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GABRIELA LOBO VEIGA

PERFORMANCE EFFICIENCY FRONTIER IDENTIFICATION: DEVELOPING A PROCEDURE TO IMPROVE OPERATIONS STRATEGY

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Thesis dissertation presented to the Industrial and Systems Engineering Graduate Program (PPGEPS) of the Pontifical Catholic University of Parana, as a requirement to obtain the degree of Doctor in Industrial and Systems Engineering.

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ABSTRACT

The new dynamic business environment increases the complexity of organizational management, enhancing the need for understanding and capitalizing on opportunities in operations function. In a resource-limited and complex context, developing an operations strategy to compete on a global basis and the right decision on whether to emphasize or not a given competitive criterion is challenging. While efficiency in operations strategy is critical to competitive success, there are research gaps from perspectives of operations strategy performance and efficiency frontier analyses. The concept of firm performance frontier is already known in the literature, however, the possibility of using to boost the results in the operations function must be acknowledged, given it can help in providing assertiveness in the design of the manufacturing strategy and the deployment of key inputs. This research proposes and implements a procedure to measure, assess and improve manufacturing performance through the identification of company operations strategies. Performance frontier methodologies support the procedural framework, which enables the recognition of the improvement opportunities in the operations strategy competitive priorities. Two literature gaps are covered, first the lack of focus on the process to identify the performance frontier in the context of operations strategy. Second, the exploitation of the competitive priorities in a market-based view approach. A conceptual and procedural framework is developed to promote the identification of the production frontier within the context of specific operations strategies, enabling the proposition of recommendations to companies to drive better-positioned operations strategies to face competitors. To this end, the first phase includes an in-depth systematic literature review and content analysis to position the research agenda as well as to establish insights into the conceptual framework. Next, Multivariate Data Analysis supports the definition of the input and output variables comprising the conceptual framework. Third, a procedural framework formalizes the process of identifying the maximum operations strategy performance frontier. A pilot case study is promoted to refine the proposed framework; then, multiple case studies are developed to test the model proposed. As a result, a deeper understanding and shared knowledge of frontier estimation of the operations strategy context are provided. The frameworks proposed can positively influence the firms to succeed, in addition to covering the gap in the market-based view approach.

Keywords: Operations Strategy, Performance frontier Analysis, Performance measures, Multivariate Data Analysis.

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RESUMO

A nova dinâmica do ambiente de negócio aumenta a complexidade da gestão organizacional, aumentando a necessidade de entender e capitalizar as oportunidades da função operações. Em um cenário complexo e de recursos limitados, desenvolver estratégias de operações para competir de forma global é um desafio, requerendo a decisão certa sobre quando enfatizar uma prioridade competitiva. Enquanto a eficiência na estratégia de operações é crítica para o sucesso no ambiente competitivo, existem lacunas da perspectiva de desempenho da estratégia de operações e análise da fronteira de eficiência. O conceito de análise de fronteira é conhecido na literatura, no entanto, entende-se que o mesmo pode ser usado para impulsionar os resultados da função operações, pois contribui para a assertividade do projeto da estratégia de manufatura e para a exploração das variáveis de entrada chaves. Esta pesquisa propõe e implementa um processo para mensurar, avaliar e melhorar o desempenho da manufatura por meio da identificação da estratégia de operações da organização. Metodologias de análise da fronteira de desempenho apoiam o modelo processual, que permite o reconhecimento das oportunidades de melhoria nas prioridades competitivas da estratégia de operações. Duas lacunas da literatura são cobertas, a falta de foco no processo para identificar a fronteira de desempenho no contexto da estratégia de operações e a exploração do conceito de prioridades competitivas em uma abordagem orientada ao mercado. Um *framework* conceitual e processual é desenvolvido para promover a identificação da fronteira de desempenho no contexto da estratégia de operações, o que habilita a proposição de recomendações para as empresas posicionarem melhor a sua estratégia de operações, frente aos concorrentes. Para isso, a primeira fase inclui uma profunda revisão sistemática da literatura e uma análise de conteúdo, para posicionar a agenda de pesquisa e obter *insights* para o desenvolvimento do modelo conceitual. Em seguida, a técnica de análise multivariada de dados suporta a definição das variáveis de entrada e saída que compõe o modelo conceitual. Em terceiro um modelo processual formaliza o processo para identificar o desempenho máximo da estratégia de operações. Um estudo de caso piloto é promovido para refinar o modelo proposto, então, múltiplos estudos de caso são desenvolvidos para testar o modelo proposto. Como resultado, um entendimento profundo e compartilhado sobre a estimação de fronteiras para a estratégia de operações é promovido. O *framework* proposto pode influenciar de forma positiva o sucesso das organizações, além disso, a lacuna relacionada à abordagem baseada em mercado é coberta.

Keywords: Estratégia de operações, medidas de desempenho, prioridade competitivas, análise da fronteira de desempenho, análise multivariada de dados

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ABBREVIATIONS

BCC - Banker, Charnes e Cooper

CCR - Charnes, Cooper, and Rhodes

CFA - Confirmatory factor analysis

DMU - Decision-making units

CRS - Constant return to scale

DEA - Data envelopment analysis

ECM - Efficiency contribution measure

EFA - Exploratory factor analysis

FHQ - Free Disposal Hull

GLS - Generalized least squares

HPM - High-Performance Manufacturing

KMO - Kaiser-Meyer-Olkin

MSA - Measure of sampling adequacy

ML - Maximum likelihood

NIRS - Non-increasing return to scale

NDRS - Non-decreasing return to scale

OEM - Original equipment manufacturer

PCA - Principal Component Analysis

VRS - Variable return to scale

RBV - Resource-Based View

SFA - Stochastic frontier analysis

SLR - Systematic literature review

SS - Sampling Size

ULS - Unweighted least squares

CONTENTS

1. INTRODUCTION

Many firms are increasingly confronted with external environmental turbulence and complexity, in this scenario how to properly adopt strategic choices in response to environmental uncertainty has become a great challenge (Okoshi et al., 2019; Narkhede, 2017; Machado et al., 2017). The changes in technology and customer expectations, which are increasingly common, are responsible for generating a complex and dynamic competitive environment (Samoilenko and Osei-Bryson, 2012; Soosay et al., 2016).

Lotfi and Saghiri (2018) defend that the unpredictable changes that the business environment is facing in the last two decades, generate a risk of unexpected disruptions which can result in poorer operational and financial performance outcomes. This new dynamic business scenario increases the complexity of the organizational context, enhancing the need for understanding and capitalizing operations function opportunities (Cagliano et al., 2005; Thun, 2008; Hill and Hill, 2017), requiring a good operations strategy.

Operations strategy can be defined as the development of competitiveness, based on the production function, to help achieve the long-term competitive objectives (Amoako-Gyampaha and Boye, 2001; Barnes, 2002). The operations strategy must consider how market needs and manufacturing capabilities might be combined by competitive strategy in a dynamic and unpredictable marketplace to sustain competitive performance (Brown and Blackmon, 2005). By definition, the operations strategy supports the achievement of business objectives, and consequently the competitive advantage, employing structural items (control policies, structure organizational, etc.), infrastructural ones (buildings, plant, equipment, etc.) (Platts and Gregory, 1990) and decision area of human aspects. The action in the decision areas generates results at competitive dimensions, like quality, speed, flexibility, dependability, innovativeness, and cost, which should be coherent with the corporate business strategy.

However, according to the well-known concept of the trade-off, it is not possible to be excellent in all performance criteria. The essence of strategy is to choose between what to do and what not to do, trade-offs, therefore, limit organizational performance (Skinner, 1969). Still, there are two recent visions of trade-offs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others. Some authors defend the cumulative capabilities model, where it is possible to compete on multiple capabilities, simultaneously, being the extensively used, currently (Nand et al., 2014; Narasimhan and Schoenherr, 2013; Singh et al., 2014). Most companies, at one time or another, will adopt both approaches (Amoako-Gyampah and Meredith, 2007; Slack and Lewis, 2018; Kathuria et al., 2018; Sarmiento, et al., 2018). The advent of technology helps in breaking the barrier of tradeoffs, but, as the resources of an organization are finite investments (Achillas et al., 2014), making choices between what to do and what not to do is still needed. Besides, that is challenging to develop an operations strategy to compete on a global basis, due to the operational and managerial difficulties. The excellent organizational performance is not reached unless it achieves optimal operations performance which is provided by the operations strategy effectiveness (Modi and Mishra, 2011; Abassi and Kaviani, 2016).

