedures and record appropriate to these principles and their application.

Along these lines, the four first principles are going to be used in this subsection as seen below in order to find the greatest risk or risks that will be considered the problems to solve:

1. Assemble HACCP team or HACCP responsible
2. Describe the product
3. Identify intended use as expected uses of the product by the end user or customer
4. Construct flow diagram
5. On-site confirmation of flow diagram by a person or persons with sufficient knowledge of the processing operation
6. List all potential hazards associated with each step, conduct a hazard analysis, and consider any measure to control identified hazards
 - In conducting the hazard analysis, the likely occurrence of hazards and severity of their adverse effects, the qualitative or quantitative evaluation of the presence of hazards should be include whenever possible
7. Determine critical control points
 - There may be more than one CCP at which control is applied to address the same hazard
 - This action can be facilitated by the application of a decision tree which indicates a logic reasoning approach
8. Establish critical measurable limits for each CCP
9. Establish a monitoring system for each CCP

4.2.4. Starting point and direction of the analysis

Once the need for improvement is detected, the level of planning by which to start with the analysis is deduced. Depending on that level, the time horizon, the type of review, the alternatives and thus, the programs and tools to be used vary.

The direction of the analysis should thereupon be defined. If the improvement is needed in a specific management area, the level corresponding to that area should be the starting point and then, probably, move to the other levels to achieve the goal. However, if the fault/problem/gap is not focused on one specific level, the analysis should start from the most global level and then keep exploring. It should be noted that a single direction is not mandatory, there will be analyses that must rise and fall from one level to another continuously.

Along these lines, if one starts on strategic level, then next step will be on tactical level and maybe then on operational level. If one start on tactical level, one can then either go up, to proceed down or go down to operational level. And if one starts directly on operational level, one can both complete on that level or go further up.

4.2.5. How to do it?

In the following figure, the path to apply the tools already explained is defined. It is considered necessary to define this path since all the tools proposed for the first step are explained but not the relationship that exists between them.

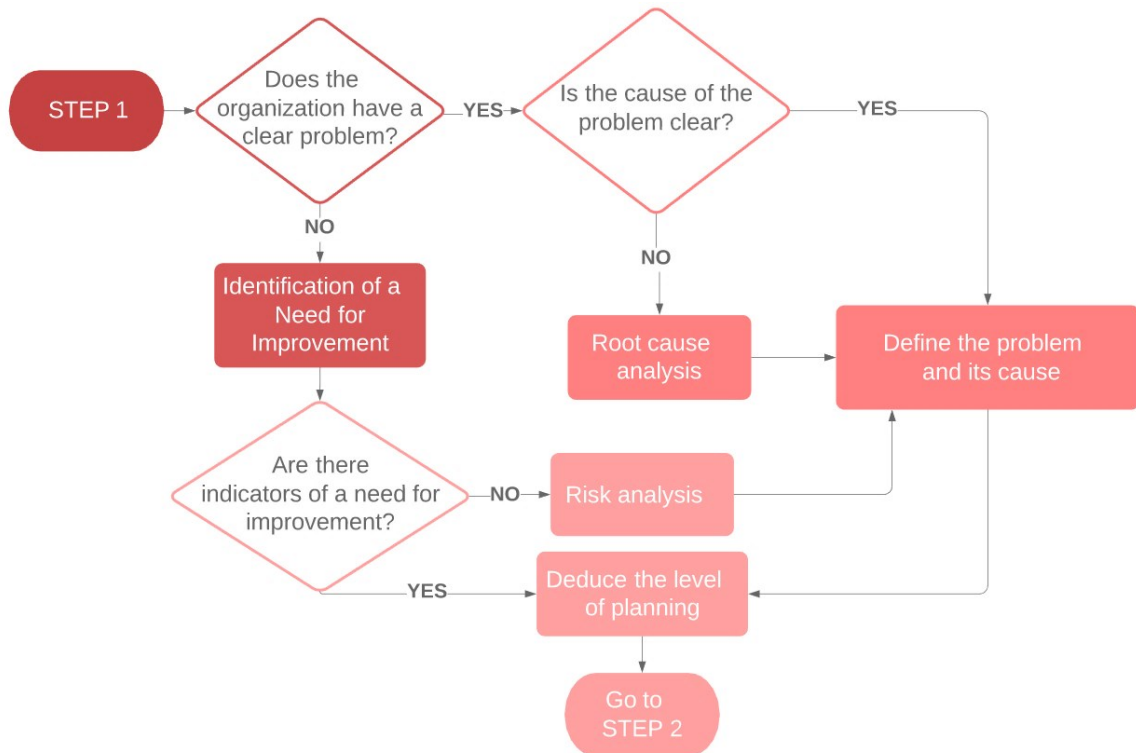


Figure 2. Flowchart to implement the first step of the framework.
Source: Own elaboration

As it can be seen, if the problem is clear and also is its cause, the definition is direct and the level of planning to start with is deduced. If the problem or its cause is not clear, the tools explained above come into play as explained in the figure 2. While the risk analysis tools are used when there are no indicators of a need for improvement, the root cause analysis tools are used when the cause of the problem is not clear.

4.2.6. Summary step 1

All the explained in the 4.2 section (STEP 1) is summarized in the following figure. This figure is created to facilitate understanding and summarize all the explanations and tools explained above. At the end of the development chapter, the scheme of the three steps and with it, the entire framework is added in a single figure.

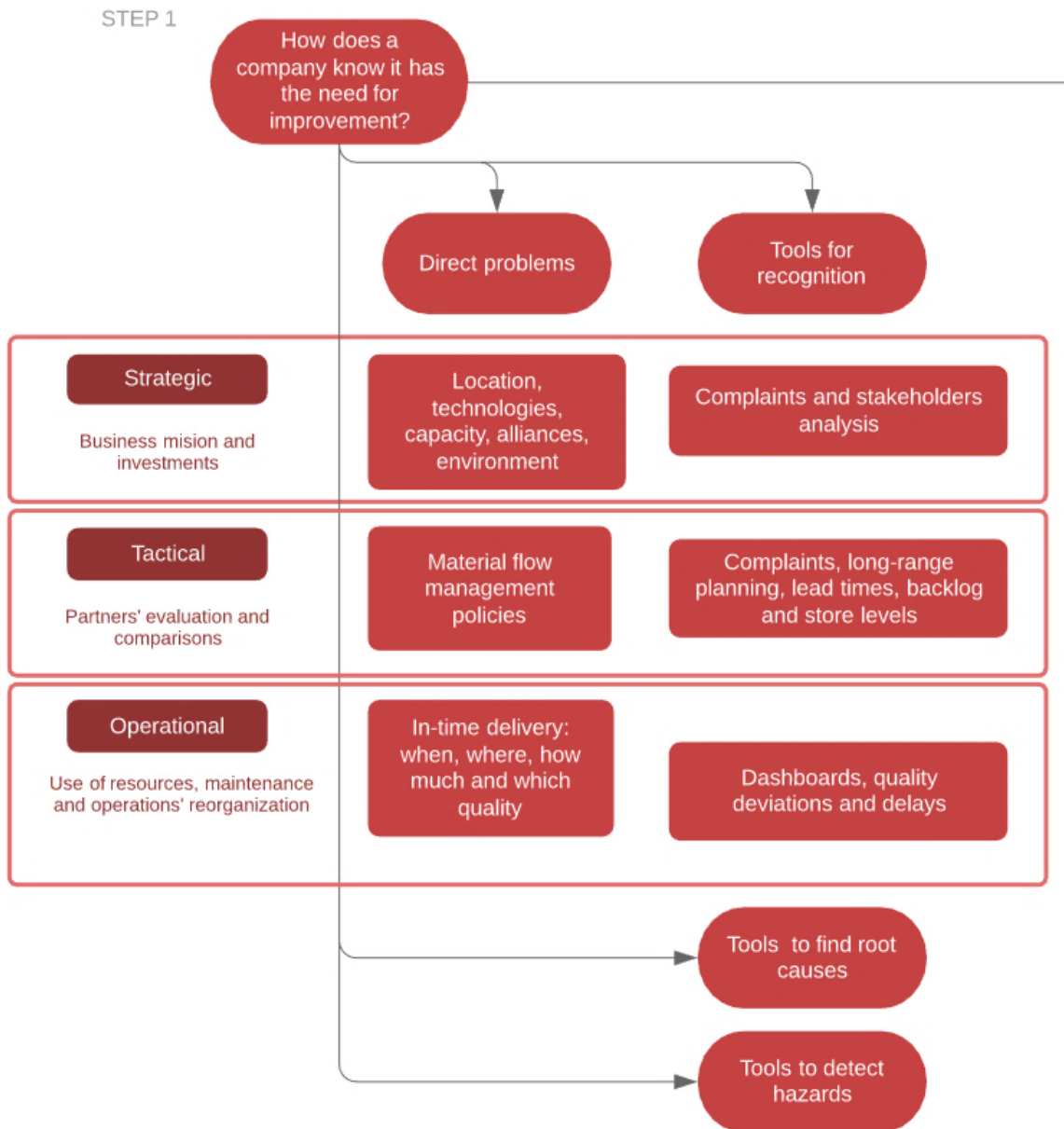


Figure 3. Structure of the first step of the framework. Source: Own elaboration

From the above figure it is noteworthy that the direct problems and the tools for identification, as in the previous sections, are classified depending on the level of planning. On the contrary, the tools to find root causes and to detect hazards are added below and are not classified since they are used to define the problem and its cause from which it is related to the previous ones to deduce the level of planning by which to begin.

4.3. STEP 2: Current State Analysis

4.3.1. Introduction

The Current State Analysis, also referred to as “Current State Review”, “Current State Assessment” and “State of Asset Management”, is a report indicating how an organization is running its operations today. Some of its primary benefits are listed below:

- To establish the baseline against which to benchmark the organization
- To collect data as the input for a gap analysis
- To help establish the organization’s maturity level relative to a selected best practice
- To help the stakeholders make an informed decision

Once the planning starting point is deduced, the current state of the company or plant in the specific level of planning is needed. Not only the current situation at the starting level should be analyzed but also, all the levels that are going to be used to find a solution to the problem found.

Depending on the level of planning and its corresponding time horizon, there are different types of review, as it can be seen in the Table 3. According to this table, the tools explained below seek to find out how the organization or the plant are running their operations today.

Table 3. Levels of planning and types of review. Source: Own elaboration

Levels of planning	Types of review
Strategic level	Qualitative: fitness to business mission and investments
Tactical level	Evaluation of partners and comparisons
Operational level	Quantitative measures: use of resources and maintenance; reorganize operations

4.3.1. Tools to be used at the strategic level

4.3.1.1. SWOT

SWOT analysis is a useful technique that focuses on Strengths and Weaknesses in the internal environment and Opportunities and Threats in the external environment. This is why SWOT is sometimes called Internal-External Analysis and it helps the organization to determine where they stand within their industry or market.

In order to implement the SWOT analysis, a group from the relevant departments and a SWOT analysis matrix must be created. Then, the internal strengths and weaknesses of the business and the opportunities and threats present in the industry/market should be listed down.

Finally, each bullet point should be rearranged in the order of importance and an analysis of how strengths can minimize weaknesses and fight off threats, and how opportunities can be used to avoid threats and get rid of weaknesses should be done.



Figure 4. SWOT analysis matrix example with questions to complete it.

Source: Own elaboration

4.3.1.2. Baldrige Excellence Builder

The Malcolm Baldrige Quality Award (MBQN) has been introduced in the theoretical references chapter. All the information related to this tool is extracted from (Baldrige Excellence Builder, 2019).

The Baldrige Excellence Builder is used to assess the organization's strengths and opportunities for improvement against the most important features of organizational performance excellence and to understand how well the organization is accomplishing what it is important for the organization.

- Are your processes consistently effective?
- Do your approaches address your organization's needs?
- How good are your results?
- Is your organization learning and improving?

The Criteria for Performance Excellence are a set of questions about seven critical aspects of managing and performing as an organization: Leadership; Strategy; Customers; Measurement, Analysis, and Knowledge Management; Workforce; Operations; and Results.

These questions work together as a unique, integrated performance management framework. Answering the questions helps the organization align the resources, identify strengths and opportunities, improve communication, productivity and effectiveness and achieve the strategic goals.

4.3.1.3. ISO 9004:2018

The ability to achieve sustained success is enhanced by managers at all levels learning about and understanding the organization's evolving context. Improvement and innovation also support sustained success. Along these lines, the ISO 9004:2018, as it was said in the theoretical references chapter, provides a self-assessment tool giving an overall view of the performance of an organization and the degree of maturity of its management system.

Maturity of an organization is the extent to which an organization has explicitly and consistently deployed practices or processes that are documented, managed, measured, controlled, and continually improved. The results of an organization's self-assessment can be valuable input into management review and therefore to get a better understanding of the organization itself. (International Organization for Standardization, 2018)

4.3.1.4. The European Foundation for Quality Management Excellence Model

The EFQM Excellence Model incorporate incorporates very interesting tools for the realization of this project such as the Fundamental Concepts of Excellence, the 9 Box Model or the Business Excellence Matrix. All these tools are explained bellow with information extracted from (EFQM.ORG, 2019).

The Fundamental Concepts of excellence can be seen in the following figure. An organisation that hopes to make the grade in the assessment, has to keep these eight concepts as the cornerstone of their improvement initiatives.



Figure 5. The Fundamental Concepts of Excellence from the EFQM Excellence Model.
Source: Made by the author based on (EFQM.ORG, 2019)

The 9 Box Model is a 32-criterion structure that underpins the EFQM Excellence Model. The boxes are divided into two groups named Enablers and Results, the first ones are used to measure the activities in the organization such as strategies, policies and processes and the people who are involved with carrying these out and the second ones are the outcomes of the Enablers. The EFQM Excellence model allows people to understand the cause and effect relationships between what their organisation does (the Enablers) and the Results it achieves.

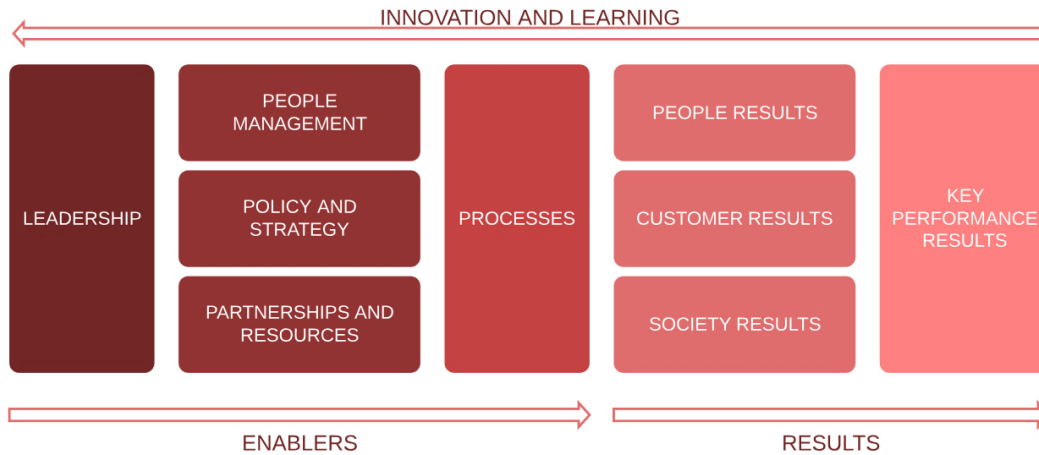


Figure 6. The 9 Box Model of the EFQM Excellence Model.
Source: Made by the author based on (EFQM.ORG, 2019)

The Business Excellence Matrix was developed as a self-assessment tool to enable an organisation to assess its current position against the EFQM Excellence Model 2013 and identify their key strengths and key improvement areas.

This self-assessment tool provides a valuable method of tracking progress through the EFQM Excellence framework, making it easier to progress through the early stages of improvement, to identify where change is needed and to get started with the implementation of process improvement goals. It is preparatory in nature, allowing your organisation to identify areas of improvement and institute process improvement practices consistent enough to withstand the scrutiny of an external assessment.

4.3.1.5. Other tools

There are several tools to evaluate the current state of an organization at the strategic level. The ones that have been considered more important have been already explained but there are three more that also need to be mentioned and are explained below from (Athuraliya, 2018). Those tools are McKinsey 7S, Nadler-Tushman's Congruence Model and Burke-Litwin Causal Model and are briefly explained below.

The McKinsey 7S is a tool that can help understand the gaps when performing a gap analysis in any business, identify areas to optimize the business performance, align processes and departments during an alliance and examine the result of future changes within the organization.

The Nadler-Tushman's Congruence Model is used to identify performance gaps within an organization by analysing the compatibility between work, people, structure and culture.

And finally, **Burke-Litwin Causal Model** is a tool used mainly when a change is going to be made. It helps to understand the relation between different components: external environment, mission and strategy, leadership, organization culture, structure, management practices, system and policies, work unit climate, task requirements and individual skills, individual needs and values and employee motivation.

4.3.2. Tools to be used at the tactical level

At this level, two tools have been proposed: The Balanced Scorecard and the Supply Chain Operations Reference (SCOR) model. These tools are used at this level because of their level of detail. While the BSC can be said to act as a connection between the strategic and tactical levels (less detailed), the SCOR model encompasses both the tactical and operational levels (rather detailed). All this is due to the type of performance measures they propose.

Pretko (2011) asserts that both tools apply multitude of performance indicators for both of short-term and long-term goals. The SCOR/Balanced Scorecard combination can enable organizations to evaluate SC improvement opportunities and set performance targets. Furthermore, their blend enables complete administration and constant improvement by incorporating the three levels of management and encouraging the decision making process efficiently and proactively.

From (mThink, 2000), the conclusion is that there is no one recommended approach or set of measures to be used to measure one's supply chain performance. However, approaches such as the Balanced Scorecard and the SCOR model provide excellent guidance when developing a supply chain performance measurement system.

4.3.2.1. The Balanced Scorecard

In 1996 Robert S. Kaplan and David P. Norton co-authored the book *The Balanced Scorecard*. More than just a measurement system, the Balanced Scorecard (BSC) is a management system that channels core competencies and emerging technologies toward strategic goals and business objectives. (Pretko, 2001)

Kaplan and Norton proposed the Balanced Scorecard as a means to evaluate corporate performance from four different perspectives: the financial, the internal business process, the customer, and the learning and growth. (Bhagwat et al., 2007)

Going one step further, the BSC is proposed to an effective management of SC, evaluating the performance measures and metrics of the SCM and giving a cohesive picture to address what needs to be measured, and how it can be deal with.

All the following information referred to the BSC is extracted from (Bhagwat et al., 2007).

In order to put the BSC to work, companies should articulate goals for time, quality, performance and service and then translate these goals into specific measures. In building a firm specific balanced SCM scorecard, following steps are recommended:

1. Create awareness for the concept of balanced SCM scorecard in the organization;
2. Collect and analyse data on the following items:
 - Corporate, business and SCM strategies;
 - Specific objectives and goals related to corporate, business and SCM strategies;

- Traditional metrics already in use for SCM evaluation;
 - Potential metrics related to four perspectives of balanced scorecard;
3. Clearly define the company specific objectives and goals of the SCM function for each of the four perspectives;
 4. Develop a balanced SCM scorecard based on the defined objectives and goals of the enterprise.

4.3.2.2. The Supply Chain Operations Reference model

In 1996, The Supply Chain Council (SCC) was formed and developed The Supply Chain Operations Reference model (SCOR). This model was developed with the main objective of describing the business activities associated with all phases involved in satisfying customer demand.

It describes supply chains in five dimensions: reliability, responsiveness, flexibility, cost and efficiency in asset utilization. The model is organized around the six primary SCM processes of Plan, Source, Make, Deliver, Return and Enable. (Pretko, 2001)

The SCOR model enables effective communication among supply chain partners by providing a standardized way of performing process modelling and performance measurements. It also provides a way to measure the maturity of an organizations and enables benchmarking with other supply chains in an effective way. The main limitation of this model is that it only includes activities related to purchasing, manufacturing and distribution, whereas activities related to sales and R&D are not included.

In this project, the SCOR model is used because of its process model which allows for simple selection of performance measurements by suggesting a set of measures, allowing for both initial performance benchmarking and continuous evaluations to support future improvement and strategic planning.

The first step using the SCOR model is to create the block model using as example the figure below. Developing the model and observing it once created can help to describe SC that are very simple or very complex using a common set of definitions across disparate industries. Businesses use these to establish the requirements for the SC by figuring out which performance attributes to prioritize and which areas the business can perform at an average pace.

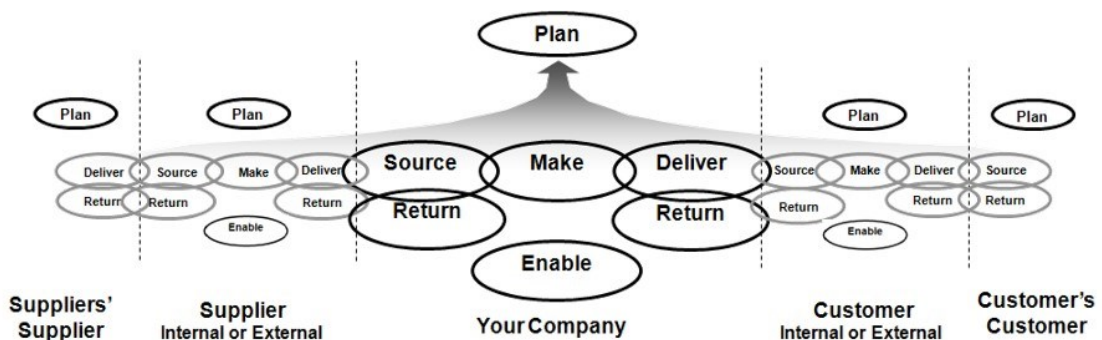


Figure 7. SCOR model. Source: (APICS, 2017)

4.3.3. Tools to be used at the operational level

Focusing on the operational level and according to (Hoyle, 2005), different tools are proposed to answer the following questions and thus, to know the current situation of the organization or the plant at the operational level.

- How do you know the process is performing as planned?
- How do you know the process is achieving the results in the best way?
- How do you know that the results being achieved are those necessary to fulfil organizational goals?

It has to be mentioned that the main problem at the operational level that this project focuses on is capability. In this way, the first tool included proposes to evaluate the manufacturing capability. Then, three more tools and measurements have been proposed in order to know the effectiveness of the equipment, the performance of the processes and the failure state.

4.3.3.1. Evaluate manufacturing capability

Competitiveness of a firm depends on how they distinguish customers from manufacturing point of view. In this way, there are seven production systems each of these is compatible to produce all output, but each one of them will be at certain level. These production systems are:

- Job Shop (JSPS)
- Batch Flow (BFPS)
- Operator-Paced Line Flow (OPLFPS)
- Equipment-Paced Line Flow (EPLFPS)
- Continuous Flow (CFPS)
- Just-in-time (JIT)
- Flexible Manufacturing System (FMS)

The given production system governs the competitiveness of a firm in fulfilling the customer expectations, i.e. competitive priority of a firm is given by the manufacturing capability with in turn is governed by a particular production system. Therefore, understanding the manufacturing capability is essential for the competitiveness.

(Lekurwale et al., 2014) proposes using analytical hierarchy process (AHP) to model the manufacturing capability evaluation problem. The following figure shows the three-step process proposed which is explained below.

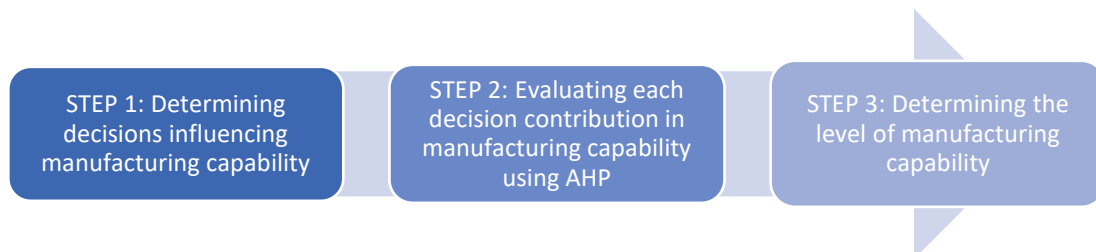


Figure 8. Process to evaluate manufacturing capability. Source: Own elaboration

Determining the level of manufacturing capability provides the feedback in the weak decision areas so that a firm can strategically focus in improving the manufacturing capability and, hence, the competitiveness.

Step 1: Determining decisions influencing manufacturing capability:

All decisions influencing manufacturing capability have been classified into six decision areas which are human resources, organization structure and control, production planning and control, process technology, sourcing and facilities.

Decisions in each decision areas should be in line with the business goal and manufacturing strategy of a firm and also the life cycle stages of a product influence the decision of a particular production system. Each of these decision areas is broken down into a series of important decisions that affect the manufacturing competitive performance and can be seen in the table 2 in the appendix (A1).

Step 2: Evaluating each decision contribution in manufacturing capability using AHP

Understanding the manufacturing capability of a firm based on each decision contribution consists of criterial relative weight calculation, criteria evaluation and overall manufacturing capability index calculation.

First, relative weights are assigned to the criteria using table 1 in appendix (A1). Weights are first assigned to the group criteria and then to individual criteria in a particular group. The effective weight of a particular criterion is equal to the product of its own weight and the weight of the criteria group.

Secondly, each criterion needs to be measured to understand its contribution. For this, ratings to each decision have been defined in table 2 in appendix (A1), and contribution of a particular decision is obtained by quantification of ratings.

Finally, the overall manufacturing capability is obtained by the sum of the product of the evaluation score in each of the criteria and the effective weight of the respective criterion.

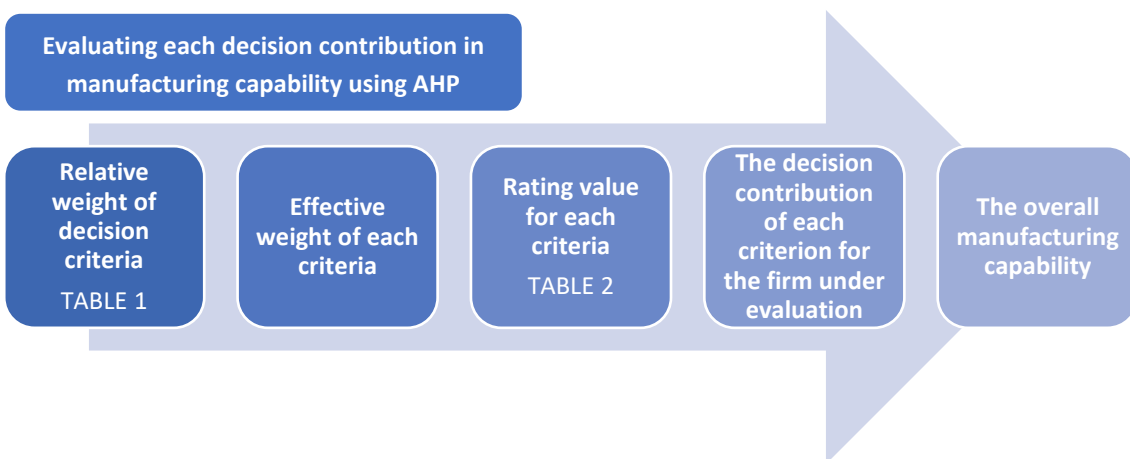


Figure 9. Steps to evaluate each decision contribution in manufacturing capability using AHP

Source: Own elaboration

Step 3: Determining the level of manufacturing capability

After calculating the overall manufacturing capability, the same procedure has to be followed considering the recommended level of each of the criterion obtaining the overall manufacturing capability of the ideal firm with the same production system.

To further improve the competitiveness, the weak decision areas have to be identified by comparing firm decisions with likely to be the ideal decision contribution, the biggest difference, the most important areas to focus on.

4.3.3.2. The Overall Equipment Effectiveness (OEE)

From (Wedgwood, 2006), all the information related to the OEE is extracted. The Overall Equipment Effectiveness (OEE) is the gold standard for measuring manufacturing productivity. It identifies the percentage of manufacturing time that is truly productive. An OEE score of 100% means 100% Quality (only good parts), 100% Performance (as fast as possible) and 100% Availability (no stop time).

Measuring OEE can be considered as a manufacturing best practice since the organization will gain important insights on how systematically improve its manufacturing process. It is the single best metric for identifying losses, benchmarking progress, and improving productivity of manufacturing equipment.

There are two different ways of calculating the OEE: the simple and the preferred calculation. The first one is just considering the OEE as the ratio of fully productive time to planned production time where fully productive time is another way of saying manufacturing only good parts as fast as possible with no stop time.

However, the simple calculation does not take into consideration the three loss-related factors of availability, quality and performance, fact that the preferred calculation does. In the preferred calculation you get the best of both worlds. A single number that captures how well you are doing (OEE) and three numbers that capture the fundamental nature of your losses (Availability, Performance, and Quality).

The preferred OEE calculation is based on the multiplication of these factors. Each of them is calculated as follow:

- Availability is calculated as the ratio of run time (planned production time minus stop time) to planned production time.
- Performance is the ratio of net run time (ideal cycle time multiplied by total count) to run time.
- Quality is calculated as good count divided by total count.

4.3.3.3. Performance measurements

As it is mentioned in the theoretical references chapter, identify the required performance measures is essential to measure and evaluate supply chains. In the table 5, some of these performance metrics can be seen.

Table 4. Performance metrics and measurements of SCM at the operational level. Source: (Bhagwat et al., 2007) modified

Performance metrics	Financial	Non-financial
Cost per operation hour	X	
Information carrying cost	X	X
Supplier rejection rate	X	X
Capacity utilization		X
Total inventory cost as: Incoming stock level, Work-in-progress, Scrap value, Finished goods in transit		X
Efficiency of purchase order cycle time		X
Frequency of delivery		X
Quality of delivery documentation		X
Driver reliability for performance		X
Quality of delivered goods		X
Achievement of defect free deliveries		X

In addition, not only generic performance measurements must be considered. Depending on the problem or fault, there are different measures to focus on. In the following table, some of these measurements can be seen depending on the issue (some examples).

Table 5. Performance measurements depending on different operational issues. Source: Made by the author based on (Wedgwood, 2016)

Issues	Measuring performance	How to do it?
On-time delivery	Accuracy	Percentage of time that the right thing is delivered in the right form Failure rate (MTTR, MTBF, MTTF)
	Timeliness	Replenishment time
Capacity is too low	Throughput	Average number of entities over a period of time
	Cycle Time	Time between outputs
Defects, Quality, Scrap and Rework	Rolled Throughput Yield (RTY) or First Time Right Primary performance metrics	Percentage of entities that make it through the process right the first time Performance characteristics
Process lead time too long	Process lead time	Process lead time
Demand too variable	Coefficient of Variation	Variability divided by the mean of demand or volume
Too many entities	Number of entities	Number of entities
High schedule variation	Variance	Difference between actual and planned
Performance characteristics not good enough	Performance characteristics	Performance characteristics
Resource usage too high	Headcount costs or the total work content	Headcount costs or the total work content
Inventory too high	Days On Hand (DOH)	Time the material is on hand
	Inventory turns	Times the inventory will turn in a specific period of time
	Inventory cost	The sum of the cost of the inventory

4.3.3.4. Failure metrics

A failure is declared when the system does not meet its desired objectives. Managing failure correctly can help an organization to significantly reduce its negative impact. Asset performance metrics like MTTR, MTBF, and MTTF are essential for any organization with equipment-reliant operations. Only by tracking these critical KPIs an enterprise can maximize uptime and keep disruptions to a minimum.

(Christiansen, 2018) is used to explain the performance metrics abovementioned.

Mean Time To Repair (MTTR) refers to the amount of time required to repair a system and restore it to full functionality including repair time, testing period, and return to the normal operating condition. MTTR is the result of dividing the total maintenance time by the total number of maintenance actions over a given period of time.

Every efficient maintenance system always needs to look at how to reduce MTTR as much as possible. Understanding MTTR is an important tool for any organization because it tells them how efficiently you can respond to and repair any issues with your assets.

There is more than one commonly used term for MTTR. Mean Time To Recovery is one of these and it is the same as Mean Time To Repair but including the failure notification time and diagnosis.

Mean Time Between Failures (MTBF) measures the predicted time that passes between one previous failure and the next one during normal operation. It captures failures that occur due to design conditions that make it necessary to take the unit out of operation before it can be repaired. So, while MTTR measures availability, MTBF measures availability and reliability.

MTBF is the result of dividing the total operational time by the number of failures. Low MTBF could either indicate poor handling of the asset by its operators or a poorly-executed repair job in the past. Manufacturers use it as a quantifiable reliability metric and as an essential tool during the design and production stages of many products.

Mean Time To Failure (MTTF) is a very basic measure of reliability used for non-repairable systems. It represents the length of time than an item is expected to last in operation until it fails. MTTF is what commonly known as the lifetime of any product or a device. It is calculated with the average of the time of failure for a long period of time of a large number of items of the same type.

4.3.4. Summary step 2

All the explained in the 4.3 section (STEP 2) is summarized in the following figure.