The firm frontier identification, which is a concept already known in the literature, can be used to boost the results in the operations function. According to Liu et al. (2018) efficiency frontier methodologies allow the examination of performance in operational processes and help organizations to test their assumptions about performance, productivity, and efficiency in operations decisions. According to Cai and Yang (2014), the extent to which a company must emphasize a competitive priority depends on its asset and operating frontier. Hill and Hill (2018) indicate that companies need to be aware of the relevant order-winners and qualifiers and the size of the gap in this criterion, as well as the investment, to close this gap. Measuring operational performance promotes managers' awareness of the efficiencies of their operations strategies, enabling accurate strategic and operational decisions to increase performance (Abbasi and Kaviani, 2016).

The firm production frontier concept specifies the maximum performance that can be achieved using a set of inputs. The distance between the production frontier and current production performance is called technical inefficiency. In this way, technical efficiency is the organization's ability to obtain the maximum result from a set of inputs (Farrel,1957; Khezrimotlagh and Chen, 2018). In this sense, this research proposes a way of integrating the firm production frontier concept within the operations strategy, contributing to the success of the resource implementation and hence, for the enhancement of operations efficiency. A conceptual and procedural framework is proposed to measure, assess, and improve organizations' manufacturing performance according to their operations strategy, improving then operations function assertiveness and therefore increasing the competitiveness of the business. Such a framework is grounded in performance frontier methodologies.

1.1. RESEARCH QUESTION

Organizations need to respond to competitors with their own increased efficiency. This occurs because modern companies typically operate in dynamic and competitive environments (Lotfi and Saghiri, 2018; Soosay et al., 2016), generating the need to position itself before the performance of competitors as well as to increase the levels of efficiency and effectiveness in the market in which it competes (Samoilenko and Osei-Bryson, 2013; Abbasi and Kaviani, 2016). In this way, companies that know the production performance frontier can be in a better competitive position as they have a reasoned decision making based on strategic information about the market.

However, the process of estimating the performance frontier in this scenario is not clearly defined in the literature. In this way, the following research question is outlined:

How to improve operations strategy based on the performance efficiency frontier concept?

The question will be answered considering the context of automotive suppliers' companies, and the following initial assumptions must be considered.

Assumption 1: The frontier calculation methodology is already known.

Intermediate questions:

How is the concept of operations strategy and performance efficiency frontier analysis related?

How to measure the operations strategy using performance efficiency frontier methodologies?

How to assess the operations strategy performance employing the performance efficiency frontier concept?

How to improve manufacturing performance based on the enhancement of the operations strategy assertiveness?

How to enable companies to timely implement performance efficiency frontier analysis providing agility on decision making?

1.2. RELEVANCE

While efficiency in operations strategy is critical to competitive success, as observed by Narkhede (2017), there exist research gaps from perspectives of operations strategy performance and efficiency frontier analysis. It is noticed that there are few literatures in the field of performance frontier analysis in the area of operations strategy. The simple search in the CAPES journals database returned 13 results considering the terms 'operations strategy' and 'frontier analysis', while only the term frontier analysis returned 5.105 results.

Looking at the few pieces of literature that integrate the concept of operations strategy and firm performance frontier, a lack of focus on the process to identify the performance frontier in the context of operations strategy is found. According to Schmenner and Swink (1998), there is not a good definition of performance frontier into operations management literature. Most of the works demonstrate examples of the frontier estimation methodologies implementation and addresses the determinants of technical efficiency — focusing, therefore, essentially on content (Ahmed et al., 2014; Yu et al., 2014; Ramanathan et al., 2016; Chang et al., 2015). The approach in the process is less explored by literature. In this way, studying the process of identifying the performance frontier in the context of the operations strategy appears as a relevant research opportunity.

Besides that, performance frontier methodologies are applied to operations strategy with a focus mainly on RBV and capabilities approach (e.g. Ramanathan et al., 2016; Yu et al., 2014; Nath et al., 2010; Ahmed, et al., 2014). The market-based concept of competitive priorities, as presented in the seminal works of Caves and Porter (1977) and Porter, (1979), is not fully explored. The lack of the exploitation of the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. To Okoshi et al. (2019) and Phusavat and Kanchana (2008), the appropriate choice of competitive priorities reflects on the future direction of a firm and has fundamental importance to the achievement of its competitive advantage which may lead to business performance increasing.

Although some researchers such as Abassi and Kaviani (2016) and Bulak et al. (2016) use competitive priorities to determinate the operations strategy performance frontier, their assessments were not from an operations strategy perspective, as they not proceed to develop recommendation into the enhancement of the competitive position. This research develops its contribution to the gap of the market-based concept of competitive priorities by providing a procedural framework to measure, assess and improve operations strategy performance frontier. The importance of this proposal is supported by Hult et al. (2004) who state that translating market requirements into action is part of a strategic plan that supports the decision-making process to orient internal changes. Industrial firms with a market orientation are likely to devise and adapt products, services, and processes to continuously meet customer needs.

From the managerial point of view, the presence of a dynamic external environment is a factor that also contributes to increasing the density of the organizational context. Nowadays, there are multiple factors that compose the operations strategy (e.g., changes in technology and customer expectations), growing the complexity of its design (Soosay et al., 2016). The support of mathematical methods to choose the key factors that can contribute to the strategic planning assertiveness. Chen et al. (2015) state that identifying companies that have a competitive advantage is an easy exercise if performance can be captured by a single performance indicator, however, in the context of multiple metrics – our existent reality – this is no longer a trivial matter.

To Bititci et al. (2011) the dynamics of the market make some organizations fail in seeing or recognizing threats and opportunities until is too late to act. To Melnyk et al. (2014) in today's dynamic and turbulent environment, changes in either the business environment or the business strategy can lead to the need for new or revised measures and metrics. Establishing a systematic process to identify the production frontier can provide more accurate information for the establishment of emerging strategies and to increase the decision-making agility. Ahmed et al. (2014) defend that efficiency scores should be updated periodically, increasing the relevance of the existence of a process. In the current dynamic competitive environments, a static model to describe the relation of inputs and outputs will have limited use and feasibility in periods of instability (Samoilenko and Osei-Bryson, 2012).

Additionally, Lotfi and Saghiri (2018) defend that the business environment is facing unpredictable changes in the last two decades, generating a risk of unexpected disruptions which can result in poorer operational and financial performance outcomes. Besides that, given the economic limitations present in the markets, obtaining assertiveness in the improvement initiatives and the operations strategy design is of paramount importance. Especially in conditions where resources for improvement and innovation are limited and, once invested, must bring returns. In this sense, the proposed model provides a contribution in direction to the success of the improvement initiatives and hence for the enhancement of technical efficiency.

Another point that makes research relevant is the realization of this study for emerging nations, specifically Brazil since most of the existing works focus on the development of capabilities in developed countries and neglect the context of emerging nations (Schoenherr et al., 2012).

In short, the research gaps that make this thesis relevant to the academic community are:

- Lack of focus on the process to identify the performance frontier in the context of operations strategy;
- Performance frontier methodologies are applied to operations strategy approach focuses on the RBV and capabilities approach. Therefore, there is a lack of focus on the market-based view;
- Lack of empirical application on the emergent economic scenario.

On the other hand, the practical implications include:

- To support the competitiveness measurement in the current complex context of multiple performance metrics;
- To know the size of the gap to become a leader in the competitive market;
- To enhance assertiveness of operations strategy;
- To outperform in the limited economic scenario;
- To provide agility in decision making into operations function;
- To better deal with emergent strategies.

In summary, this research proposes a conceptual and procedural framework to measure, assess and improve operations strategy efficiency.