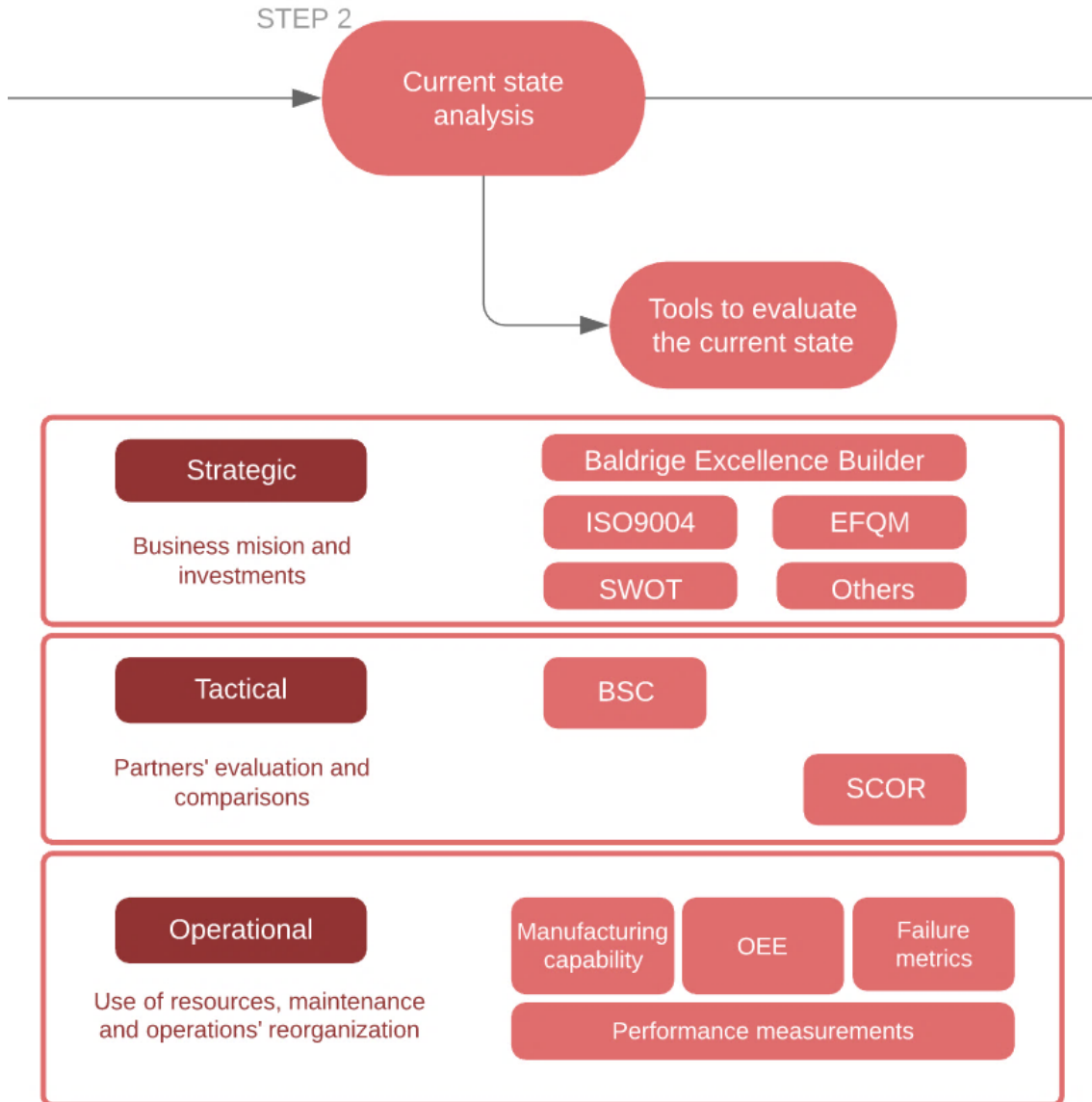


Figure 10. Structure of the second step of the framework. Source: Own elaboration

4.4. STEP 3: Create and evaluate alternatives

4.4.1. Introduction

In the third step of the present framework, several tools are explained in order to create and evaluate alternatives of solution according to the planning level deduced in the first step, i.e. depending on the level of planning, table 3 explained the types of review that entail a series of tools for their evaluation.

This section can be considered as a gap analysis. A gap analysis is a tool used to compare where a company is against where it would like to be. It helps find solutions to issues that are holding the organization back from growing as a business.

In the first two steps of the framework the problem or improvement needed is defined and the current situation of the company referred to that improvement is analysed. In order to carry out the gap analysis, the only thing that remains to be done is to define the objectives and with it the future or desired state in order to be able to look for solutions to close the gap between the current and the desired state.

Benchmarking is a tool that can be used to define the desired state, but also, the company has its own objectives and desired values for different performance measures. Not only benchmarking but also other tools such as VSM, SCOR, Brainstorming or Gemba are included in this section in order to find solutions and support the organization to close the gap.

It has to be mentioned that the creation and evaluation of alternatives at the strategic level are not going to be explained since it is considered out of the scope of this project as it has been explained in the conclusion of the step one. However, there are some concepts or actions that involve more than one level, including the strategic one, which are going to be added and briefly explained.

4.4.2. Relation to theories

Capacity decisions related to a process need to be made in light of the role the process plays within the organization and the SC as a whole, because changing the capacity of a process will have an impact on other processes within the firm and across the chain. In order to carry out a capacity decisions, different areas within the organizations such as accounting, finances, marketing, management, operations, purchasing and human resources need to collaborate.

The type of capacity decisions differs for different time horizons. Both long-term and short-term issues associated with planning capacity and managing constraints are important and must be understood in conjunction with one another. (Krajewski et al., 2019)

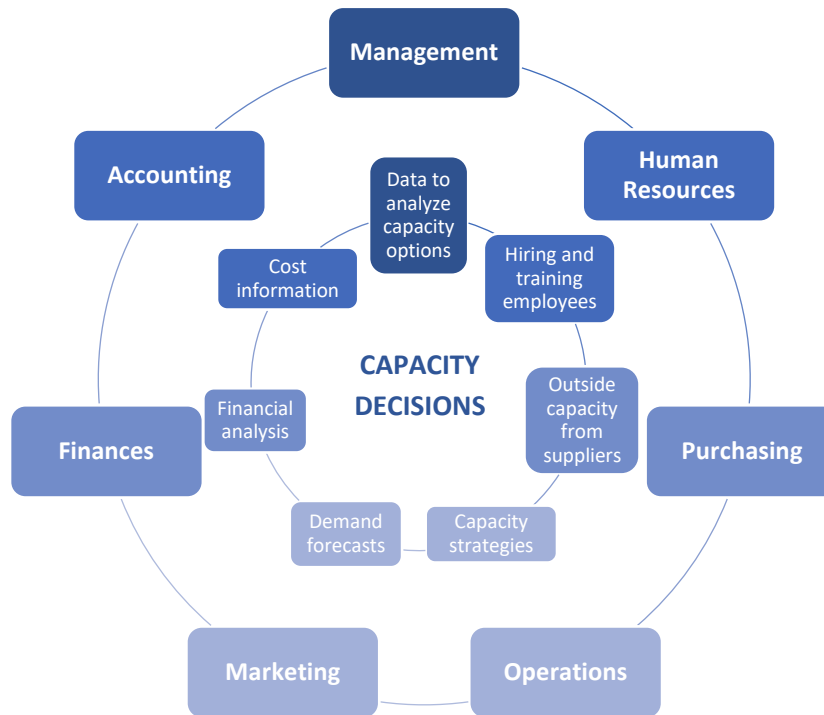


Figure 11. The different areas that intervene in a capacity decision.

Source: Made by the author based on (Krajewski et al., 2019)

In order to define the capacity scale, the number and size of different sites between which the capacity is distributed, the specific activities allocated to each site and the location of each site, the capacity strategy of an operation needs to be carried out. When the nature of competition shifts in some way, companies often need to reconfigure their capacity. This process of changing usually involves deciding when capacity levels should be changed, how big each change step should be and overall how fast capacity levels should change.

Although capacity decisions are taken for different time-scales and spanning different areas of the operation, each level of capacity decision is made with the constraints of a higher level. (Slack, 2017)

Capacity planning can be the solution to some operational performance problems since if it does not exist the quality of a project may suffer, the staff may suffer from low morale clogging up a project or making them quit, the satisfaction of customer requirements may not be met and thus could damage the reputation and cause loss of current and future clients.

Benchmarking has been considered a very useful tool to decide where to focus the company's efforts and guide the direction of incremental continuous improvement. In this way, it is a good means to achieve superior performance and for all these reasons, it can be very useful when making not only capacity decisions but also performance improvements in an organization.

As it can be seen in the figure 11, **suppliers** play an important role in the capacity decisions and for that they need to be evaluated. The suppliers' evaluation has to be made to not only evaluate their performance and thus, all the SC performance but also consider different solutions as outsourcing.

Outsourcing refers to obtaining certain services or products from a third party company, essentially sourcing something like accounting services or manufacturing of a certain input to another company. It gives a competitive advantage whenever a portion of the value chain can be located outside the company to gain cost or differentiation advantages. The key reasons a business would choose to outsource are cost, specialization and flexibility. However, there are also several disadvantages that can cause the balance to decline towards insourcing such as the dismissal of personnel from the main company, loss of direct contact with the work performed by the subcontractor or loss of flexibility in manufacturing. (Foster, 2012)

Training employees is also included in the figure 11 and it needs to be also considered as an available solution for operational performance problems.

When talking about **operational level**, most of the proposed tools are aimed at finding the gaps in which to focus efforts to achieve the improvement such as Process Documentation or Gemba. In addition, Benchmarking, Brainstorming and experience have been proposed to find solutions to a specific problems.

4.4.3. Tools to be used at the tactical level

4.4.3.1. Tools to create hypothetical situations and measure the performance

Both, the Balance Scorecard and the SCOR model, can be used to evaluate alternatives in the same way as to evaluate the current state of the organization or plant. In this case, the situation to be evaluated is hypothetical since the alternative to be analysed is supposed to be implemented and performance measurements are done in that state. Next, it is checked if the existing gaps have been partially or completely closed and, thus, analyse the effectiveness of the alternative.

Along these lines, it is more than likely that several alternatives must be analysed at the same time to see which one closes the gap or gaps better.

4.4.3.2. Value Stream Mapping (VSM)

Foster (2012) defines the Value Chain as “a tool that disaggregates a firm into its core activities to help reduce costs and identify sources of competitiveness”. The core activities or Value-Added (VA) activities can be considered those that add value to the customer.

The Value-added (VA) activities are those that change the size, shape, fit, form, or function of materials or information to meet customer demand and requirements. The Non-Value-Added but Required (NVAR) activities are the ones that do not bring value to the customer but are needed for some reason by the business or for legal or regulatory reasons. And the Non-Value-Added (NVA) or pure waste activities are the activities that are not required by anyone and would best be removed completely. (Wedgwood, 2016)

The Value Stream Mapping is an available tool that can be used, for example, to identify Non-Value-Added (NVA) activities when the process lead time is too long, to evaluate the time the NVA activities uses from the total process when the resource usage is too high, to evaluate the inventory when excess inventory ties up resources unproductively or to evaluate a process where the fault or the need for improvement has been found.

Along these lines, the Value Stream Mapping is used as follows:

1. Decide the scope in which to work
2. Define the steps
3. Identify and indicate the information flows
4. Collect critical data
5. Add data and timelines to the map
6. Identify the wastes: transport, inventory, motion, waiting, over-processing, overproduction and defects.
7. Create the ideal value stream map

4.4.3.3. Tools for suppliers' selection and evaluation

Strategic relationship with suppliers is a key ingredient to the success of a SC. Strategic sourcing decisions must not be solely based on operational metrics, but also incorporate strategic dimensions and capabilities of suppliers into the decision-making process.

Analyzing articles and other literature related to the evaluation of suppliers as it has been done in article (Ho et al., 2009), it has been concluded that the individual approaches are more popular than the integrated ones. The most popular individual approach is the Data Envelopment Analysis (DEA) followed by mathematical programming, AHP, CBR, ANP, fuzzy set theory, SMART and GA. DEA has attracted more attention because of its robustness, and it has been modified to handle also qualitative data so it can be now be used to consider stochastic performance measures and handle imprecise data.

(Talluri et al., 2002) propose a methodology for strategic sourcing which utilizes a combination of traditional and advanced DEA models in estimating the efficiencies of alternative suppliers, and the variability in their efficiency scores. The robustness of the methodology over existing DEA models is that a combination of methods that effectively discriminates among suppliers and avoids some of the pitfalls associated with the traditional DEA models is used.

When talking about the integrated approaches, it is shown in (Ho et al., 2009) that the integrated Analytic Hierarchy Process (AHP) approaches are more prevalent. The wide applicability is due to its simplicity, ease of use, and great flexibility. The most popular combination is the AHP-GP since the Goal Programming (GP) can compensate for AHP providing more and useful information for the decision makers. However, although the above-mentioned approaches can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business objectives and requirements of company stakeholders on the evaluation criteria. In reality, the weighting of supplier evaluating criteria depend a lot on business priorities and strategies. To enable the voice of company stakeholders is considered, an integrated analytical approach combining AHP and QFD should be used.

Other authors, as well analyzed in the article (Chen, 2010), developed and proposed other variations of the DEA method and more AHP-based decision methods. However, the establishment of a supplier evaluation model from the above studies mostly did not focus on the needs of ends costumers from the perspectives of SC or the strategy of the enterprise itself. In this way, (Chen, 2010) proposes a structured methodology for supplier selection and evaluation based on SC integration architecture, to help leading enterprises establish a systematic approach to selecting and evaluation potential suppliers for SC. This methodology can be seen in the following figure.

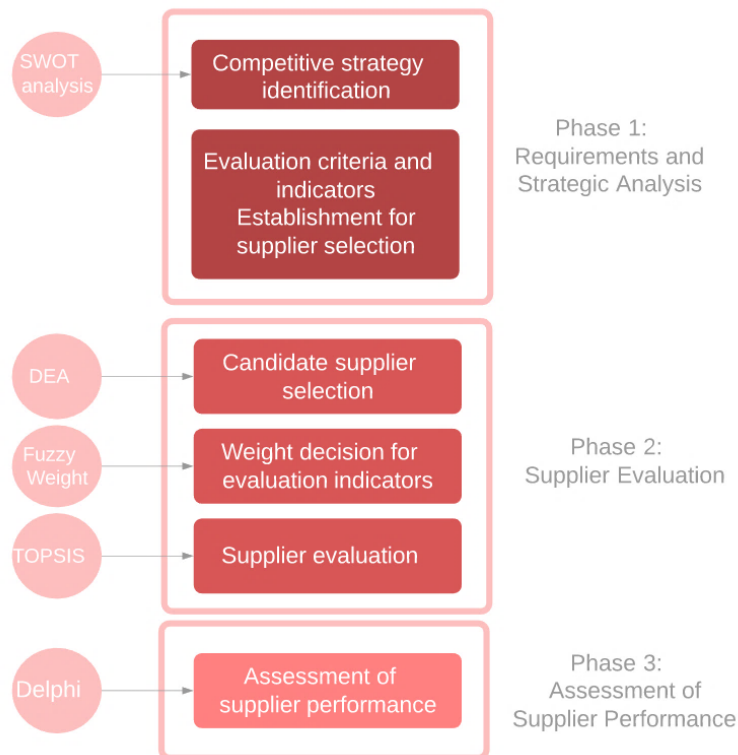


Figure 12. Structured methodology for supplier selection and evaluation in a supply chain.

Source: Made by the author based on (Chen, 2010)

The three different phases are: (1) Requirement and strategic analysis, (2) Supplier selection and evaluation, and (3) Assessment of supplier performance.

During the first phase, enterprise competitive strategy is used to provide a foundation for establishing evaluation criteria and a framework of supplier selection indicators. SWOT analytic method thus is first employed to identify enterprise competitive strategy. Next, evaluation criteria and indicators for supplier selection are established.

The second phase primarily searches for suitable suppliers. To simplify the supplier selection and evaluation procedure, DEA analysis is first performed to delete some less qualified suppliers. Fuzzy weight and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are then applied for precise supplier evaluation.

While the fuzzy theory is used to decide the strength of customer preferences in relation to each criterion to calculate the weights of supplier evaluation indicators, the TOPSIS is a multiple criteria decision making model used to evaluate candidate suppliers.

Finally in the third phase, the Delphi method, which is a forecasting process framework based on the result of multiple rounds of questionnaires sent to a panel of experts, is used to design the questionnaire for assessing supplier performance.

The role of quality in supplier evaluation and selection has emerged as primary dimension of performance since higher product quality can yield lower total costs and it permits many firms to compete on a global basis.

(Curkovic et al., 1996) asserts that in measuring and assessing their suppliers' quality management systems, purchasing managers are increasingly turning to established quality auditing and measurement systems. One audit framework often applied is the Malcolm Baldrige Award criteria.