1.3. RESEARCH OBJECTIVES

The performance frontier estimation methodologies are ways of benchmarking, being a powerful tool to recognize the high or acceptable performance and expose the low-performance level, aiming to take corrective actions (Akdeniz et al., 2010). Performance efficiency frontier methodologies allow the examination of performance in operational processes and help organizations to test their assumptions about performance, productivity, and efficiency in operation decisions (Liu et al., 2018). This work seeks to contribute to obtaining a sustainable competitive advantage by manufacturing companies. For this purpose, a process to identify measure, assess, and improve operations performance through the integration of the operations strategy and performance frontier concepts, is suggested. Given the preceding contextualization, the general objective of this work can be outlined:

Propose a framework to improve organizations' operations strategy based on performance efficiency frontier methodologies.

To achieve this general objective, the following specific research objectives are outlined:

RO1) To map the literature related to performance efficiency frontier analysis and operations strategy.

RO2) To propose a conceptual framework to translate the concept of operations strategy into the performance efficiency frontier methodology.

RO3) To propose a procedural framework to measure, asses and improve the operations strategy performance by employing performance efficiency frontier methodology.

RO4) To develop guidelines contemplating the steps for the application of the procedural framework.

The specific research objectives are following detailed and related to the intermediate research questions.

RO1) To map the literature related to performance efficiency frontier and operations strategy.

This specific research objective aims to answer the intermediate question: How is the concept of operations strategy and performance efficiency frontier analysis related? A systematic literature review is developed seeking papers that relate both concepts, and a content analysis enables the identification of how they are together approached.

RO2) To propose a conceptual framework to translate the concept of operations strategy into the performance efficiency frontier methodology.

This specific research objective aims to answer the intermediate question: How to measure the operations strategy using performance efficiency frontier methodologies?

Once the relationship between operations strategy and performance frontier analysis is understood, a conceptual framework can be developed to formalize such a relation. The purpose here is to provide a structure of operations strategy coherent with the requirements for implementing performance frontier methodologies. This structure covers the operations strategy constructs that will be used in a procedural framework, the upcoming objective.

RO3) To propose a procedural framework to measure, asses and improve the operations strategy performance employing performance efficiency frontier methodology.

This research objective focuses on implementing the conceptual framework defined in the previous objective. The procedural framework establishes the steps to perform the frontier analysis and to provide recommendations for the aimed company to be better positioned in the competitive environment. In doing so, this RO deal with two intermediate questions:

How to assess the operations strategy performance employing the performance efficiency frontier concept?

How to improve manufacturing performance based on the enhancement of the operations strategy assertiveness?

RO4) To develop guidelines contemplating the steps for the application of the procedural framework.

This research objective aims to establish the guidelines for implementing the procedural framework. The proposal is to standardize the largest possible number of procedural framework steps to reduce the company's effort to implement the model. This can make it possible to apply the framework more frequently, helping organizations in making timely decision making which is particularly important to deal with emergent strategies. In this way, this RO answers the following intermediate research question:

How to enable companies to timely implement performance efficiency frontier analysis providing agility in decision making?

1.4. CHAPTER STRUCTURE

The chapter structure is summarized in Figure 1.

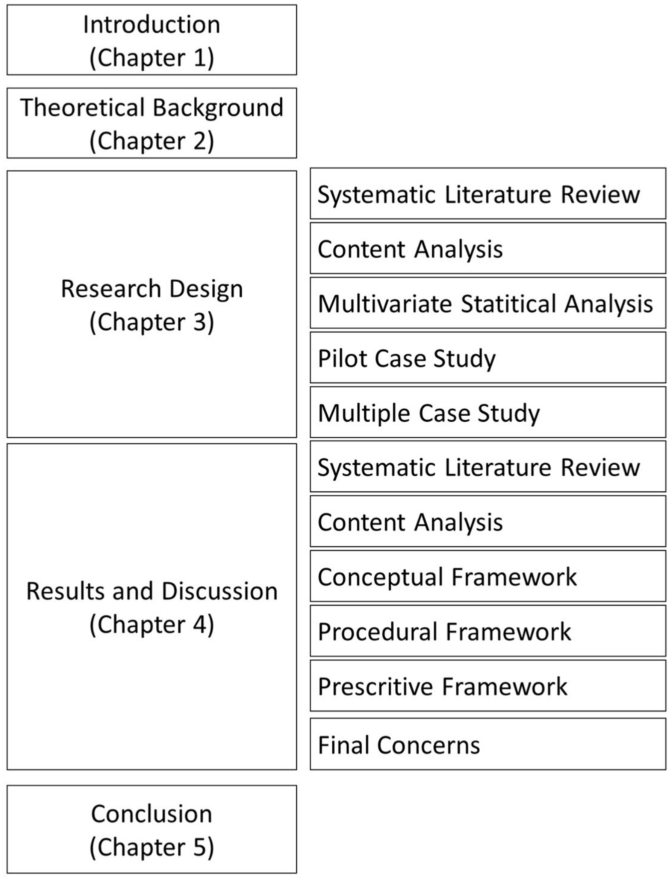


Figure 1 – Chapter structure.

1.5. PUBLICATION PLAN

Table 1 shows the articles presented in this study, including the research phase, the related research objective as well as the intended journal or conference for publication.

Table 1 - Research papers

Phase	Research Objective	Title	Journal/ Conference	Status
Systematic literature review and a bibliometric analysis	RO 1	Efficiency Frontier Identification Based on Operations Strategy - A Retrospective Analysis of Leading Authors	Procedia Manufacturing/ ICPR 2019	Accepted
Content Analysis	RO 1	A Content Analysis on Efficiency Frontier Identification and Operations Strategy	Procedia Manufacturing/ ICPR 2019	Accepted
Conceptual Model	RO 2	Efficiency Frontier Identification on the Context of Operations Strategy – A Study on Representative Constructs and Variables.	Procedia Manufacturing/ ICPR 2019	Accepted
Conceptual Model	RO 2	Defining variables to assess operations strategy efficiency	International Journal of Productivity and Performance Management	Submitted
Procedural Model and Pilot case study	RO 3	Assessing manufacturing performance through operations strategy lenses	International Journal of Production Economics	Submitted
Multiple case studies	RO 3	Implementing a procedure to asses and improve Operations Strategy	Journal of Operations Management	Submitted
Prescriptive model – Implementation Guidelines	RO 4	A procedure for assessing and improving operations strategy	Production Planning and Control	Submitted

2. THEORETICAL BACKGROUND

The firm production frontier specifies the maximum performance that can be achieved by a given set of inputs (Farrel,1957). The frontier methods imply the performance through an efficiency score, which is calculated as the distance from the organization to the best practice frontier. The efficiency frontier is estimated through the observation of inputs and outputs of each organization (Chen et al., 2015). Farrel (1957) defines the distance between the production frontier and real production as technical inefficiency. In this sense, technical efficiency is understood as the organizational ability in obtaining the maximum results by a set of inputs. The frontier analysis methods are approached as a means of defining and measuring firm-specific capabilities. This chapter approaches the main concepts regarding performance efficiency frontier and operations strategy.

2.1. OPERATIONS STRATEGY

In 1969, Skinner's seminal work disseminated the concept of manufacturing strategy by proposing a framework that emphasizes the need to consider the production function in the development of the corporate strategy.

Since then, the importance of the operations function is growing. Not just because the operations function is large and, in most businesses, represents the majority of its assets and its people, but because the operations function gives the ability to compete by providing the ability to respond to customers and by developing the capabilities that will keep it ahead of its competitors in the future (Slack and Lewis, 2018).

Operations strategy is the total pattern of decisions that develop the long-term capabilities of any operation and their contribution to the overall strategy, through reconciliation of market requirements and operation resources (Slack and Lewis, 2018). The operations strategy defines how manufacturing will support the achievement of business objectives by providing structural items (buildings, plant, equipment, etc.) and infrastructural ones (control policies, organizational structure, etc.) to ensure effectively (Platts and Gregory, 1990). To Brown et al. (2005) operations strategy is about all activities from basic inputs into completed products and services for the client.

The traditional model of manufacturing strategy distinguishes between content and process (Leong et al., 1990; Acur et al., 2003). The ‘process’ of operations strategy is the procedures that are, or can be, used to formulate operations strategy. It determines how an operation pursues the reconciliation between its market requirements and operations resources in practice (Slack and Lewis, 2018). To Leong et al. (1990), the process refers to the implementation, development, and use of the manufacturing strategy. Slack and Lewis (2018) define four stages: formulation, implementation, monitoring, and control.

The ‘content’ of operations strategy is the building block from which any operations strategy will be formed (Slack and Lewis, 2018). The content covers the decision areas of the competitive dimensions (Leong et al., 1990), as demonstrated in Figure 2.

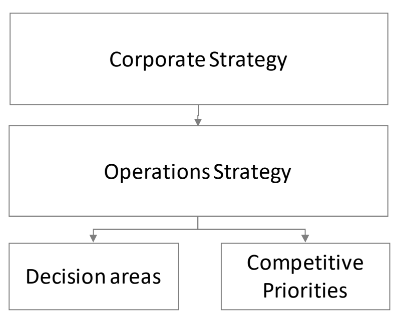


Figure 2 - Operations strategy
Source - Adapted from Leong et al. (1990)

Identifying the decision areas allows the organization to relate its daily decisions to the position of its competitive strategy. Besides, it provides a tool for diagnosing the historical pattern in decisions related to the organization's competitive performance and provides a level of detail that can be used as a guide for future decisions (Wheelwright and Bowen, 1996).

Skinner (1969) proposed that key choices in the manufacturing strategy area consist of plant and equipment, production planning and control, workforce, product development and engineering, and organization and management. The areas addressed by Hayes and Wheelwright (1985) are capacity, facilities, equipment and process technology, vertical integration, suppliers, new products, human resources, quality, and systems.

For competitive priorities, there are several approaches to define the most important competitive dimensions. The five most approached performance objectives are quality, cost, dependability, flexibility, and speed. These five generic performance objectives have meaning for all types of operations and are related to satisfying customer requirements (Slack and Lewis, 2018).

The organizations must recognize the performance criteria to which they compete, and then develop such an objective inside its operations. However, it is important to observe that even if a performance objective has little value externally in terms of helping the company to achieve its desired market position, the operation may still value high performance in that objective because of the internal benefits it brings Slack and Lewis (2018).

The competitive priorities are segregated into qualifying, order-winning, and less important criteria. The order-winning criteria are those in which the company must seek to outperform its competitors to win customers. The qualifying criteria are those in which the organization must achieve the minimum level of performance accepted by the market to qualify to compete in it. Having a higher level of performance in the qualifying objectives does not contribute to the increase of its competitive power. Lastly, the least important criteria are those on which the customer is not based to make his purchasing decision (Corrêa and Corrêa, 2004).

Based on such a definition, the importance and performance matrix proposed by Slack et al. (2018) allows the recognition of the relative importance of each of the manufacturing performance objectives according to the clients' priorities, which should be the manufacturing priorities. The matrix allows the evaluation of the actual performance achieved by the production function by comparing the performance of the organization with that of the competition. Therefore, it becomes possible to recognize the gaps between what is important to the operation and what performance is being achieved by classifying it into four zones, as can be seen in

Figure 3. Identifying this gap guides the choice and implementation of improvement plans.

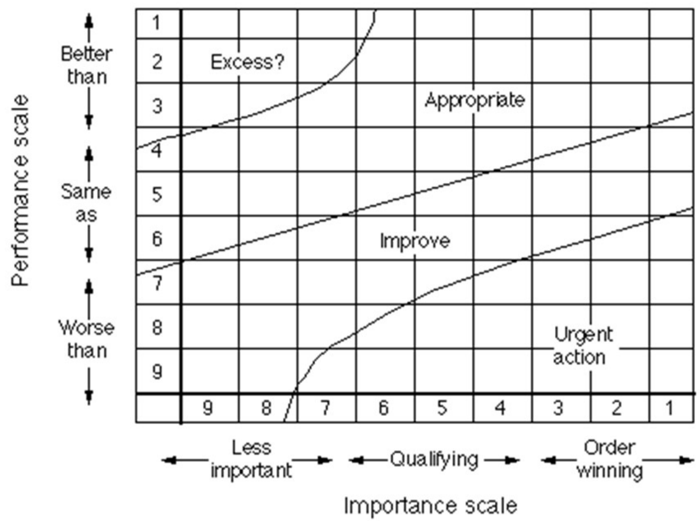


Figure 3 - Importance and performance matrix
Source - Slack et al. (2018)

In the appropriate zone, the performance objectives considered as satisfactory are classified. The improvement zone covers the relevant improvement objectives but does not represent urgent cases. The urgent action zone, however, reveals the objectives that must be improved quickly, because its performance is less than expected, due to the importance attributed by the clients. The excess zone may represent that you are achieving better performance than the customer requires and recognizes (Slack et al., 2018).

Analyze the competitive position for each competitive criterion is of primary importance since there are commonly tradeoffs between performance objectives. In other words, improvement in one performance criterion can be achieved only by sacrificing the performance of another.

However, there are two visions of trade-offs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others (Slack et al., 2018, Kathuria et al., 2018; Amoako-Gyampah and Meredith, 2007; Sarmiento, et al., 2018). Some authors defend the cumulative capabilities model, where it is possible to compete on multiple capabilities, simultaneously, being the extensively used, currently (Nand et al., 2014; Narasimhan and Schoenherr, 2013; Singh et al., 2014). Most companies, at one time or another, will adopt both approaches (Nand et al., 2013; Wu et al., 2012). This is best illustrated by the concept of "performance efficient frontier" in production performance. The performance frontier is defined in the operations management literature as the maximum performance that can be achieved by a manufacturing unit given a set of operating choices. In operations management literature, the performance frontier concept is also under the names of production function or trade-off curve (Schmenner and Swink, 1998).

Slack et al. (2018) illustrate the idea by mean of an example of figure 4, which shows the performance of a set of same sector companies in terms of their efficiency in cost and portfolio variety. It is assumed that all operations would ideally like to be skilled at offering a very wide variety and at the same time having very high levels of cost-efficiency. However, increasing the complexity that a wide variety of product or service offers brings, generally, reduces the ability of the operation to operate efficiently. On the other hand, one way to improve cost efficiency is to severely limit the variety to be offered to customers.

The figure shows that companies A, B, C, and D have chosen a different balance between variety and cost-efficiency. But none is dominated by any other, in the sense that any operation necessarily has "superior" performance. However, operation X has lower performance because operation A can offer a greater variety at the same level of efficiency in cost, and operation C offers the same variety, but with better efficiency in cost. The convex line in which operations A, B, C, and D meet is known as the "efficient frontier". They may choose to position themselves differently (presumably because of different market strategies), but they cannot be criticized for being inefficient.

Yet, any of these operations that sit on the efficient frontier may come to believe that the balance they have chosen between variety and cost efficiency is inappropriate. In these circumstances, they may choose to reposition themselves at some point along the efficient frontier.

Companies located at the performance efficiency frontier that aim to improve the effectiveness of their operations should seek to overcome the trade-off that is implicit in the efficiency frontier curve. For instance, in Figure 4, suppose that operation B wants to simultaneously improve variety and cost efficiency by moving to position B1. It may be able to do this, but only if it adopts improvements in operations that expand the efficient frontier.

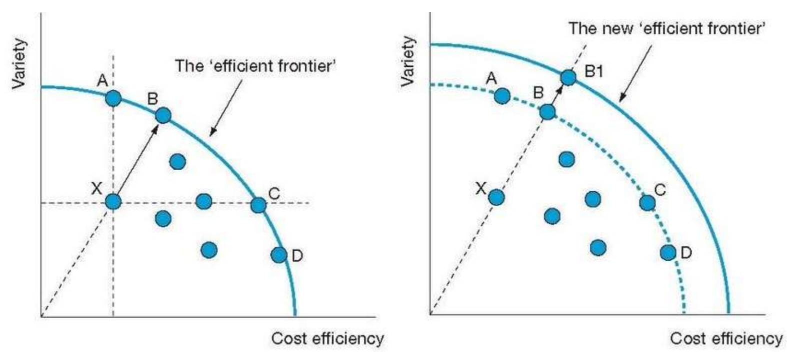


Figure 4 - Efficiency frontier

Source - Slack et al. (2018)

The operations strategy addresses what needs to be done to overcome current and future challenges posed by the competitive environment and encompass the long-term development of operations resources and processes to them to sustain competitive advantage. Thus, the operations strategy consists of reconciling two types of pressure. One derives from market requirements and another from the intrinsic characteristics of operations resources, see Figure 5.