The Baldrige Award criteria are a set of relative and competitive standards in terms of overall measurements, with attempt to rank order the applicants. It provides not only an indicator that a supplier has complied with process requirements, but also quality assessments and results, business process and support service results; competitive comparisons and benchmarks; and continuous improvement practices to recognize and foster excellent quality practices.

The ISO criteria (explained in the theoretical references chapter) can be useful as a pre-qualifying instrument for documenting processes of suppliers that are just initiating their quality improvement efforts. Once a supplier is pre-qualified and its processes are established, the Baldrige framework can be used to establish a baseline for continuous improvement, it can provide an indication of the effectiveness of suppliers' efforts to reengineer processes and ensure that initiatives are carried across functional boundaries.

4.4.3.4. Benchmarking

When establishing a benchmarking process, the organization should take into account that successful benchmarking depends on factors such as support from top management, the methodology used to apply benchmarking, an estimation of benefits versus costs, an understanding of the characteristics of the subject being investigated and implementing lessons learned to bridge any determined gaps. (International Organization for Standardization, 2018)

Benchmarking has evolved from its early conception and many types of benchmarking and related categorization strategies have been identified by the literature. Thus, there are several methodologies, tools or frameworks to carry out a benchmarking process but, in this subsection, only the methods that the author has considered most useful for the problem in question are going to be explained.

First of all, and as was explained in the comparative analysis concept section, any benchmarking framework needs, as a **previous step**, companies to know about themselves. It does not make sense to compare with other companies without knowing previously in which areas they should focus on or what parameters to compare; no company can cover all aspects and parameters at the same time. This process can be carried out in many different ways but in this framework, it has already been carried out in the second step named "Current State Analysis".

Once the company or the plant knows about itself, the tools explained below can be applied.

Integrated Strategic Benchmarking Framework

The integrated strategic benchmarking (ISB) proposed by (Meybodi, 2006) requires that the benchmarking organizations understand their own strategy, detect possible discrepancies in the process and identify critical areas for organizational success. The main objective of the ISB is to focus benchmarking endeavours on those activities that are basic to organizational success, those activities that are responsible for delivering the most customer satisfaction or offer distinguishing competencies to differentiate the organization from competitors.

A questionnaire-based survey to audit manufacturing process with questions that managers need to answer about themselves and competitors. The survey contains series of questions related to corporate missions and goals, competitive priorities, manufacturing performance objectives and manufacturing action plans as it can be seen in the appendix (A2). These four areas are considered at the tactical level. However, one of them is also found in the operational one, as it is explained in said level.

The company that is auditing inner manufacturing strategy with this survey should rate each element on the degree of importance (1 = low importance, 5 = high importance) to the company for the next five years. Focusing on the competitive priorities, to understand competitive strength of the organization, for each element of competitive priorities the respondents should also rate relative competitive strength of their organization with respect to the competitors who are doing best in that area. A five-point scale, where 1 corresponds to weak and 5 to strong, is used to indicate manager's perceptions of the company's current competitive strength relative to the best competitor.

Thereupon and before committing resources to benchmarking, it is important to understand the causes for all the misalignments, the imbalances between importance and strength (they can be a critical area that needs to be investigated for future benchmarking), the inconsistency between the different areas (corporate missions and goals, competitive priorities, manufacturing performance objectives and manufacturing action plans). (Meybodi, 2006)

Rapid Plant Assessment and Rapid Sustainable Plant Assessment

These two tools are explained in a way that is not specified for what levels are used. However, at the end of this explanation, a table is added to specify which areas should be studied at the tactical level since it is the one analyzed in this section.

When auditing a plant, there are many reasons why this can be a waste of time. However, there are methods that can significantly help the auditing process to be carried out effectively. In this way, **the Rapid Plant Assessment (RPA)** is proposed as a tool to briefly evaluate the competitiveness of manufacturing facilities, maximizing the return on a typical plant tour for audits where assessing lean, efficiency, or effectiveness is an important goal. The following explanation of the RPA and then, the RSPA is given by (Steingrímsson et al., 2012).

The RPA was developed in the late 1990s by R.E. Goodson. For this tool to work, a small team that have equipment knowledge, production experience and insight into best and worst practices is needed.

The backbone of the RPA is a RPA rating sheet with yes or no questions that are used to identify if the plant uses best practices from eleven different categories:

- Customer satisfaction
- Safety, environment, cleanliness and order
- Visual management system
- Scheduling system
- Use of space, movement of materials and product line flow
- Level of inventory and work in progress
- Teamwork and motivation
- Conditions and maintenance of equipment and tools
- Management of complexity and variability
- Supply chain (SC) integration
- Commitment to quality

Between the main limitations of this tool, it can be seen than social and environmental goals are not taken into account, limiting the potential of RPA on economic issues only; it is only one factor to consider when assessing a company, i.e. it's not the whole picture; and, it's not a complete lean assessment but a tool for rapid or initial assessment.

From (Posey, 2017), the tables to carry out the RPA are extracted, and they are included in the appendix (A3).

The today's manufacturing plants need to manage the three dimensions of sustainability; economic, environmental and social in order to remain in a profitable position, maintain an attract customers as well as qualified employees and to meet requirements set by laws, rules and regulations. This is where **the Rapid Sustainable Plant Assessment (RSPA)** emerges.

The RSPA uses sustainability indicators that are the information used to measure and motivate progress towards sustainable goals and is considered to apply for manufacturing companies of all shapes and sizes, since the purpose is to identify what aspects of the sustainability can be improved.

Its structure is based on specific indicators which the evaluators (the same team is needed) must grade and they are grouped into the following subcategories:

Table 6. RSPA Subcategory Breakdown Structure. Source: (Steingrímsson et al., 2012)

Environmental	Economic	Social
<ul style="list-style-type: none"> • Environment • Resources • Energy 	<ul style="list-style-type: none"> • Production • Quality management • Product • Innovation 	<ul style="list-style-type: none"> • Equitableness • Transparency • Working surroundings • Health

When a company carries out any of the two tools described, RPA or RSPA, receives a rating scale to each of the categories and in the case of the RSPA, it also receives an average score to each of the three dimensions of sustainability. This enables the company to focus their attention to results that are not good enough.

As it is explained above, the following table contains the areas for both tools which should be analyzed when carrying out the benchmarking process at the tactical level.

Table 7. Areas to focus on at the tactical level when implementing the RPA and RSPA.

Source: Own elaboration

Tool	Study area	At the tactical level
RPA	Customer satisfaction	X
	Safety, environment, cleanliness and order	
	Visual management system	
	Scheduling system	X
	Use of space, movement of materials and product line flow	
	Level of inventory and work in progress	
	Teamwork and motivation	
	Conditions and maintenance of equipment and tools	X
	Management of complexity and variability	X
	Supply chain integration	X
	Commitment to quality	X
RSPA	Environment	X
	Resources	X
	Energy	X
	Production	X
	Quality management	X
	Product	
	Innovation	
	Equitableness	X
	Transparency	
	Working surroundings	
	Health	X

4.4.4. Tools to be used at the operational level

4.4.4.1. Process documentation

Athuraliya (2019) asserts that the process documentation provides a detailed description of how to carry out a business process and it is used a guide to help employees at all levels, including decision makers and stakeholders. This process helps improve process, train employees, preserve company knowledge, mitigate risks and maintain operational consistency and it is a vital part of patents and trade secrets. In addition, between its benefits it can be found an effective collaboration and performance, the identification of bottlenecks and inefficiencies in processes, saves in time and prevention of errors, the overall quality of processes and a raise in employee productivity and satisfaction.

Its implementation consists on:

1. Identify the process
2. Define the process scope
3. Explain the process boundaries
4. Identify the process outputs and inputs

5. Brainstorm the process steps and organize them sequentially
6. Describe who is involved
7. Visualize the process using a process flowchart
8. Note down exceptions to the normal process flow
9. Add control points and measurements
10. Review and test the process

4.4.4.2. Gemba

Gemba, translated as the real place, is a philosophy that reminds the organization to get out the offices and spend time on the plant floor, where real actions occur. This philosophy, as part of the lean philosophy, promotes a deep and thorough understanding of real-world manufacturing issues by first-hand observation and by talking with plant floor employees.

4.4.4.3. Benchmarking

Not only the tools but also the framework explained at the tactical level to carry out a benchmarking process can be used at this level. The main difference are the areas where to focus the efforts. When implementing the Integrated Strategic Benchmarking Framework, the main area is the manufacturing performance objectives. However, with the RPA and the RSPA is not that easy. For this reason, the following table is created where the areas where to focus on at the operational level are those with an X in the following table.

Table 8. Areas to focus on at the operational level when implementing the RPA and RSPA.

Source: Own elaboration

Tool	Study area	At the operational level
RPA	Customer satisfaction	X
	Safety, environment, cleanliness and order	X
	Visual management system	X
	Scheduling system	
	Use of space, movement of materials and product line flow	X
	Level of inventory and work in progress	X
	Teamwork and motivation	X
	Conditions and maintenance of equipment and tools	
	Management of complexity and variability	
	Supply chain integration	
	Commitment to quality	X
RSPA	Environment	X
	Resources	X
	Energy	X
	Production	X
	Quality management	X
	Product	
	Innovation	
	Equitableness	X
	Transparency	
	Working surroundings	
	Health	X

4.4.4.4. Brainstorming and experience

Brainstorming is a technique used to generate new ideas around a specific area of interest. Using rules which remove inhibitions, individuals are able to think more freely and move into new areas of thought. No idea is scrutinized or criticized until the meeting to generate new ideas ends and then the thoughts are assessed.

(Forbes, 2018) proposes ten tips to carry out the brainstorming process efficiently:

1. Ask questions and don't rush your solutions
2. Break things down to a granular level
3. Get all hands on deck
4. Find a fresh set of eyes
5. Accommodate for different styles of brainstorming
6. Apply structure
7. Identify your 'north star'
8. Get out of the office
9. Get anonymous feedback
10. Find a tool that helps you become process-driven

In the brainstorming process, the **experience** plays an important role. Experience is gained not only over the years but also through work, projects, mistakes and successes. Learning is progressing and growing by defeating the challenges and impediments, considering the mix-ups and overcoming them. Learning from experience is one of the most crucial and common methods for learning accessible to everybody.

Along these lines, experience can be very useful to create options and thus, it can be considered as a powerful tool to create and even evaluate alternatives.

4.4.5. Summary step 3

All the explained in the 4.4 section (STEP 3) is summarized in the following figure.

As it is explained in the delimitations, the tools necessary to create and evaluate alternatives at the strategic level are considered to be out of the scope of this master thesis. That is exactly what is included in the structure of the third step.

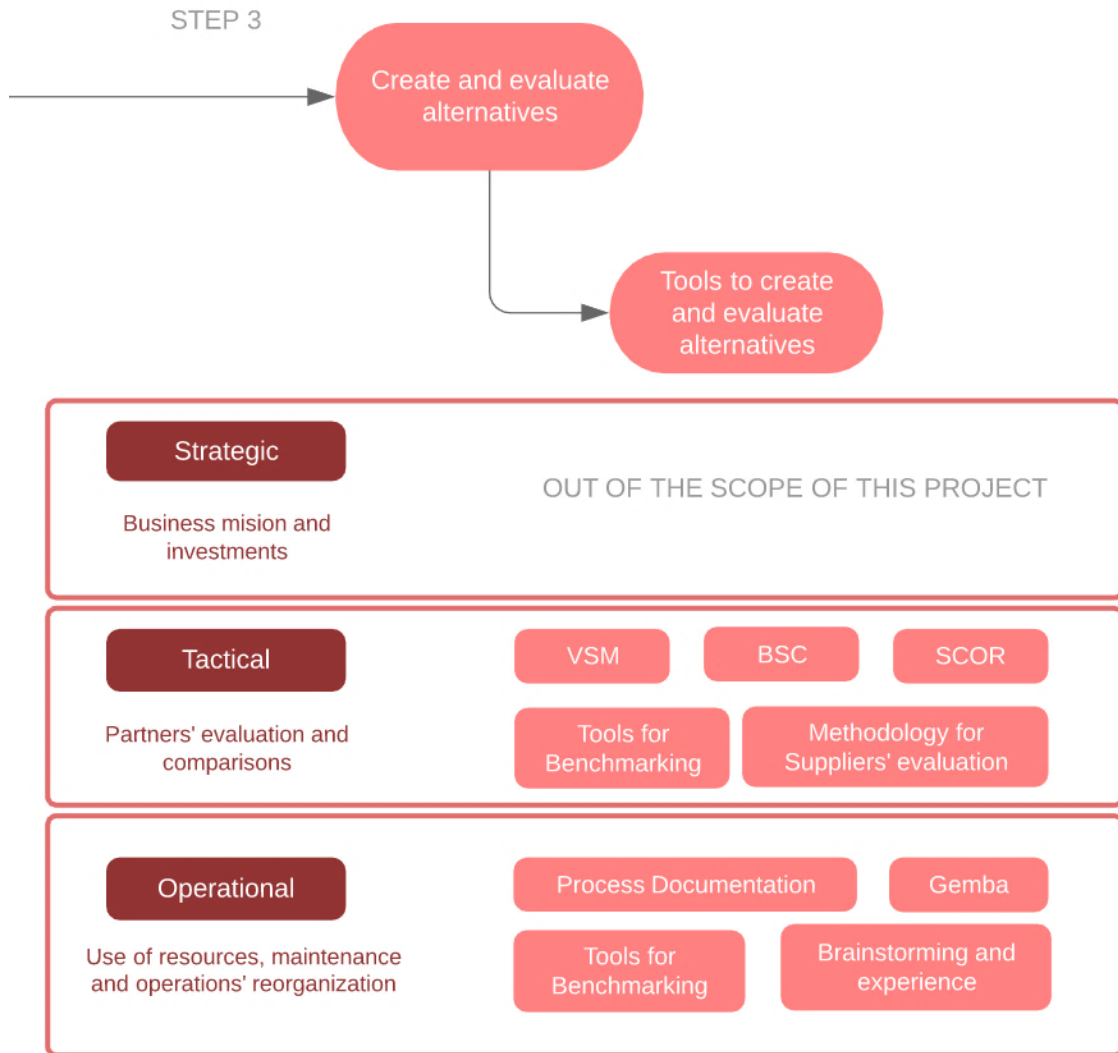


Figure 13. Structure of the third step of the framework. Source: Own elaboration

4.5. Complete framework structure

In this section, the complete framework structure is added. This structure is a combination of the figures 3, 10 and 13 and is created not only to summarize all the work carried out and with it the complete framework but also to be able to explain to the companies how the framework works and increase the understanding and the effectiveness of the comments.

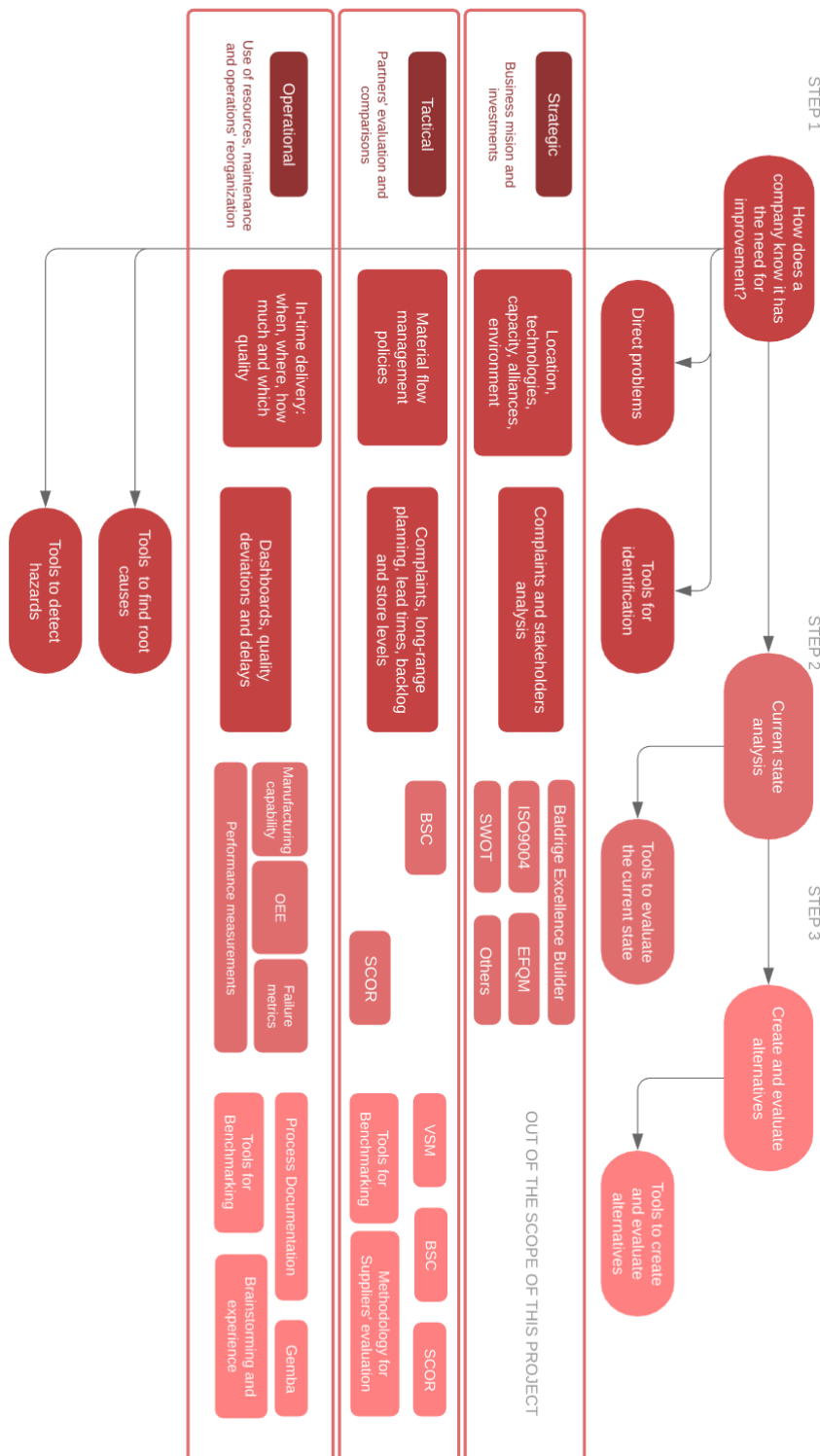


Figure 14. Complete structure of the framework. Source: Own creation

5. EMPIRICS

In this chapter, empirical data is extracted from three different interviews. The three cases are divided in a small introduction about the company, how the organization or plant works today and how they handle operational performance improvements or problems.