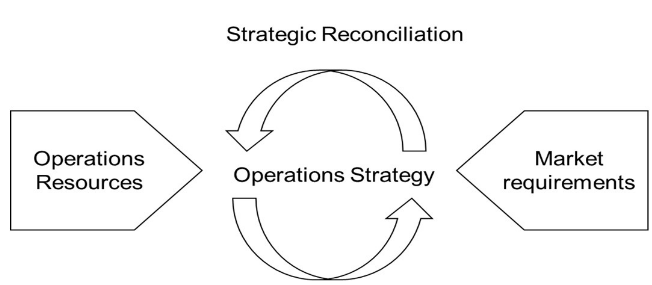


Figure 5 - Operations strategy

Source - Slack and Lewis (2002)

The operations strategy addresses what must be done to overcome the current and future challenges imposed by the competitive environment, as well as covering the long-term development of operations resources and processes, seeking to provide a competitive advantage. In this way, the operations strategy consists of the reconciliation of two types of pressure. One derives from the requirements of the market and another, from the intrinsic characteristics of the operations resources.

The operations strategy may have a market perspective or a resource perspective (Hill and Hill, 2018). Market perspective is where an understanding of the market is developed, and the translation of its needs is used in the development of the operations strategy (Slack and Lewis, 2002). While the resource perspective, where new strategic options emerge naturally because of the resources of the organization (Wernerfelt, 1984). The firm's internal resources and its external market power are fundamentally intertwined (Hill and Hill, 2017; Makhija, 2003). To Nand et al. (2013) organizations need to better identify, establish and combine their capabilities in response to the internal and external contingencies.

2.1.1. Resource-based view

The resource-based view (RBV) concept defends that the sustainable competitive advantage of a firm is heavily influenced by the dynamics of how the firm's resources are acquired and managed (Moingeon et al., 1998). To Soosay et al. (2016) in the RBV perspective, the company should focus on managing internal resources and markets where these resources can be explored. Hitt et al. (2016) defend that there is still space to explore resource-based theory in operations management research.

The resource-based view concept was proposed by Wernerfelt (1984). The resource-based approach is to explore the potential of existing resources and capabilities to enter or create new markets or outperforming current competitors. The RBV concept advocate that competitive advantage is determined by unique, valuable, and non-imitable firm resources (Barney, 1991; Peteraf, 1993, Prahalad and Hamel, 1990).

In 1991, the seminal work of Barney (1991) represented an important milestone for the resource-based view theory when distinguished between different types of resources as important potential drivers of the performance of firms. To the author firm’s resources must have value, rareness, imperfect imitability, and imperfect substitutability to become a source of sustained competitive advantage.

Teece et al. (1997) proposed the concept of dynamic capabilities, the company's ability to integrate, built, and reconfigure internal and external competences to address the dynamic environments. Peters et al. (2019) emphasize the dynamic capabilities importance in the conditions of market turbulence. To Biesenthal et al. (2019) the dynamic capabilities interfere in the operational capabilities at different organizational levels. Mills et al. (2003) have explored the concept of competences architecture and provide a relationship between organizational resources, capabilities, and competences.

Vastag (2000) illustrates the Schmenner and Swink (1998) framework of performance frontier in the RBV perspective. To the author, the operating frontiers of organizations represent unique, valuable and resource rarely to a given firm, which is difficult to replicate.

2.1.2. Market-based view

The Market-based view has its foundation of Porter studies and suggests that it enhance the market position if the source for competitive advantage (Caves and Porter, 1977; Porter, 1979).

At the market-based view (MBV) approach, companies proactively identify where market advantage could be gained by outperforming the current norms on the relevant market drivers and then allocating resources to this end (Hill and Hill, 2018). To Soosay et al. (2016) MBV has the strategic plan defined from an evaluation of the market trends and its potential evolution.

To Hult et al. (2004), market orientation is related to concern for markets which should be part of the organizational culture. Translating market intelligence into action is part of a bigger planning and decision-making process that affects even internal changes. Companies with a market orientation are likely to develop and adapt products, services, and processes that to meet continuously the market needs.

The concept of competitive priorities can translate customer demands into manufacturing objectives, enabling the MBV approach. The concept of competitive priorities considered to the development of this research is next described.

2.1.2.1. Competitive priorities

Competitive priorities are defined as the aspects of operations performance that satisfies market requirements and therefore the operation is expected to pursue (Slack and Lewis, 2018). They are referred to in this dissertation as ‘competitive priorities’, ‘performance criteria’, ‘performance dimensions’, and ‘competitive criteria’. Beyond the traditional competitive priorities (quality, cost, speed, dependability, and flexibility), other criteria have been recently approached by the literature due to the current dynamic context.

Innovativeness is a competitive priority with the rising importance since it is widely accepted that innovation contributes to the opening of new markets or expand existing ones (Hult et al., 2004; Pallas et al., 2013), which is of primary importance in the environment of ascending competition. Innovation is also recognized as a new competitive priority to compete in global markets (Laosirihongthong et al., 2014; Hult at al., 2004; Bouranta and Psomas, 2016; Miltenburg, 2008).

Reliability is approached as a criterion detached from quality from some authors. For example, Narkhede (2017) indicates that is is an important approach mainly for the USA, Europe, Japan, and India, being explored by various authors on manufacturing practices.

Wang (2019) and Díaz-Garrido et al. (2011) included environmental as a recent concert, bring this priority together with the classical competitive priorities. Vivares-Vergara et al. (2016) also bring environmental protection as a competitive priority in their study related to human resources management. Environmental performance is part of the sustainability definition which demonstrates as being an important competitive dimension nowadays (Gavronski, 2012). Sustainability encompasses three pillars, environmental, social, and economic (Elkington, 1997).

Cost

According to Lotfi and Saghiri (2018), it is widely accepted that the firm’s operations need to be cost-efficient. Narkhede (2017) reveals cost as the most important competitive criterion among the manufacturing industry's competitive criteria. The lower the cost of producing their products and services, the lower can be the price to their customers (Slack and Lewis, 2018). It can be the total cost and the ability to optimize the utilization of manufacturing resources (Sansone et al., 2017). To Slack and Lewis (2018) cost is any financial input to the operation that allows it to produce its goods and services, which can be segregated into three categories:

(1) Operating expenditure – the amount of money needed to fund the ongoing production of products and services. It includes expenditure on labor, materials, rent, energy, etc.

(2) Capital expenditure – the amount of money needed to fund the acquisition of the ‘facilities’ to produce its goods and services (e.g., land, buildings, machinery, vehicles, etc.)

(3) Working capital – the amount of money needed to fund the time difference between regular outflows and inflows of cash. In most operations, payments must be made on the various types of operating expenses that are necessary to produce goods and services before payment can be obtained from customers.

Lotfi and Saghiri (2018) state that agile is a suitable strategy for responsiveness. The authors also indicate that resilience leads to better performance in terms of cost. Resilience is about the capability to deal with unexpected events.

Dependability

According to Sansone et al. (2016), dependability is the ability to provide reliable delivery by meeting schedules or keeping promises. Slack and Lewis (2018) consider dependability as the fulfillment of delivery promises.

Dependability = due delivery time - actual delivery time.

When delivery is on time, the equation should equal zero. Positive means it is early, and negative means it is late. Some authors refer to dependability as speed reliability (Choudhari et al. 2010; Größler and Grübner, 2006).

A way of improving dependability is merely by quoting long delivery times. But ones have to consider that both objectives are linked and important to clients (Slack and Lewis, 2018).

Long delivery times are often a result of the slow internal response, high work-in-progress, and large amounts of non-value-added time. All of these can cause confusion, complexity, and lack of control, which are the root causes of poor dependability. Good dependability can often be helped by fast throughput (Slack and Lewis, 2018).

Lotfi and Saghiri (2018) prove that resilience also leads to better performance in terms of delivery.

Environmental Factors

Environmental factors include the items of the production process and products that interfere in the protection of the environment (Díaz-Garrido et al., 2011). Wang (2019) indicates that the public concern about the natural environment is rapidly growing and this fact transforms the competitive landscape. To Famiyeh et al. (2018), the investments in environmental practices must not be faced as a cost to avoid but rather an opportunity to create value for firms and their customers. The authors develop their contribution indicating that environmental management practices have a positive effect on competitive operational performance. Wang (2019) also reinforces the impact of green culture on the performance advantage.

Flexibility

To Asadi et al. (2017) the competitive advantage is related to flexibility due to the need to cope with ever-changing market demands. Anand and Ward (2004) reinforce that the unpredictability or the volatility aspects of environmental dynamism requires for manufacturing flexibility strategies. In this sense, flexibility can contribute to the improvement of profit rate and sales growth.

Flexibility is understood as having the capacity to adapt the operation whenever necessary and with enough speed, either by changes in demand or by needs of the production process (Slack and Brandon-Jones, 2018). For example, be able to produce a bigger variety of products or services. An operation that moves quickly, smoothly and cheaply from doing one thing to doing another can be considered more flexible than others that can achieve the same change at greater cost and/or organizational disruption (Slack and Lewis, 2018).

Flexibility can be evaluated by range flexibility (how much the operation can be changed) and response flexibility (how fast the operation can be changed). Response flexibility is related to the incurred cost of change (Slack and Lewis, 2018).

The types of flexibility that would contribute to its competitiveness are (Slack and Lewis, 2018).

(1) Product or service flexibility – the ability to introduce and produce different products or services or to modify existing ones;

(2) mix flexibility – the ability to change the variety of products or services being produced by the operation;

(3) volume flexibility – the ability to change the level of the volume to be processed;

(4) delivery flexibility – the ability to change planned or assumed delivery dates.

Asadi et al. (2015) identified the main requirements for flexibility, mainly on a reference of the assembly system, which includes adaptable material, supply, versatile workforce, standardized work content, integrated product properties, and strategic planning.

Dey et al. (2019) have identified the following flexibility dimensions: product, volume, new product development, routing, operation, process, expansion, machine, labor, material handling, continuous improvement flexibility, throughput time reduction, ramp-up time reduction, decoupling point, postponement flexibility. According to the authors, however, the required flexibility characteristics depend on the organizational strategic goals. (e.g. mass production or differentiation).

Innovativeness

Innovativeness is defined as the capacity to engaging in innovation, which in turn is related to the introduction of a new process, products and ideas in the organization (Hult et al., 2004). The advent of digital transformation enhances innovation importance in the current scenario (Khin and Ho, 2019; Ferreira et al., 2019; Vial, 2019). It is widely accepted that innovation interferes in the firm's success and competitive advantage Innovation can open new markets or expand existing ones (Hult et al., 2004; Pallas et al., 2013). Rubera and Kirca (2012) promoted a study that indicates that firm innovativeness affects its market and financial position, the two outputs of our study. Cho and Pucik (2005) also prove that innovativeness interferes with market value through growth and profitability. The authors also indicate that innovativeness mediates the relationship between quality and growth. Lin and Tsegn (2016) also approached innovativeness as a competitive priority in their research on sustainable supply chain management under uncertainty.

To Laosirihongthong et al. (2014) there are two major determinants for innovation performance, internal and external factors. The internal factors are related to R&D and technology investment, knowledge and creativity management, organizational structure and culture, and cross-functional teams. The external perspective regards inter-organizational networks and partnerships in innovation, aiming for a shorter development process.

Hult et al. (2004) promote a review of relevant literature on innovativeness and proposed that the key driver is market orientation, learning orientation, and entrepreneurial orientation.

Pallas et al. (2013) indicate that the dimensions that contribute to innovation are strategic focus on innovation, extrinsic motivation system, openness in communication, and management encouragement.

Quality

Quality means that the products and services are ‘fit for purpose’, that is, they do what they are supposed to do. Quality is also about the ‘specification’ of a product or service, usually meaning high specification. Specification quality is also a multidimensional issue, which can be separated into ‘hard’ and ‘soft’ aspects of specification quality. Hard dimensions are those concerned with the evident and largely objective aspects of the product or service. Soft dimensions are associated with aspects of personal interaction between customers and the product or (more usually) service (Slack and Lewis, 2018). To Sansone et al. (2017), the competitive criterion includes performance, conformance, and durability.

From the hard and soft quality dimension of Slack and Lewis (2018), examples of factors of influence are presented in Table 2.

Table 2 - Quality dimensions

Examples of ‘hard’ dimensions of specification quality	Examples of ‘soft’ dimensions of specification quality
- Features	- Helpfulness
- Performance	- Attentiveness
- Reliability	- Communication
- Aesthetics	- Friendliness
- Security/safety	- Courtesy
- Integrity	

Source - Slack and Lewis (2018)

Speed

Speed is related to the lead time to delivery (Slack and Lewis, 2018). Vázquez-Bustelo et al. (2007) indicate that in tempestuous environments, the joined use of agile manufacturing practices promotes competitive manufacturing strength, leading to better performance, reinforcing the UpToDate importance of speed. Speed indicates the time between the beginning of an operations process and its end. It is an elapsed time that can be considered from the time when the customer requests a product or service, to the time when the customer receives it. Or it may be used internally in operation, considering the time between when material enters an operation and when it leaves fully processed (Slack and Lewis, 2018).

Considering the broader definition, that considers the time when the customer requests a product or service, to the time when the customer receives it, the speed is influenced by (Slack and Lewis, 2018):

- actual time to ‘produce the product or service’ (the ‘core’ processing time);
- time to clarify a customer’s exact needs (e.g., designing a product or service);
- ‘queuing’ times before operations resources become available;
- time to deliver, transport, and/or install the product or service.

To Vázquez-Bustelo et al. (2007), agile manufacturing is a global production model that is influenced by:

- highly trained, motivated and empowered employees working in teams;
- the use of advanced design, manufacturing and administrative technologies;
- internal integration of operations, with suppliers and customers;
- concurrent engineering; and
- knowledge management.

Reliability

Reliability, together with durability, often are presented as a single competitive priority (Sansone et al. 2016). In this research, reliability is defined as the quality of being trustworthy or performing consistently well (Slack et al., 1997), therefore, it is a dimension of quality (Bulak and Turkyilmaz, 2014; Vivares et al., 2018). Reliability is related to customer service (Choudhari et al. 2010). Serviceability advent may contribute to enhance the company's focus on reliability performance (Szász and Seer, 2018; Benedettini et al., 2015; Baines et al., 2013).

Slack and Lewis (2018) indicate the internal and external consequences of having excellent performance on the performance dimensions, in Table 3.

Table 3 - Internal and external benefits of excelling at each traditional performance objective

Performance objective	Internal Benefits (consequences)	External Benefits (consequences)
Quality	- Error-free processes - Less disruption and complexity - More internal reliability - Lower processing cost	- High-specification products and - services - Error-free products and services - Reliable products and services
Speed	- Faster throughput times - Less queuing and/or inventory - Lower overheads - Lower processing cost	- Short delivery/queuing times - Fast response to requests
Dependability	- Higher confidence in the operation - Fewer contingencies needed - More internal stability - Lower processing cost	- On-time delivery/arrival of products - and services - Knowledge of delivery times
Flexibility	- Better response to unpredicted events - Better response to a variety of activities - Lower processing cost	- Frequent new products and services - Wide range of products and services - Volume adjustments - Delivery adjustments
Cost	- Productive processes - Higher margins	- Low prices

Source - Slack and Lewis (2018)

Table 4 summarizes the competitive criteria definition.

Table 4 - Competitive criteria definition

Competitive Priority	Definition	Authors
Cost	Offer products at lower costs than competitors or be cost-efficient. Costs are about the ability to optimize the utilization of manufacturing resources.	Slack and Lewis (2018), Lotfi and Saghiri (2018), Sansone et al. (2017).
Dependability	Fulfill the promises of deadline delivery. Besides on-time delivery, it also Includes delivery date estimation and communication.	Slack and Lewis (2018), Yusuf et al. (2014).
Environmental Factors	Items of the production process and product that interfere in the protection of the environment	Vivares-Vergara et al. (2016); Díaz-Garrido et al. (2011).
Flexibility	Have the capacity to adapt operation whenever needed and with the necessary speed, either due to changes in demand or production process needs. Cope with ever-changing market demands.	Slack and Lewis (2018), Slack and Brandon-Jones (2018), Asadi et al. (2017), Dey et al. (2019).
Innovativeness	Capacity in engaging in innovation, which in its turn is related to the introduction of new processes, products or ideas in the organization	Hult et al. (2004), Laosirihongthong et al. (2014).
Quality	Offer products according to design specifications.	Slack and Lewis (2018), Bernroider et al. (2014), Chen and Tan (2013).
Reliability	Quality of being trustworthy or of performing consistently well. Reliability is approached as a criterion detached from quality by some authors.	Slack et al. (1997). Narkhede (2017).
Speed	Deliver to customers faster than competitors	Slack and Lewis (2018), Vázquez-Bustelo et al. (2007).