5.1. Introduction

When looking for the companies with which to carry out the study, specific requirements were not needed (since all the companies have or need operational performance problems or improvements), they were not required to be from a specific industry or to be of a specific size.

Then, the interviewee had to be familiar with the topic of discussion in order to give insights related to the research questions. Thus, for getting the right information by an interview, the person selected had to know the general information about the company and their situation, know about their system to measure their performance, about the process to make improvements or solve operational performance problems and about the process of supplier selection and evaluation.

The supervisor of this Master Thesis recommended a number of companies and also, some key persons of those companies that could fulfill the requirements and participate in the interview. In this way, the companies chosen were:

Case I: EWP Windtower Production AB, a European corporation in power producing machinery industry. Enercon, with market representation in 36 countries, 10.000 employees and 35 years in the market, is the parent company of EWP Windtower Production AB.

Case II: Haldex, a Swedish engineering industry group with activities in brake and air suspension systems for heavy vehicles, with factories all around the world, 2.200 employees approximately and 132 years of experience.

Case III: Baxter, an American corporation in Health care industry, with factories all around the world, representation in more than 35 different countries, 88 years in the market and more than 47.000 employees.

An interview question guide included in the appendix (A4) is created following the same structure as the framework. These insights are discussed in the following sections as part of the analysis of this project. Along these lines, this chapter comprises a briefly introduction of each of the companies and all the necessary information to answer the following questions:

- How does the organization or plant work today?
- How does the organization or plant handle operational performance improvements or problems? (Research Question RQ2)

It worth nothing to say that a briefly explanation of the tools included in this chapter is added in the appendix (A5).

5.2. Case I: EWP Windtower Production AB

EWP Windtower Production AB is a company of 200 employees, located in Landskrona whose parent company is Enercon. EWP produces wind turbine tower in steel for the European market.

Related to Enercon, Enercon GmbH is the largest German wind turbine construction company. Its head office is in Aurich (Lower Saxony). It was founded in 1984 by its current owner Aloys Wobben, it has a worldwide workforce of 10,000 employees and a turnover of more than 1,200 million euros. It also holds more than 40% of all world patents in the manufacture of wind turbines. (Enercon, 2019)

With its technological innovations, ENERCON has been setting new standards for more than 30 years as one of the world's leading wind energy companies. ENERCON is not only the pioneer of wind energy worldwide, but as a system supplier for renewable energies, it also provides answers to the energy technology challenges of tomorrow. (Enercon, 2019)

In order to get more information, Fredrik Clausson, the Managing Director of EWP Windtower Production AB in Landskrona, was interviewed. EWP Windtower. Along these lines, all the following information is extracted from (Clausson, 2019) and (Enercon, 2019) and it is specified if the information refers to EWP or Enercon.

5.2.1. How does the organization or plant work today?

ENERCON has three business principles which are responsibility, independence and longevity and two performance-demanding principles which are technology leadership and quality leadership.

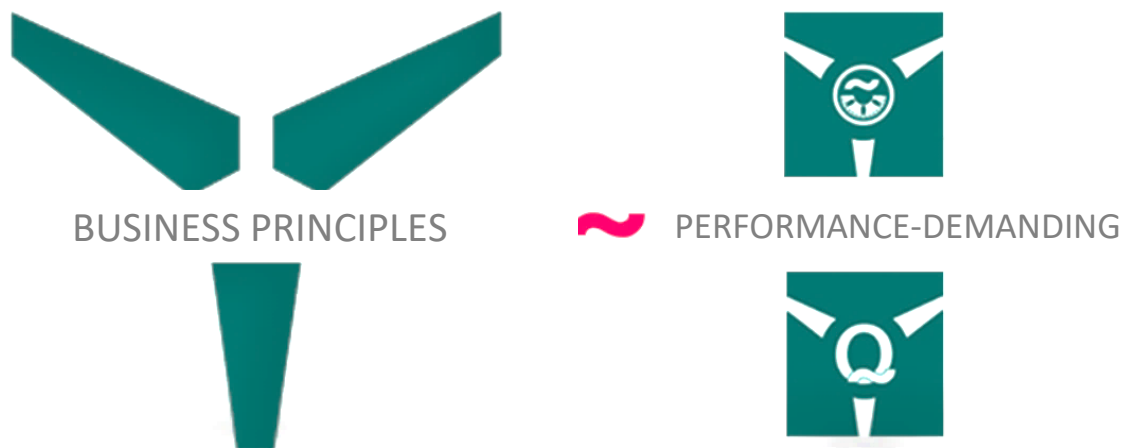


Figure 15. Enercon corporate culture summary. Source: (Enercon, 2019).

Starting with responsibility and as a consequence of the long-term company development, ENERCON provides a stable working environment and offer the divisions and the respective employees a high degree of personal responsibility (Enercon, 2019). Along these lines, each production centre of ENERCON is managed independent so one could say that they are different companies with their own Chief Executive Officer (CEO).

In this way, ENERCON follows a decentralised decision-making process to encourage creativity and initiative with a strong focus on results.

When talking about continuous improvement process, it was extracted from the interview with Fredrik that at EWP, no type of continuous improvement process is carried out. There are solution processes but most of the time it is heads on, i.e. most of the time the problem is solved directly by facing it, due to the large number of problems that currently arise.

Many of the workers have had individual training in different Six Sigma methods or tools and they use them but do not report it on any paper.

ENERCON is in a very strong situation right now due to the increased use of renewable energies. Currently, EWP has approximately the 60% spare capacity to increase in its plant. In the case that more capacity is needed, EWP would not have to do any study or analysis to increase or redistribute its capacity since the investment would most likely be too large and the possibility too costly. What would be done would be to build a new plant and thus, to create a new company in ENERCON in a different part of the world.

EWP manufactures 85% of its pieces in-house and the rest is purchased. “No company can manufacture everything just as it cannot buy everything”, (Clausson, 2019).

Both ENERCON and EWP are not good at competing not only as a company but also as a supply chain. When EWP decide its suppliers, it does it based on quality, knowledge, price, delivery and capability, “but most of the time, the suppliers’ selection is done by finding one and starting the discussions. If they are capable, then let’s try. It is not that there is much to choose from.” (Clausson, 2019)

Related to suppliers, appears the second of the principles of ENERCON, the independence. Their exclusive suppliers have a fundamental role in ensuring this independence, as they enable ENERCON to react to customer requests and internal challenges flexibly and quickly (Enercon, 2019). EWP evaluate the existing suppliers just in mind and feeling, they do not measure delivery, accuracy or quality.

Finally, the word leadership arises. Innovations are fundamental to success in ENERCON since they want to be the first to establish new ideas on the market and new standards in the industry. In addition, they aim to develop and produce the highest-quality wind energy converter on the market.

5.2.2. How does the organization or plant handle operational performance improvements or problems?

In EWP, they use the KATA Process Improvement and the DMAIC (Define, Measure, Analyse, Implement and Control) process to solve operational performance problems. Both processes are briefly explained below.

KATA is a Japanese designed approach to make a business more productive through thinking. The scientific technique of thinking enables a company to foresee issues, come up with real solutions to these problems before they occur, and plan accordingly. It has the following four steps: Define the challenge; Grasp current condition; Establish target condition; and Determine solutions. (Forss, 2013)

The DMAIC is the classic Six Sigma problem-solving process. DMAIC resolves issues of defects or failures, deviation from a target, excess cost or time, and deterioration. Six Sigma reduces variation within and across the value-adding steps in a process. DMAIC identifies key requirements, deliverables, tasks, and standard tools for a project team to utilize when tackling a problem. (Krishnan et al., 2013)

The DMAIC process is used in EWP due to the understanding that it involves among all the departments since they all speak the same well-known language. They use several tools such as Fishbone Diagrams, SIPOC, Measurement Templates, etc. but what tools to use in each of the phases of the DMAIC process is not defined. The main limitation the interviewee sees to that process is the need of measuring data and the time it takes to get through due to this.

5.3. Case II: Haldex

Haldex is a Sweden-based organization, working worldwide with workplaces in 18 countries. It has 8 production sites, 3 distribution sites, 1 re-manufacturing site and a network of small friction relining sites. Haldex develops and provides reliable and innovative solutions that improve security, vehicle elements and environmental supportability in the worldwide business vehicle industry. They are the world-driving supplier of brake adjusters for drum brakes and have the quickest developing market share for air disc brakes. (Corporate Haldex, 2019)

Their 2,176 workers spread across four continents challenge regular thinking every day to guarantee that the items they deliver focus on safety, efficiency and uptime. Haldex has a sales of around SEK 4.4 bn. (Corporate Haldex, 2019)

In order to get more information, Johan Valette, the Vice President of Haldex Way and Corporate Social Responsibility (CSR) in Landskrona, was interviewed. Along these lines, all the following information is extracted from (Valette, 2019) and (Corporate Haldex, 2019).

5.3.1. How does the organization or plant work today?

First of all, it should be noted that the plant in Landskrona, where the interviewee works, is the head office of Haldex.

As it was mentioned above, Johan Valette is the Vice President of Haldex Way, which is the Haldex Group's overall manage system, the framework for strategic deployment and result driven improvements. It is composed by the values, priorities and behaviours, the strategic direction, the RADAR Logic and the standardized work and methods as it can be seen in the following figure.

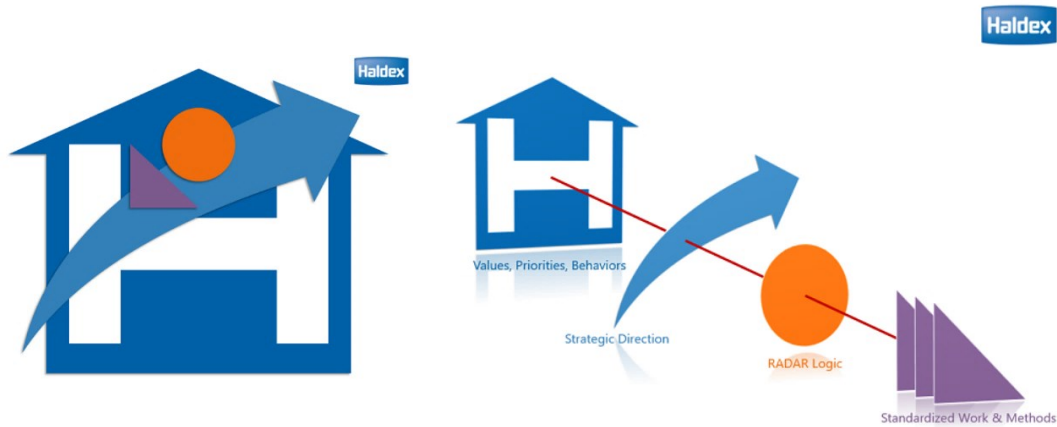


Figure 16. Haldex Framework for Strategic Deployment and Result driven Improvements and its different components. Source: (Corporate Haldex, 2019)

Focusing on what is more interesting for the realization of this thesis, the RADAR Logic and the Standardized Work & Methods are explained. The RADAR is the logic for result driven improvement in line with strategic direction. It is formed in a loop to evaluate and measure the performance and trigger continuous improvements. It is very similar to the PDCA (Plan-Do-Check-Act), but “it puts more emphasis on the result since it starts and ends with it” (Valette, 2019).



Figure 17. The Radar logic of Haldex Way. Source: (Corporate Haldex, 2019)

In terms of Standardized Work, this lean tool is an effective way for process improvement, especially when it is applied to manual tasks such as assembly lines. It is part of Toyota Production System and based on wastes reduction. It consists of three elements: Takt time, which is the rate at which products must be made in a process to meet customer demand; the precise work sequence in which an operator performs tasks within takt time; and the standard inventory, including units in machines, required to keep the process operating smoothly.

The benefits of standardized work include documentation of the current process for all shifts, reductions in variability, easier training of new operators, reductions in injuries and strain, and a baseline for improvement activities.

At Haldex, they carry out several processes for improving their performance, too diverse and too many such as Standardized Work, Total Productive Maintenance (TPM), Lean Daily Management (LDM) system, Gemba and Problem Solving. They also carry out hazard analysis (Audits, Assessments, FMEA, etc) and root causes analysis such Pareto Chart, the 5 Whys, Fishbone Diagram, Scatter Diagram and also Go&See, Is/IsNot and the classic Six Sigma toolbox.

Along these lines, Six Sigma and Lean tools are used in Haldex. The main criterion for selecting the tool is the final purpose since they have a result and objective driven approach (RADAR).

Recently, Haldex has faced different capacity problems such as capacity balancing, in process balancing, levelling and single piece flow which were solved using SMED (Single-Minute Exchange of Die), Spaghetti Diagrams and reduction of cycle times. In addition, the main indicators to first know they need to increase the capacity are cost (the cost advantage gained by improving productivity) and the customer need and second to relocate the capacity are customer demand and supply chain optimization.

When talking about the percentage of in-house manufacturing, Valette said that it was confidential. However, he also said that a lot of components in Haldex are manufactured out-house and then they are assembled to the complete product. It is known that they have a mix of in-house and out-house manufacturing, but the strategic core components are manufactured in-house.

Talking about the advantage of the SCM, the suppliers are a very important part of Haldex since they buy a lot of components and thus, a lot of the value added work comes from the suppliers. In this way, they try to provide good forecasts to the suppliers in order to make them able to plan the production and avoid variations down into the supply chain, they enable them deliver on time. They try to have clear quality requirements and specifications on the product and also, try to find improvements from the supplier themselves or together with the suppliers.

All potential suppliers go through the supplier selection process to evaluate and make due-diligence on a lot of factors such as firstly hygiene factors, corporate social responsibility to make sure, for example, that there is no child labour or that they meet environmental requirement standards, and financial viability. They also evaluate the capacity now and going forward, the quality and the price. The footprint can make a difference.

Assessing the risk is also a part of this process so Haldex has dual and also triple sourcing.

With regard to continuously evaluate suppliers' performance, they don't pull the suppliers to the same process again but with more or less the same subset of the criteria of the supplier selection process. All suppliers are evaluated once a quarter and they are classified A, B or C. They have most B-suppliers and some A and C. This classification is for all direct-material suppliers.

- A: really good suppliers they are happy with.
- B: they ask for improvements in certain areas.
- C: they either demand improvements or look for another supplier.

5.3.2. How does the organization or plant handle operational performance improvements or problems?

In order to carry out or solve operational performance improvements or problems, they need to measure their performance and they do it continuously using tools such as process KPIs (Key Performance Indicator), Real Time Management (RTM) and Statistical Process Control (SPC).

Subsequently, to carry out improvements, they use the Haldex Way since, as it was explained above, it is a framework for building up culture of continuous improvement by advancing and refining every day activities, with the target of effectiveness and exactness in Haldex Processes.

Valette was asked about the importance of measuring the current state of the plant before trying to solve a specific operational problem and the answer was that it is essential. Along these lines, to know the current state of the plant, they use tools such as Go&See, first of all if it is possible, and Real Time Management (RTM) and Lean Daily Management (LDM) system afterwards.

When creating alternatives to solution, it depends on the character of the problem, i.e. if the root cause is known or not. If it is known they focus directly on how to solve the problem rather than analysing it, then the selection of the method is more based on how they can both effectively and efficiently solve it, what capabilities do they have and what are the key success factors for solving this problem. If it is not known, then the selection of the problem-solving method is carried out depending on the complexity and the available data.

Along these lines, the DMAIC is a Six Sigma process (already explained) that is used in Haldex when the root cause of the problem is not known, and the problem is highly complex.

Finally, the interviewee was asked about benchmarking. He answered that they carry out benchmarking processes internally, externally and through consultants. A common and very good way is to Go&See with a specific and very clear scope on what you want to benchmark.

5.4. Case III: Baxter

Baxter International Inc. is a Fortune 500 American health care organization with base of operations in Deerfield, Illinois. The organization essentially centres around products to treat haemophilia, kidney disease, immune disorders and other chronic and intense medical conditions. For over 85-years, they have been at the critical crossing point of saving and sustaining lives. Currently, they are determined and extraordinarily situated to understand their most noteworthy chance to change worldwide healthcare for years to come. (Baxter, 2019)

In order to get more information, Johan Wiesel, the head of Supply Chain Operations in Lund, was interviewed. Along these lines, all the following information is extracted from (Wiesel, 2019) and (Baxter, 2019).

5.4.1. How does the organization or plant work today?

First of all, it should be noted that Baxter has a joint address of all its plants. The overall performance indicators roll up in a similar way. All the plants are following the same procedures, using the same tools and methodologies to solve problems or find improvements. The interviewee thinks that it is very important since they have maintained globally one quality management system and although there could be some small local abbreviations, they all have the same structure.

As the head of Supply Chain Operations, Wiesel considers the advantage that the SCM brings very important. They are not done until they reach the customer, so they are measuring the customer satisfaction in the most challenging way since they are looking not only at each order line but also at the full order. They push that measurement all the way back in their supply chain to the production.

In order to continuously improve their performance, Baxter uses the Lean Daily Management (LDM). The LDM is the system that allows a plant to deliver customer value through proper support and leadership to those who are closest to the process. Some of the Lean Daily Management elements which are used in Baxter are visual control boards, Leader Standard work, tiered meetings and daily accountability.

Most of the Lean philosophy they use, according to Wiesel, is about the communication, working with improvements and notes and getting things on the table. The daily meeting for anyone in any role to bring things up, the tier structure, the visual management, the 5S and the Gemba walk are the pillars.

It worth nothing to say that Baxter has an Environmental Management System (EMS) which is a component of a mining management system that creates a framework for the methods, responsibilities, and processes required to avert adverse environmental, economic and social effects and allows for continuous improvement. The latter vary between organisations, but typically will include waste, emissions, energy use, transport and consumption of materials.

In addition, as manufacturers of medical devices, they need to have a different number of ISO certificates. It is mandatory in medical devices to follow the ISO 13485 that is an extension of the ISO 9001. Baxter follows a management-systems approach guided by its global EMS requirements. The company applies the ISO 14001 standard to systematically manage its environmental aspects and the OHSAS 18001 standard to manage its health and safety hazards and risks.

Wiesel was asked about capacity decisions. Right now, they are going to close a big part of the existing plant in Lund because they are moving to Italy where they have a sister plant. It was a business case driven decision based mainly cost and consolidation mass production effects.

When talking about the percentage of in-house manufacturing, the monitors and machines they produce in Lund have a lot of bought components and some of sub-assembly. They get the components or sub-parts and assemble it all together. It could be cases where they have 75-80% done outside, depends on the product. For some products (one of the disposables), they buy the plastics, but they do the moulding and extrusion themselves.

In Baxter, their products follow the make-to-order policy, customized to the dimensions of the hospital. However, they can plan the materials since they know which raw materials are used.

During the interview, the area in which most efforts were used was the suppliers. First of all, Baxter works to develop mutually beneficial relationships with small and diverse suppliers and strives to continue to increase the diversity of its supplier base. In terms of their evaluation and selection, Wiesel made a point of explaining how strict the evaluation of suppliers in terms of medical devices and pharmaceuticals business is. They need to make sure they have put up specifications of what exactly they are asking for in a certain way so they make sure they can measure the suppliers' performance against it. Baxter is doing quality, financial and environmental audits to all the suppliers.

In terms of the suppliers' selection, there are a lot of capable suppliers, but they need to fit in a pharmaceutical company with very high requirements. The pharmaceutical sector was compared with the automotive and the conclusion was that although the suppliers manufacture high technologies driven components, the requirements are much stricter.

The most important thing so, is the requirements to satisfy the quality needed. They need to be very specific in the requirements since if a misunderstanding appear, they would have to accept and rewrite or update the specifications to make it clearer and avoid that again. A lot of medical devices industry is about making sure that there is no gap in understanding in between the different entities.

All of the suppliers are measured continuously. They do not inspect everything 100%, "it is not possible" (Wiesel, 2019), but they are doing a lot of incoming inspections and based on the implication of the product/component, they set up the controls.

5.4.2. How does the organization or plant handle operational performance improvements or problems?

When facing a need for improvement, the most important things from the interviewee are to understand where they are or how it looks like today, the current state and to gather a lot as much information as possible, input from different people. "Normally, it is impossible to solve any issues yourself" (Wiesel, 2019).

In order to carry out performance improvements, they use daily meetings, analysis of any deviation from quality requirement and if they have repetitiveness of the same issue coming up then they are trending that, so they are doing a trending analysis. The main two strategic frameworks for managing operational performance would be the long-range or strategic planning and the ISO.

As part of the abovementioned EMS, they do self-assessment and one audit in-house to improve yearly. They also use the Balanced Scorecard with the same purpose.

To identify a need for improvement, Wiesel said what they are really looking at is the customers, that the reason why customer complaints becomes very important to detect a fault on the supply chain side, they try to get all the feedback in. In the manufacturing unit, everything might not be linked to a customer complaint, it can be more of "What we see and what we have?". Along these lines, quality control becomes the "point to measure if we have done the right things" (Wiesel, 2019).

As a company, they carry out hazard analysis, but not so much is Wiesel's role so he cannot say he is an expert. However, on the supply chain side, they do hazards evaluation based on the products they have and if there is any risk for the employee in the warehouse or for the product during transportation. As a producer or manufacturer of the product we put in the market, we do a number of different risks analysis as well. They use the HACCP mainly when detecting hazards but also FMEA which is more quality related.

They measure their performance with the tier model. If they focus on a specific process, then they would look at the current indication, e.g. process driven measurements, rather than the overall KPI since those indicators are more related with capacity, deliverables, etc.

Moreover, to continuously measure their performance, they use the production service level and the daily "on-time in-full" (OTIF).

When talking about the creation and evaluation of solutions, brainstorming he would say it is probably, what he has learnt at least, one of the most effective ones to find new ideas along with the 5 Whys because when they find a problem or a point where they need to do something, it is often to sit down together in the plant, make a group exercise and to get the current analysis up.

When having to recruit a new supplier, the procedure is first market screening from which the different supplier options are selected and then, the formal supplier evaluation explained in the previous subsection.

They carry out a benchmarking processes both in terms of on the market like where they are placed on the market (sales benchmarking), and in terms of production. Best practices are more picked up from joint groups or joint forums, and that does not need to be necessary in the pharmaceutical industry, you can cross industries. Recently, they have carried out a benchmarking process related to market intelligence and sourcing alternatives.

6. ANALYSIS

In this chapter, the comparison between the already developed framework and the empirics findings is made. From that comparison and adding some more information from the interviews, comments and limitations of the framework arise and also the necessary corrections for the development of the final framework.

6.1. Introduction

In this chapter, the comparison between the already developed framework and the empirics is made. With that purpose, the empirics should be analyzed, and the important information should be extracted from it. In addition, information provided by the interviewees that has not been included in the previous chapter, is included in this chapter to answer the following questions:

- What comments did they have about the presented framework?
- What reflections arose from the explanation of the framework?
- Did they come up with any improvement to the framework?
- Did they come up with any limitation to the model or to its use?

In terms of the improvements, it should be mentioned that some small improvements are applied directly while the other improvements, bigger than the first ones, are commented and its applications is made and explained to develop the final framework.

With regard to the limitations, although these limitations arose before the improvements, they are independent of these and, therefore, remain valid.

6.2. Comments and reflections about the framework

6.2.1. Comparison with improvement processes

One of the main questions that arises from the interviews is what can the present framework offer that processes such as performance improvement or problem-solving processes already offer? Answering this question, the research question RQ3 (“What are the advantages and disadvantages of the present framework with respect to other improvement or problem-solving processes?”) is also answered.

Since Six Sigma and Lean are two highly mentioned concepts, the comparison between the presented framework and the DMAIC process must be explained, highlighting the differences and the similarities between them. Not only the interviewees explained a lot of tools from the Six Sigma Lean toolbox, but also the present framework includes a lot of them. To carry out this comparison, (Go Lean Six Sigma, 2012) is used.

The DMAIC represents the five phases that make up the process: Define, Measure, Analyse, Implement and Control. The first phase is to define the problem, improvement activity or opportunity for improvement as in the first step of the framework called "How does a company know it has a need for improvement?". In this step, the identification of a need for improvement is done and thus, the problem or improvement is defined.

The second and third phases (Measure and Analyse) consist in measuring the process performance and analyze why the process is performing the way it is, which matches with the objective of the second step called "Current State Analysis". In this step, the process or processes involved are understood, and their current performance is measured.

The fourth phase is called Improve since it consists in looking for how the process should be in order to perform the right way. This corresponds to the objective of the third step of the framework where a series of tools and methods are proposed to evaluate some alternatives that give solution to the problem or improvement. However, the third step of the framework only proposes the methods to find solutions, it does not propose solutions.

In this way, this project fully matches with the first three phases of the DMAIC process and partly with the fourth but does not contemplate the implementation of the solutions or their control.

As it is said in the introduction of the development (Chapter 4), this framework is proposed to prevent operational performance problems more than solve them. In this way, it is a more open-minded in finding tools for measurement, more specific and more systematic problem-solving structure than the Six Sigma or DMAIC is, especially for small and medium sized companies without Lean or Six Sigma.

Furthermore, from the interviews some negative comments about the DMAIC are extracted. Valette (from Haldex) asserts that the DMAIC is a very good method but it is expensive, time-consuming and it is difficult to scale it up as a problem-solving method known by all because high level of expertise is needed, and it is difficult to generate among 200 employees. (Valette, 2019)

Wiesel (from Baxter) added that the tools themselves are not the most important when he was asked if he would use a new framework with the presented characteristics although is not as well-known as, for example, the DMAIC process. Wiesel asserts that the methodology and getting people activated and triggered into a way of thinking and sharing is the most important part when trying to improve.

Finally, comparing the presented framework with the generic Problem Solving (PS) methodology, the conclusion is that it is not a Problem Solving process since different tools and methodologies are proposed to create and evaluate some alternatives to solution, but it does not propose tools to evaluate all the possible alternatives, implement the solutions or assess the effectiveness that are three of the main steps of the PS process. (Pal et al., 2017)

6.2.2. Interviewees' reflections

First of all, it should be mentioned that Fredrik Clausson from EWP had a tight schedule at interview so many comments and reflections regarding the presented framework could not be collected. However, he spent time explaining how they worked in his company and listening to what this master's thesis consisted of.

When the interviewees were asked about the main structure of the framework, different answers were received. First, Wiesel (from Baxter) said: "It looks like good structured because you start in the right order. First of all, finding an improvement or the improvement finds itself and then in order to know what we are improving, we need to understand the current situation. And then you look at the alternatives. It is quite often to try to come up quickly with a solution, but if you spent some time doing the current state analysis, you probably come up with more different ideas of how you can solve it." (Wiesel, 2019)

He also agreed with the three levels and according to the classification of the tools in those levels, he thought that the framework becomes more like a strategic plan for how an organization works with different tools. "You probably need to have all of them so when we grow out a map as a company, we need to have this type of playground to know how we want to look at things in a longer term and then we would not change so much on the strategic level because you laid that out in a longer perspective but on tactical and operational part you do more of the details and the day-to-day more closer follow-ups" (Wiesel, 2019).

Valette (from Haldex) answered mentioning according to the Haldex Logic. As RADAR is focused on the result, the first step would be to define what they want to achieve and then how can they get that more than what is the problem they have to face. However, he agreed that to decide the level of planning according to the fault or improvement and with that measure the current situation of the company in the specific level makes sense.

In addition, Valette and Wiesel validated the examples of direct problems and tools for identification, but they thought some concepts, which are explained in the following section, should be added.

Wiesel validated the tools to detect hazards since the two proposed are the same tools that are used in Baxter and also the definition of the direction chosen when the level of planning of the fault is deduced. Once the improvement is defined, "you focus on one level, but you can move up or down depending on the needs of the improvement" (Wiesel, 2019). Valette validated the tools to find root causes since all the proposed are used in Haldex.

Wiesel also added that when implementing the current state analysis at the strategic level, he recognises all the names, but he can't say he knows all the content because they do not focus on the names, they focus on the practice i.e. how can the tool be useful to them. In addition, a lot at that level comes centralized so it is not possible to set up a strategy around how they are going to look at that level.

To sum up the interviewees' reflections, the direct problems, the tools for identification, to detect hazards and to find root causes were validated. Moreover, the classification of the tools depending on the level of planning the problem or improvement is found makes sense to them and although it depends on the type of logic that they use in the company, the three steps of the framework represent a logical process.

6.3. Framework improvements

All the improvements commented by the interviewees are briefly commented first and then, in the following two subsections, explained and added to the final framework.

When the first step of the framework was explained to the different interviewees, some corrections or improvements were mentioned.

In the interview with Johan Valette (Valette, 2019), the existence of the four Lean criteria was mentioned. These four balanced goals or criteria are Safety, Quality, Delivery and Cost. Valette, mentioned that, when talking about direct problems, he saw delivery and quality at the operational level, but he did not see safety and cost. Likewise, at the tactical level, he thought that quality and cost should be also included.

From the interview with Johan Wiesel (Wiesel, 2019), some vocabulary problems were discussed. The tools for identification have that name and not tools for recognition, as it had been determined at first because of Wiesel. Wiesel said that recognition is usually understood as something positive and in the framework, it was being used for problems to be solved or improvements needed to be implemented.

When the second step was introduced and explained to the interviewees, Wiesel commented that all the tools to measure the current state at the operational level were very production oriented. In this way, the daily OTIF (delivery performance) is added to the framework by Wiesel's proposal.

Lastly, the third step was described, and many more comments emerged.

Valette asserts that Standardized work and Real Time Management (RTM) were needed at the operational level. "Standardized work is not only a solution but also a tool to identify deviations, it is the basis for operational leadership, continuous improvement, training and for solving problems" (Valette, 2019). About RTM, Valette affirms that it is used to make problems evident immediately. Along these lines, Standardized work and RTM were proposed as tools to evaluate alternatives, especially to remove variations, at the operational level.

When going up to the tactical, Valette found necessary to add the Sales and Operations Planning in order to see if there is a mismatch between volumes and capacity and also, to see the customer needs, the own capacity and the suppliers' capacity and thus, see if there is a problem in between and figure out how to manage it.

Wiesel explained the difference between the levels of use of the Value Stream Mapping (or Process Mapping since there is no big difference) and Process Documentation. The VSM was firstly included in the operational level but moved after the interview with Wiesel to the tactical. In the process of implementing the VSM, the process is being studied from the start to the end while the Process Documentation is more about execution, each individual step or sub-process is examined.

6.3.1. Explanation of the new concepts and tools

Safety, Quality, Delivery and Cost (SQDC)

Safety, Quality, Delivery and Cost are four parameters that can be used to provide information about how the process is operating. Along these lines, measuring these parameters helps organizations to detect the need for an operational performance improvement or problem.

From the interviewees, including these parameters is mandatory since they strongly influence the performance of a plant. In addition, some other parameters such as inventory, productivity and environment could be also considered.

Daily OTIF

The indicator "OTIF" means "on-time" and "in-full". The OTIF requires that both, orders on time and completed, be fulfilled at the same time. It is measured from the perspective of the customer and includes two customer-assessed requirements: that the customers got what they asked for at the time they asked for it. (Torres-Rabello et al., 2011)

This indicator can be used not only to measure the company delivery performance but also, to assess a supplier capability (capability to deliver on time and in full). However, there are other metrics such as the supplier fill rate that cover more aspects of supplier performance (right quantity, product, documentation, date and condition). (Kritsotakis et al., 2014)

Standardized Work

From (Fin et al., 2017), standardized work is defined as an effective way for process improvement, especially when it is applied to manual tasks. Tasks standardization aims to guarantee that both material and human resources utilization are performing optimally. By thoroughly studying an activity and having concepts clearly stated, it is possible to verify details, irregularities and wastes that, when added up, represent a big potential to system improvement. Increasing productivity and repeatability (creating a logic sequence that enables the reduction of errors and waste probability) are two of its main advantages.