This definition delimitates the scope of the competitive dimensions approached in this research work.

2.2. PERFORMANCE EFFICIENCY FRONTIER ANALYSIS

A Production function (production frontier) is a function that gives the maximum possible values of the output factors from the value of input factors (Khezrimotlagh and Chen, 2018). The firm production frontier discussion was first approached by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency” in the Journal of Royal Statistical Society.

The performance frontier is estimated based on the observation population of the company’s inputs and outputs (or a representative sample) (Chen et al., 2015). It is a ratio between outputs and inputs. Results smaller than 1 represent inefficient firms (Bulak et al., 2016). The frontier estimation includes the constraint that it is not possible to exceed the result of 1 (Anjos, 2005; Duarte and Macedo, 2003).

$$Efficiency = \frac{Value\ of\ outputs}{value\ of\ inputs}$$

The efficiency concept has two components: technical efficiency and allocative ones. Technical efficiency is about the managerial ability to transform input into outputs while allocative efficiency regards to the managerial ability to define the optimal proportion of inputs and outputs considering the market price of them (Wilhelm, 2013). Technical efficiency is, therefore, the organization's ability to obtain the maximum result from a set of inputs (Farrel, 1957). The distance between the production frontier and current production performance is called technical inefficiency. When a point is technically inefficient, at least one of its input or output factors can be improved to reach the production function to be technically efficient (Khezrimotlagh and Chen, 2018).

Some methods for calculating technical efficiency are proposed in the literature. The best known are the SFA (Stochastic Frontier Analysis) and DEA. To Bogetoft and Otto (2011) DEA has its origin in the research stream of management science, mathematical programming, and operations research while the SFA has an economics – and econometrics- oriented background.

Some of the approaches are parametric, and some are non-parametric. The parametric models undertake a particular a priori specification on the production process (i.e., how the inputs are converted into outputs). A benefit of this model is its well-established statistical inference making it easy to include environmental characteristics. The non-parametric ones let the data speak for themselves, bringing more flexibility. For this reason, non-parametric models are very attractive.

Both approaches can be deterministic or stochastic. The classification of deterministic or stochastic models depends on the causes of the difference in the performance of the productive units (decision make units -DMU). The model is deterministic when the performance differences of production units concerning the frontier are attributed entirely to technical inefficiency (Duarte and Macedo, 2003). In the deterministic data, all observations belong to the production set (Emrouznejad and Witte, 2010).

There are also two other sources of observed production variation to the frontier, the 'exogenous factors', which are outside the control of the organization, such as weather conditions or interruption in the inputs supply; and 'managerial capacity', which are placed under the control of the organization. This distinction, in turn, is provided by the stochastic production frontier model. The limitations of the deterministic frontier approach appear when factors outside the control of the organization are counted as inefficiency (Duarte and Macedo, 2003). The stochastic data allow for noise in the data and capture the noise by an error term, even if it is difficult to distinguish the noise from inefficiency (Emrouznejad and Witte, 2010).

Agner et al. (1977) developed the concept of the frontier production function, making clear the idea of deterministic and stochastic models. They suggest a new approach to the estimation of the frontier production function, specifying the error term as being made up of two components, one normal and the other from a one-sided distribution.

The timeline presented in Table 5 introduces the main events in the performance efficiency frontier analysis theory development.

Table 5 - Timeline of performance efficiency frontier analysis theory development

Date	Occurrence
1928	Cobb and Douglas proposed the function, which took the authors' name, that uses the nonlinear specification of the production function and is widely applied in economics to represent the relationship of a given output and the various inputs.
1951	Koopmans has adapted the Pareto rule in the work “Activity analysis of production allocation” and established as a principle of productive efficiency that an organization is not efficient unless the enhancement of one product requires the decreases of the level of other output, or the enhancement of, at least, one input (Ferreira and Gomes, 2009; Daraio and Simar, 2007).
1951	Debreu has introduced the first radial measure of the technical efficiency which allows the maximum equiproporcional reduction of all the inputs, or the maximum equiproporcional expansion of all the products. An index equal to unity indicates that the producer is technically efficient; an index less than unity indicates technical inefficiency and the consumption of all inputs can be reduced in the same proportion (Ferreira and Gomes, 2009).
1953	Malmquist index proposition to evaluate the efficiency change over time (Malmquist. 9153).
1957	Firm production frontier concept firs discussion with the Farrel publication of the seminal paper "The measurement of productive efficiency” in the Journal of Royal Statistical Society, extending the Debreu (1951) work and introducing the concept of allocative efficiency.
1963	Dantzig contributed to the basic linear programming computational algorithm (the simplex method) used to solve frontier problems (Daraio and Simar, 2007).
1977	Suggest a new approach to the estimation of the frontier production function, approaching stochastic definition (Aigner, Lovell and Schmidt, 1977).
1978	The proposition of the original DEA constant return to scale (CRS) model, by Charnes, Cooper, and Rhodes (CCR) to measure radially technical efficiency indices.
1984	DEA extension to variable return to scale (VRS), by Banker, Charnes, and Copper (BCC).
1984	Deprins, Simar and Tulkens (DST) proposed the “Free Disposal Hull (FDH)” estimator, that maintains free disposability while relaxes convexity, unlikely DEA that relies on the convexity assumption.
1989	Banker et al. (1989) proposed the Golden Rule to determine the minimum number of required DMUs according to the quantity of input and output variables.
1993	Andersen and Petersen (1993) proposed the concept of “Super efficiency” that aims to rank efficient DMUs.

2.2.1. DEA (data envelopment analysis)

For various years, since the Debreu (1951) definition of technical efficiency, the problem of measuring technical efficiency was the determination of the optimal level of a company. In 1978, Charnes, Cooper, and Rhodes proposed a methodology to measure radially technical efficiency indices, the Data envelopment analysis (Wilhelm, 2013).

The Data Envelopment Analysis (DEA) is a non-parametric method proposed by Charnes, Cooper, and Rhodes (1978) which the original DEA constant return to scale (CRS) model, later extended by Banker, Charnes, and Copper (1984) to variable return to scale (VRS). In DEA, the performance frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to evaluate the performance of organizations based on multiple metrics (Bulak et al., 2014). It can be considered a technique that aims to compare the operational performance of production units. It is a measure of relative efficiency, as it considers the data presented, therefore, determining an absolute efficiency value, outside the group of analysis, is not possible (Anjos, 2005; Golany and Roll, 1989). The objective of the methodology is building a performance frontier, whose points represent efficient combinations of inputs to produce a given product, from a set of production possibilities that covers all possible combinations of products, using a given set of inputs. The model allows the conversion of several inputs and outputs into a single efficiency measure, enabling verifying which units are efficient and which are not (Anjos, 2005).

The traditional DEA methods, CCR (Charnes, Cooper and Rhodes, 1978) and BCC (Banker, Charnes and Copper, 1984) use clear and specific data for inputs and outputs. One difference between the models is in connection with productive components; the CCR model is used to calculate the scale efficiency indicator and the BCC model the technical efficiency (Anjos, 2005). Both aim to measure the efficiency of a decision-making unit (DMU). Any group of entities that receives the same inputs and produces the same outputs can be designated as DMU (e.g., a firm). For Golany and Roll (1989) the analysis group must include a homogeneous set of DMUs, wherein comparison makes sense. A homogeneous group is one where: the units under consideration perform the same tasks and have similar objectives; all the units are under the same set of 'market conditions' and the inputs and outputs are the same.