In addition, a properly documented Standard Work provides a tool for managing Safety, Quality, Delivery and Cost which are four parameters, explained above, the interviewees consider essential to measure in order to detect problems or improvements.

It has to be designed by the workers and be used as a basis for improvement, since the lack of stability and standardization could result in no production in a just in time system. To execute standardized work, it is mandatory that exact procedures are determined to be executed by each operator, based on takt time, work sequence and standardized inventory.

The main steps to apply standardized work in a company are: (1) set time to produce one unit; (2) elaborate production capacity sheet; (3) determine the standardized operations routine; (4) prepare the standardized operations sheet and; (5) train and verify the personnel. (Fin et al., 2017)

Real Time Management (RTM)

Real Time Management (RTM) is used to make problems evident immediately (Valette, 2019). From (Rydén et al., 2019), the RTM helps enterprises stay relevant and competitive, because managers have the ability to see how customers react to everything they do. It enables an organization to respond to customers and competition as quickly as they can, to gauge market trends in real time and to deliver goods and services at a faster pace.

Sales and operations planning (S&OP)

Association of Operations Management (APICS) defines S&OP as a “process that provides management the ability to strategically direct the businesses to competitive advantage on a continual basis by integrating customer focused marketing plans for new and existing products with the management of supply chain”.

However, there are a lot of S&OP definitions from different authors. From (Kumar, 2016), the S&OP is considered as:

- A set of processes that enable a company to respond effectively to demand variability and take timely decision.
- An enterprise-wide risk management process.
- Builder of bridges between the business or strategic plan and the operational plans of a firm, i.e. a facilitator and integrator of strategic and tactical planning components of an organisation.

A typical S&OP process covers the following steps:

1. Review the current plan
2. Consider how to introduce new products and phase out older ones
3. Review current demand and create a demand plan that includes marketing and sales forecasts
4. Create an operations plan to satisfy the demand plan, or identify capacity and component shortages
5. Do a financial review to make sure the scenarios meet financial targets
6. Hold an executive S&OP meeting to review the proposed scenarios and determine which plan best meets the company’s objectives

S&OP grew out of a need to balance supply and demand, although it can go far beyond this simple goal. S&OP calls for a way to work together to gain a consensus on the best plan and how to execute it.

6.3.2. Final framework

In this section, the complete final framework structure is added. The following figure is similar to the figure 14 but including the improvements explained above. Comparing the two figures, the differences can be observed at the operational and tactical level. At these levels, some direct problems (step 1) and some tools, mostly in the third step, are added.

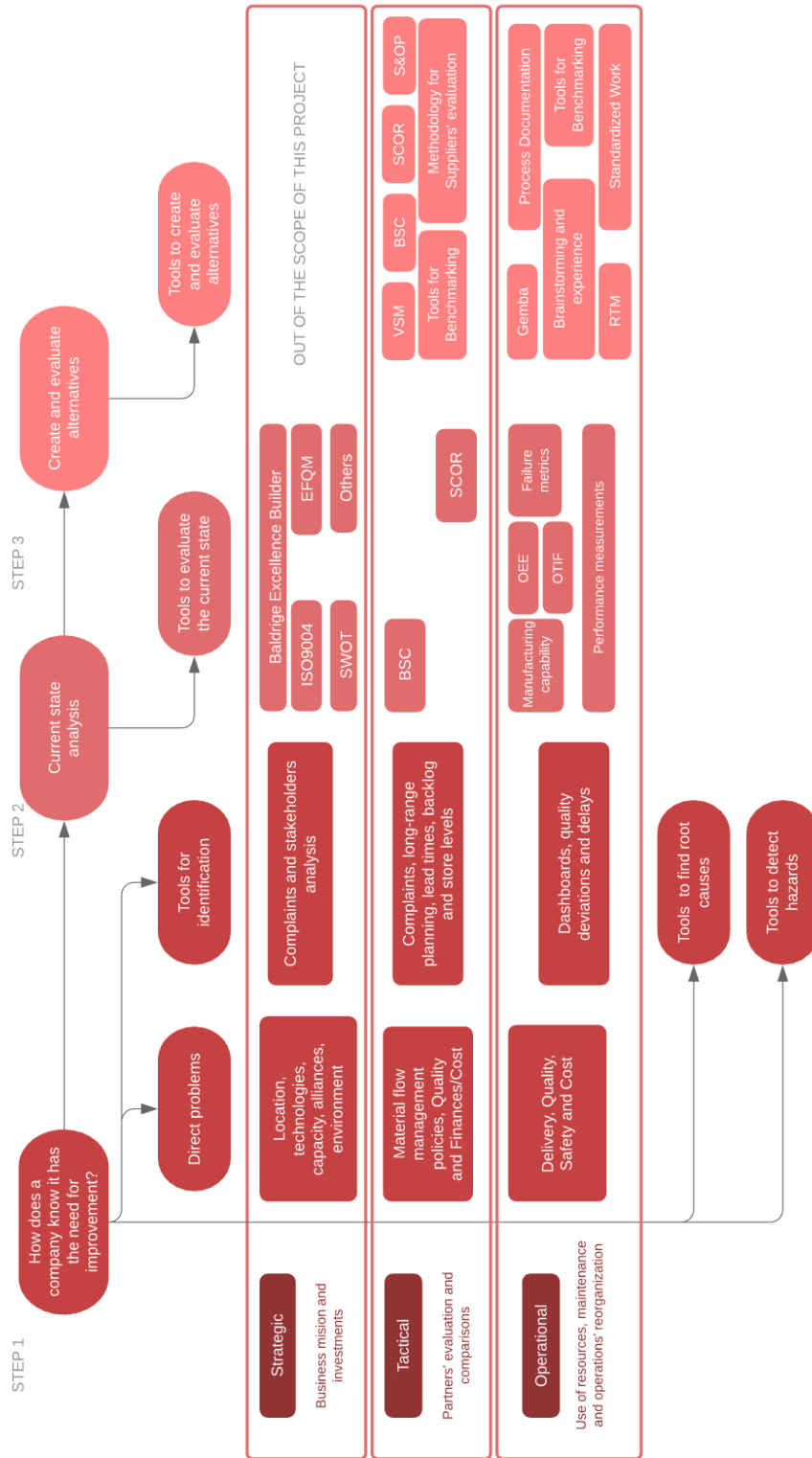


Figure 18. Complete structure of the final framework. Source: Own creation

6.4. Limitations

As it is explained in the delimitations section, the timeframe has had impact in the scope of this Master Thesis. Furthermore, doing this project in the division of production management (Department of Industrial Management and Logistics) has impacted on the content included in the developed framework.

Along these lines, the main limitations due to time and division are three:

(1) Strategic tools to create and evaluate alternatives are not considered in the framework. At the strategic level, the evaluation and implementation of solutions is carried out through long-term planning that involves many more factors than the daily or the short-term planning such as big investment, bureaucracy, organizational culture, strategic alliances, infrastructure, etc. (Schmidt et al., 2000). However, there are some alternatives that have been considered at the operational or tactical levels that involve more than one level, including the strategic one, and that have been added and explained in the corresponding sections.

(2) Not all the existing tools can be included in the framework although they can be very useful to the purpose of it. This is the reason why the author, with the tutor help, had to select the most interesting, from her point of view, or important tools and methodologies to measure the current state and to create and evaluate alternatives to solution.

(3) Not all the possible alternatives are evaluated. This project has focused on finding improvements or solving problems in the best possible way. Therefore, the tools or methodologies proposed to evaluate alternatives include, for example, the use of best practices or the complete integration of the supply chain.

Not directly related to time or division, there are some other limitations that should be mentioned:

(4) This framework does not propose a route to solve operational performance problems or to make an effective performance improvement. It does propose the three main steps to identify that problem or need for improvement and evaluate some solutions but depending on the need, there are different tools to use at each of the levels and that is what is not explained.

(5) From (Clausson, 2019), (Valette, 2019) and (Wiesel, 2019) is extracted that although they consider this framework very useful, it is useful in a specific set of situations and thus, it is no universal. In this way, it is a diagnostic framework for operational performance that companies can have in their toolbox to use it when they think convenient.

7. REFLECTIONS

In this final chapter, discussions and reflections regarding choice of methodology are presented. Then, the recommendations for future work are presented and finally, the academic contribution of this master thesis is reviewed.

7.1. Discussion

Working according to the described methodology (chapter 2) has allowed this Master Thesis: (1) to be based on the existing literature to explain all the concepts, tools and methodologies included as well as to detect the operational performance and supply chain requirements; (2) to collect the current practice of three companies facing operational performance improvements; and (3) to include a diagnostic framework of operating performance contrasted and validated by three different managers. In addition, this methodology makes the author confident that the presented results can be considered both useful and trustworthy.

The framework is mainly theoretical although it has been compared with the current practice of three different companies which gives empirical support about the reliability and validity of its contents.

This Master Thesis started with the main objective of developing a framework to help companies with several workshops to perform benchmarking when capacity problems wanted to be solved in the best possible way. This was the first idea since in business with several fabrication units or workshops in different countries, a benchmarking of efficiency/efficacy is of great value for continuous improvements and investment plans and it is also of importance when deciding sourcing like nearsourcing or outsourcing to be able to make comparisons. (Shen et al., 2000)

However, as the author acquired more knowledge by reading different articles and related books, it was decided to develop a more generic framework and consider benchmarking as one of the proposed alternatives of solution. Along these lines, benchmarking became one of the proposed alternatives and the framework then focused on the problems of operational performance.

From this point, the three steps of the framework were decided, after brainstorming and literature research, and the tool search started. It was not until the collection of many of the tools when the classification of these in the three different levels of planning was proposed in order to be able to decide in what level the analysis had to focus as starting point.

It worth nothing to say that from the beginning, the framework, whatever its purpose was, had to be validate and contract with different companies. Even so, it was decided to wait until the objective was clear to contact the companies and thus be able to give them a brief introduction of this Master Thesis and obtain their collaboration.

7.2. Further research

This thesis focused mainly on the collection of tools to define and identify operational performance problems or improvements. The framework developed includes the tools and methodologies that the author, with the help of the tutor and the interviewees, has considered most relevant.

According to Valette (Valette, 2019) and Wiesel (Wiesel, 2019), the tools included to measure the current state and create and evaluate alternatives are very good examples but there are many others that could also be very useful. Along these lines, one of the further steps could be to complete this set with the basic daily current used tools and for that, some more interviews with more managers of different companies would be necessary.

As it was explained in the analysis chapter, this framework does not include the implementation or the effectiveness assessment of the solution. In this way, this framework could be completed adding two more steps: (4) Implement the solution, and (5) Assess the effectiveness of the solution. With this addition, it would go from being a diagnostic framework, to an improvement framework since it would include not only the definition of the problem, the current situation analysis and the evaluation of some alternatives, but also the implementation of the selected alternative and an analysis of its effectiveness.



Figure 19. Further step including steps four and five. Source: Own elaboration.

In order to make this improvement, the Advanced Product Quality Planning (APQP) which is often illustrated in the Plan-Do-Check-Act (PDCA) cycle can be considered since the PDCA is an iterative methodology for implementing improvements: establish plan and expected results (Plan), implement the plan (Do), verify expected results achieved (Check), review and assess (Act) and do it again.

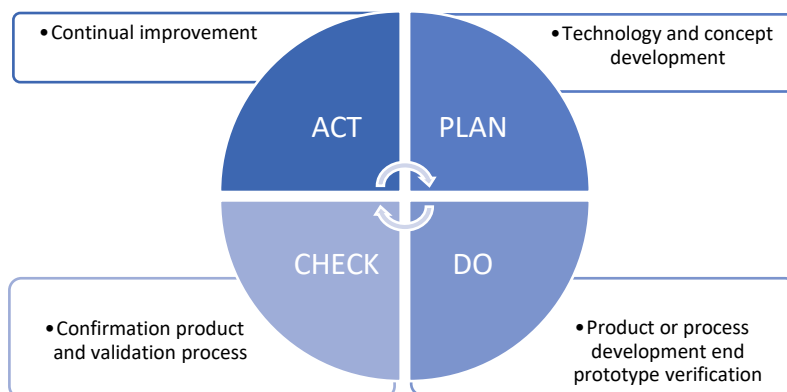


Figure 20. PDCA illustration. Source: Made by the author based on (International Organization for Standardization, 2015)

In addition, when assessing the effectiveness of the solution, if the result is not adequate, then the responsible must start over at the correct step. It is possible that the problem lies in not having well defined the problem to be solved or the improvement, or having recognized it incorrectly, then it should be restarted by the first step, or it may be that the selected alternative is not the most efficient, then it would have to be start again by step three. Then, a flowchart could be created to flesh the proposed improvement out.

It could be considered as a further step to use the presented framework to report sustainability. Sustainability reporting have been used by organizations in an attempt to provide accountability to their stakeholders. A better understanding of current practices is important to provide a base for comparative and trend analyses. (Mori Junior et al., 2014)

Sustainability reporting can help organizations to measure, understand and communicate their economic, environmental, social and governance performance, and then set goals, and manage change more effectively. A sustainability report is the key platform for communicating sustainability performance and impacts. Along these lines, complementing with tools that also evaluate other aspects not included in the framework such as the environment or the governance, this framework could be used to report sustainability.

7.3. Author's contribution

During the realization of this thesis, the three research questions are answered. In order to back the conclusions of those questions up, a literature review along with a study of three companies were used. Moreover, a diagnostic framework of operational performance is proposed.

Thanks to the interviews, it has been possible to explain how different companies, of different sizes and industries whose analyzed plant is located in Skåne are currently working and how they solve operational performance problems or improvements.

From the interviews, it was concluded that there are companies with very different ways of working. From companies with their own framework for strategic deployment and result driven improvements to companies in which problems are solved directly, without any standardized tool or process.

The developed framework can help both cases: the first type of company can use the developed framework to think about basic tools or ideas that had not been considered or to include recent methodologies for, for example, implement a benchmarking process. The second type can adopt this framework as its own framework to define and identify problems and improvements or simply use the tools included in this one that they consider most useful.

In between, companies that use a large number of tools and practices, although not completely included in a single structure, can be found. These companies can also take advantage of the presented framework not only to include some tools to their way of working, but also to include their tools in and improving the presented framework, create their own framework to define and identify operational performance problems or improvements.

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APPENDIX

A1. Evaluate manufacturing capability (Lekurwale et al., 2014)

Table A1.1. Scale of relative importance

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
2	Weak over slight	
3	Moderate importance	Experience and judgment slightly favour one activity over another.
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favour one activity over another.
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practice.
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of

Table A1.2. Qualification of rating values

Decisions (criteria)	Decision choices	Rating values
Level of skill	Highly skilled	0,47
	Skilled	0,28
	Semi-skilled	0,13
	Mixed	0,08
	Unskilled	0,04
Nature of job	Broad	0,081
	Two or three	0,189
	Fixed/explicit (one type)	0,73
Performance appraisal	Individual	0,833
	Team-based	0,167
Training need	Low	0,610
	Moderate	0,220
	High	0,100
Wage rate	Very high	0,080
	Low	0,081
	Moderate	0,189
Work content	High	0,73
	Small	0,081
	Moderate	0,189
Employee participation	Large	0,73
	Low	0,081
	Moderate	0,189
	High	0,73

Table A1.2 (continuation).

Decisions (criteria)	Decision choices	Rating values
Decision-making	Decentralize	0,875
	Centralize	0,125
Organization structure	Flat	0,73
	Hierarchical	0,189
	Mixed	0,081
Importance of line staff	Low	0,094
	Moderate	0,167
	High	0,739
Quality responsibility	Worker	0,600
	Worker and supervisor	0,240
	Team	0,100
	Quality control specialist	0,090
Planning strategy	Process control specialist	0,060
	Level	0,076
	Chase	0,792
Raw material inventory	Mixed	0,131
	Low	0,655
	Medium	0,250
Work in process inventory	High	0,095
	Low	0,655
	Medium	0,290
	High	0,050

Table A1.2(continuation).

Decisions (criteria)	Decision choices	Rating values
Finish good inventory	Low	0,751
	Medium	0,178
	High	0,071
Planning input	Forecasting	0,082
	Customer order	0,761
	Mixed	0,158
Setup to run time	Low	0,655
	Medium	0,250
	High	0,095
Scheduling uncertainty	No	0,532
	Rare	0,270
	Few	0,122
	Large	0,076
Production information required	low	0,510
	Moderate	0,300
	High	0,130
	Very high	0,070
Length of planning horizon for finish goods	Low	0,079
	Medium	0,263
	High	0,658
Batching of backlog for planning	Larger	0,750
	Smaller	0,250
Type of layout	Process	0,747
	Product	0,134
	Cellular	0,120
Degree of automation	Little	0,739
	Medium	0,167
	Extensive	0,094
Type of tooling	Low volume	0,751
	Medium volume	0,178
	High volume	0,071
Use of AMT for product and process design	Little	0,084
	Medium	0,211
	Extensive	0,705
Batching of backlog for planning	Larger	0,750
	Smaller	0,250
Degree of coupling	No integration	0,676
	Loose integration	0,174
	Medium integration	0,104
	High integration	0,045

Table A1.2(continuation).

Decisions (criteria)	Decision choices	Rating values
Degree of vertical integration	Low	0,792
	Medium	0,131
	High	0,076
Material requirement prediction	Difficult to predict	0,070
	Somewhat predictable	0,280
	Highly predictable	0,650
Number of suppliers	Few	0,648
	Many	0,230
	Large	0,122
Control over suppliers	Low	0,088
	Moderate	0,128
	High	0,247
	Very high	0,537
Relationship with suppliers	Transactional	0,059
	Acceptable	0,119
	Long term	0,247
	Strategic	0,576
Size of facility	Small	0,760
	Medium	0,158
	Large	0,082
Type of facility	General purpose	0,500
	Low automation	0,300
	Medium automation	0,120
	Special purpose	0,070

A2. Integrated strategic benchmarking framework (Meybodi, 2006)

This appendix contains the table that groups the four areas and the elements that are evaluated in the questionnaire-based survey which conforms the integrated strategic benchmarking framework proposed by (Meybodi, 2006).

Table A3.1. Areas and elements evaluated by (Meybodi, 2006) method.

Corporate mission and goals	Build market share Maximize profits Focus on customer satisfaction Build and exploit core competencies Understand competitors' strategy Understand global strategies Understand technology
Competitive priorities	Price Conformance Performance Reliability Fast delivery On time delivery Customization Product development speed (NPD) Volume flexibility Service after sales
Manufacturing action plans	Employee training Employee empowerment Employee teamwork Employee fair compensation Manufacturing reorganization Manufacturing automation/technologies Make-to-stock strategy Batch process Line/continuous process Flexible manufacturing process Vertical integration Outsourcing Supply chain management Quality at the source Quality circle Quality improvement tools Statistical process control charts Quality function deployment Process capability ISO 9000 Brainstorming Process analysis Concurrent engineering Value analysis Just-in-time system

Table A3.1(continuation).

<p>Manufacturing action plans (continuation)</p>	<p>Design for manufacture and assembly Integrate IS into supply chain Link manuf. strategy into corporate strategy</p>
<p>Manufacturing performance objectives</p>	<p>Reduce direct and indirect labour costs Reduce materials costs Reduce overhead costs Reduce inventories Reduce set-up/changeover costs Improve labour productivity Increase production volume Increase product standardization Increase parts standardization Increase capacity utilization Reduce logistics and material handling costs Reduce defects Reduce errors Improve supplier quality Reduce number of suppliers Improve supplier relationships Change manufacturing organization culture Eliminate wastes Improve product design Improve manufacturing process Increase customization Improve employee morale Improve inter-functional communication Improve team decision making Improve service after sales Increase delivery speed Increase new product development speed Increase delivery reliability Reduce set-up/changeover time Reduce manufacturing lead time Reduce procurement lead time Reduce cycle time Improve rapid volume changes</p>

A3. Rapid Plant Assessment

In order to implement the Rapid Plant Assessment (RPA) the following tables are needed:

Table A4.1. RPA Table 1

Rated by: _____		Rapid Plant Assessment						
Tour Date: _____		Table 1--Rating Sheet					Plant: _____	
	Ratings	Poor	Below Average	Average	Above Average	Excellent	Best in Class	
No	Measure Score	1	3	5	7	9	11	Scores
1	Customer Satisfaction							
2	Safety, environment, cleanliness, & order							
3	Visual Management Deployment							
4	Scheduling system							
5	Product flow, space use & material movement means							
6	Inventory & WIP Levels							
7	People teamwork, skill level, & motivation							
8	Equipment & tooling state & maintenance							
9	Ability to Manage Complexity & Variability							
10	Supply Chain Integration							
11	Quality System Deployment							
	Totals							

Table A4.2. RPA Considerations Table 1

abr-02		Rapid Plant Assessment Rating--Table 1 Rating Considerations Chart 1
No	Measure	Factors
1	Customer Satisfaction	Customer ratings, quality certifications & ratings, warranty & product liability costs, employee knowledge of external and internal customer requirements, visitor materials & welcome, market share, rate of new product introduction & acceptance
2	Safety, environment, cleanliness, & order	Safety & environment record, place for everything & everything in its place, cleanliness of operations--exterior & interior, floors, equipment, spills, leaks, noise, lighting, paint, dust, air quality, employee dress, restroom conditions, desks & workbench order & cleanliness, degree of "spiffing" for visitors (negative), inventory order, material flow order & cleanliness, color & other coding for safety & order
3	Visual Management Deployment	Operations mission & performance objectives visible; visibility of labeling & coding of product lines, inventory, equipment, & tooling; color coding & differentiation; visibility of customer identification & ratings; visibility of charts tracking operation's & teams' safety, quality, & productivity, control room showing status of total operation, customer order & order fulfillment visibility, Kanban deployment, inventory count can be made visually, machines & tool labeling--costs, preventive maintenance visibility, product displays, audit results visible
4	Scheduling system	Degree of scheduling to customer order, order process efficiency, product line scheduling at single point, scheduling buckets (each order, hourly, daily, weekly, or monthly), supplier scheduling & delivery, replenishment versus order fulfillment, computer scheduling versus kanban, pull versus push systems, flow time efficiencies, backroom costs of scheduling, MRP costs, data entry costs
5	Product & material flows; space use	Product line versus shop layout, rolling carts pulled by tractors or by hand or conveyers versus forklifts, travel distances between processes, material movement responsibility--process owned or separate material staff, container size (forklift requirement?), containers designed for parts families, single versus multiple docks to minimize material travel, space utilization, goals for space use reduction
6	Inventory & WIP Levels	WIP levels at each process, WIP in transit in plant, separate stores versus line side storage, number of inventory storage areas, finished product levels, total inventory to sales ratio, process cycle time to flow time ratios, countability of inventory, WIP movement triggered by computer, material department or next process, theoretical versus actual flow times
7	People teamwork, skill level, & motivation	Team problem solving capability & history, employee willingness to talk about customers, products, & company; uniformity of dress; communications & recognition environment; sales per employee; team meeting areas & performance charts; training investments, educational support, benefit package & costs, unionization activity, workforce-management relationship, community support, company-supported activities (picnics, open houses, sports teams, local involvement, employee knowledge of & support of customers & business, work instructions standards
8	Equipment & tooling state & maintenance	Preventive maintenance system, setup change times, integrated go-no go quality checks, machine performance data availability, knowledge & utilization of bottleneck processes, process control capability, total asset utilization, operator routine maintenance, maintenance staff & teams, MRO replenishment efficiency, tool & fixture orderliness, cleanliness, & storage location, equipment improvement policy, equipment technology strategy
9	Ability to Manage Complexity & Variability	Use of common parts, processes, & procedures prototype process, paper transactions required on floor, keyboard entries versus bar coding, backroom paperwork & computer transactions costs, matching of data collected with data needed, simplicity & clarity of operations layout, indirect to direct labor ratio, support staff to total workforce ratio, overhead cost ratios, commonality of tooling & fixturing, commonality of equipment & tools, commonality of support software & applications programs across the operation & among sister plants, equipment efficiencies, ability to handle variable demand, ability to eliminate controllable variations, ability to smooth demand, ability to handle supply chain, number of suppliers
10	Supply Chain Integration	Number of suppliers, supplier release system--from inventory levels or customer order, supplier certification, sourcing policies--short-term or long-term, supplier quality ratings, delivery, & productivity objectives & history, new product development responsibility, responsibility for kitting parts, C-stock replenishment efficiency, supplier material scrap & rework, supplier cost-saving ideas implemented, supplier knowledge of lean
11	Quality System Deployment	Quality certification, quality process & measurement at each process & for each product, scrap & rework, problem solving process, product & customer quality data, quality ratings, new product startup process, continuous improvement environment, degree of focus on customer satisfaction, implementation of best practices, degree operational strategies are linked to corporate strategy, total quality system well-developed & deployed

Table A4.3. RPA Table 2

Plant	Rapid Plant Assessment	Date	abr-02
No	Table 2--Assessment Questionnaire		Yes/No
1	Are visitors welcomed and given information about plant layout, workforce, customers, and products?		
2	Are ratings for customer satisfaction and product quality displayed?		
3	Is the facility safe, clean, orderly, and well lit? Is the air quality good and noise levels low?		
4	Does a visual labeling system identify and locate inventory, tools, processes, and flow?		
5	Does everything have its own place, and is everything stored in its place?		
6	Are up-to-date operational goals and performance measures for those goals prominently posted?		
7	Are production materials brought to and stored at line side rather than in separate inventory storage areas?		
8	Are work instructions and product quality specifications visible at all work areas?		
9	Are updated charts on productivity, quality, safety, and problem solving visible for all teams?		
10	Can the current state of the operation be viewed from a central control room, on a status board, or on a CRT?		
11	Are production lines scheduled off a single pacing process with appropriate inventory levels at each stage?		
12	Is material moved only once as short a distance as possible and in appropriate containers?		
13	Is the plant laid out in continuous product flow lines rather than in "shops"?		
14	Are work teams trained, empowered, and involved in problem solving and ongoing improvements?		
15	Do employees appear committed to continuous improvement?		
16	Is a timetable posted for equipment preventive maintenance and continuous improvement of tools and processes?		
17	Is there an effective project management process, with cost and timing goals, for new product start-ups?		
18	Is a supplier certification process--with measures for quality, delivery, and cost performance--displayed?		
19	Have key product characteristics been identified and fail-safe methods used to forestall propagation of defects?		
20	Would you buy the products this operation produces?		
	Total number of Yeses		

Correlation of Lean RPA Categories explained in the corresponding section to the questions of the "Table 2" (Table A4.3):

Table A4.4. Correlation between categories and questions RPA

Lean RPA Rating Categories	Lean RPA Questionnaire questions
Customer Satisfaction	Questions 1,2,20
Safety, Environment, Cleanliness, and Order	Questions 3-5,20
Visual Management System Deployment	Questions 2,4,6-10,20
Scheduling System	Questions 11, 20
Space, Movement, and Flow	Questions 7,12,13,20
Inventory and WIP	Questions 7,11,20
Teamwork, Skills, and Motivation	Questions 6,9,14,15,20
Tooling and Equipment Condition/Maintenance	Questions 16,20
Management of Complexity and Variability	Questions 8,17,20
Supply Chain Integration	Questions 18,20
Quality System Deployment/Commitment	Questions 15,17,19,20

A4. Interview guide

DEFINE/IDENTIFY: A need for improvement

1. What do you think is the most important thing when you face a need for improvement?
2. Do you have any framework to carry out performance improvements?
3. Are you carrying out any process to improve yourselves or to improve your performance?
4. How do/did you know you need/needed to improve? Indicators?
5. How do you identify where or what do you need to improve? Critical areas?
6. Do you carry out any hazard or risk analysis? How do you do it?
7. Do you have capacity problems right now or have you had them recently? How did you recognize the problem? What did you measure? What did you do to solve it? Which solutions did you implement? How did you decide the solution?
8. Do you have any problem with suppliers? How did you recognize the problem? What did you measure? What did you do to solve it? Which solutions did you implement? How did you decide the solution?
9. Do you use some Six Sigma or Lean tools? DMAIC process?
10. Is there a joint address of all the plants?
11. Do you consider that the competitive advantage that the Supply Chain Management brings (competing not only as a company but also as a supply chain) is important?

MEASURE: Current state

12. When you want to know what is your current state, what do you do?
13. How do you measure your performance?
14. How do you measure your capacity?
15. How do you measure your productivity?
16. Are you implementing some strategic framework for managing organizational performance? Such as the Malcolm Baldrige National Quality, the European Foundation for Quality Management, the Balanced Scorecard, the Supply Chain Operations Reference model or some ISO (International Organization of Standardization).

ANALYSE/IMPLEMENT: When talking about solutions:

17. What methods do you use to create alternatives to solutions?
18. How do you evaluate the alternatives?

Evaluation of suppliers

19. What percentage of total production do you manufacture in-house? What happens with the rest? Do you outsource any product or service?
20. When you have to recruit a new supplier, what do you do?
21. Do you have any continuous process of supplier's evaluation?

Benchmarking

22. Have you or your company carried out some benchmarking process? And what for? How did you do it? Method? What did you get from that process?

GETTING A BETTER UNDERSTANDING:

The framework is composed by three steps: (1) How does a company know it has a need for improvement? (2) Current State Analysis and (3) Create and evaluate alternatives.

23. What do you think about the main structure (The three steps)?

FIRST STEP: How does a company know it has a need for improvement?

- Direct problems (Table 2)
- Tools to recognize a Need for Improvement (Table 1)
- Tools to find root causes: Pareto Chart, The 5 Whys, Fishbone Diagram and Scatter Diagram
- Tools to detect hazards: Failure Mode and Effects Analysis (FMEA) & Hazard Analysis and Critical Control Point (HACCP)

24. What do you think about the tools used?

25. What do you think about deciding the starting point/level of planning depending on the fault or improvement?

26. What if the tools to carry out the Current State Analysis and the Creation and Evaluation of alternatives are classified depending on the level of planning?

SECOND STEP: Current State Analysis

- Strategic level: SWOT, Baldrige Excellence Builder, ISO 9004:2015, EFQM Excellence Model and others (McKinsey 7S, Nadler-Tushman's Congruence Model and Burke-Litwin Causal Model)
- Tactical level: Balance Scorecard and SCOR
- Operational level: Evaluate manufacturing capability, Overall Equipment Effectiveness (OEE), Performance measurements and Failure Metrics

27. What do you think about the tools used?

28. What other tool do you think is important to consider?

THIRD STEP: Create and evaluate alternatives

- Tactical level: BSC and SCOR, Evaluation of suppliers (Structured methodology), Benchmarking (Integrated strategic benchmarking framework and RPA&RSPA)
- Operational level: Value Stream Mapping (VSM), Process Documentation, Gemba, Benchmarking and Brainstorming and experience

29. What do you think about the tools used?

30. Do you think it is important to describe the route to follow when facing different operational performance problems?

31. What other solutions do you think are important to mention and even to evaluate?

32. Can you see any limitation?

A5. Briefly explanation of the tools mentioned in the interviews

5S	It is a workplace organization method that uses a list of five Japanese works translated as Sort, Set in order, Shine, Standardize and Sustain to describe how to sort out a work space for efficiency and effectiveness. (Rewers et al., 2016)
Daily OTIF	The indicator “OTIF” means “on-time” and “in-full”. The daily OTIF requires that both, orders on time and completed, be fulfilled at the same time daily. (Torres-Rabello et al., 2011)
DMAIC process	The DMAIC process is the classic Six Sigma problem-solving process. It resolves issues of defects or failures, deviation from a target, excess cost or time, and deterioration. (Krishnan et al., 2013)
Is/IsNot	A simple method for bounding a problem and understanding scope. It deconstructs the Problem into 4 logical components: What the problem is; Where the problem occurs; When it occurs; and the Extent to which it occurred.
KATA process	KATA is a Japanese designed approach to make a business more productive through thinking by four steps: Define the challenge; Grasp current condition; Establish target condition; and Determine solutions. (Forss, 2013)
SMED	Single Minute Exchange of Die, a process of reducing changeover (setup) time by classifying elements as internal or external to a machine’s operating time and then converting the internal elements so they can be done externally. (Rewers et al., 2016)
Spaghetti Diagram	A visual representation using a continuous flow line tracing the path of an item or activity through a process. (Wedgwood, 2016)
SPC	Statistical Process Control, a method of quality control which employs statistical methods to monitor and control a process. (Wedgwood, 2016)
Standardized Work	Standardized work is an effective way for process improvement. Tasks standardization aims to guarantee that both material and human resources utilization are performing optimally. (Fin et al., 2017)
TPM	Total Productive Maintenance, a tool used to eliminate waste associated with technological machines in the enterprise with the main objective of increase the efficiency and productivity of machinery and equipment. (Rewers et al., 2016)
Visual management	It is a promote as a workplace where all associates understand and manage their own work in safe, clean, organized environment that fasters open communication, pride and continuous improvement. (Modi et al., 2014)