The comparison generates a ranking of a given DMU in terms of its relative efficiency, where the DMU with the highest ranking is considered relatively efficient. DEA envelops the data set with the frontier of the most efficient DMU. In DEA, a group of DMUs is used to assess each other with each DMU having some degree of managerial autonomy in decision-making (Liu et al., 2018).

The objectives for applying DEA can vary, Golany and Roll (1989) include:

- Identification of the sources of relative inefficiency in the input-output dimensions;
- Raking the DMU by their efficiency outcomes;
- Evaluating the effectiveness of the program that is out of company control, as well as differentiating between program inefficiency and managerial ones;
- Creating a quantitative basis for allocating resources;

Figure 6 illustrates the DEA frontier by considering a simple case with two input variables and one output of six companies (DMU), labeled A-F.

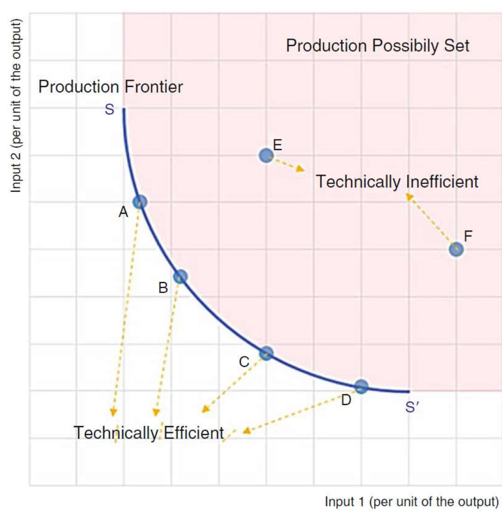


Figure 6 - DEA frontier

Source - Khezrimotlagh and Chen (2018)

The curve SS' is called the production function, and the above area of the curve is related to the production possibility set. The firms A-D which lie on the production function are technically efficient, and the firms E and F are technically inefficient.

DMUs that achieve 100 percent efficiency are considered efficient, while DMUs with efficiency scores below 100 percent are inefficient (Chen et al., 2015). A score less than 100 percent (to input orientation models) means that a linear combination of other units from the sample could produce the same vector of outputs using a smaller vector of inputs (Esmaeilzadeh and Hadi-Vencheh, 2015).

The DEA does not require assumptions of the weights of the production function and probability distributions for technical inefficiency. The DEA model calculates weights for each company employing an optimization procedure, which compares the companies of the sample. DEA does not specify the fundamental production functional form to measure the production efficiency of a DMU. Hence DEA is a versatile tool (Chang et al., 2015). The linear programming use reduces the risk of model errors; however, because it is a deterministic approach, it can be sensitive to outliers (Chen et al., 2015).

2.2.1.1. DEA models

DEA models are divided into two groups, input-oriented and output-oriented. An input-oriented DEA model shows a proportional relation of inputs while consuming the current level of outputs for an inefficient organization to become efficient. So, an input-oriented model is concerned with the minimization of the use of inputs for achieving a given level of outputs.

On the other hand, an output-oriented DEA model determines how efficient a firm is consuming its current level inputs to convert into output to become efficient. Output oriented approach seeks the maximization of the level of outputs per given set of inputs — Figure 7 illustrates both situations. To the input-oriented model, the graphical representation in a two-dimensional space is done through a piecewise convex linear isoquant with the origin, for which the space of production possibilities is indicated by the letter B. To the output-oriented model, the graphical representation is done through a concave isoquant to the origin, for which the space of production possibilities is indicated by letter A (Ferreira and Gomes, 2009).

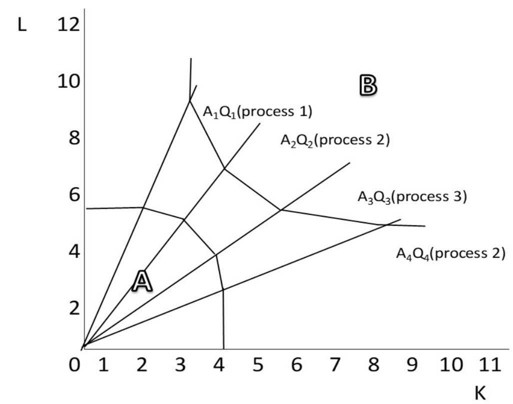


Figure 7 - Regions of possible solutions to the input-oriented model (B) and output-oriented model (A)
Source - Ferreira and Gomes (2009)

In some cases, DMUs may have a two-stage structure, in which the first stage uses inputs to generate outputs that become the inputs of the second stage and the second stage then utilizes these first-stage outputs to produce its outputs (Hemmati et al., 2016).

The CCR model considers constant returns to scale, while the BCC one is suitable to variable returns to scale. Constant returns to scale (CRS) are verified when higher inputs quantities cause a proportional increase of the products, assuming that the units operate at an optimal scale, with maximization of the inputs uses. In the situation of variable returns to scale (VRS), firms may have increasing or decreasing returns. Increasing returns occur in the situation of greater quantities of inputs cause more than the proportional increase of the outputs; decreasing returns is when the increase of inputs causes the fall of outputs. Also, non-increasing (NIRS) results occur when the inputs are increasing results in a less than the proportional output increasing; and, finally, non-decreasing returns (NDRS) to scale are observed in units that, by increasing inputs, production remains constant (Anjos, 2005).

When the model is CRS, the efficiency index to the input-oriented model is the same as the index of the output-oriented model. In contrast, to VRS the efficiency obtained from an input-oriented model is different from the one obtained from an output-oriented model (Ferreira and Gomes, 2009).

2.2.1.1. Mathematical representation

The proposal of Charnes et al. (1987) is that the efficiency of any DMU is obtained as the maximum of the ratio of weighted output to weighted inputs, subjected to the condition that similar ratios of every DMU be less or equal to unity. They are applied to constant return to scale (CRS). The model determines the technical efficiency utilizing the optimization of the ratio between the weighted sum of outputs and the weighted sum of inputs. Consider initially a DMUo (objective) whose products can be represented as y_{mo} (where m is the output) and x_{ro} (where r is the input); both are the known variables. The decision variables are the weights, μ_j(j = 1, 2, …, m) and v_i (i = 1, 2, …, r), and they are still unknown and should be determinate for each DMUo. The technical efficiency for each DMUo is as follows (Ferreira and Gomes, 2009).

$$\text{Maximize } E_{fo} = \frac{\sum_{j=1}^{m} \mu_j y_{jo}}{\sum_{i=1}^{r} v_j\, x_{io}} = \frac{\mu_1 y_{1o} + \mu_2 y_{2o} + \ldots + \mu_m y_{mo}}{v_1 x_{1o} + v_2 x_{2o} + \ldots + v_r x_{ro}} \qquad (1)$$

Subject to:

$$E_{fo} = \frac{\sum_{j=1}^{m} \mu_j y_{jk}}{\sum_{i=1}^{r} v_j\, x_{ik}} = \frac{\mu_1 y_{1k} + \mu_2 y_{2k} + \ldots + \mu_m y_{mk}}{v_1 x_{1k} + v_2 x_{2k} + \ldots + v_r x_{rk}} \leq 1, \forall \text{ k, or k} = 1,2,\ldots, n$$

$\mu_1, \mu_2, \ldots, \mu_m \geq 0; \forall j$, or j = 1,2,…,m

$v_1, v_2, \ldots, v_r \geq 0; \forall i$, or i = 1,2,…,r

Being

Virtual output = $\mu_1 y_{1o} + \mu_2 y_{2o} + \ldots + \mu_m y_{mo}$

Virtual input = $v_1 x_{1o} + v_2 x_{2o} + \ldots + v_r x_{ro}$

The objective is to determine the weights μ_j and v_i to maximize the ratio between outputs and inputs. The constraint means that the ratio of virtual outputs and virtual inputs can be at most 1 for each DMU. By definition, y_{jk} are x_{ik} higher than 0. The above model is an extended nonlinear programming formulation of an ordinary fractional programming problem. The following equation presents the reduction to linear programming forms for the CRS model (constant return to scale).

Linear CRS programming form	
CRS Input-oriented model	CRS output-oriented model
Maximize Efo = $\sum_{j=1}^{m} \mu_j y_{jo}$ (2) (μ, v) Subject to: $\sum_{i=1}^{r} v_i\, x_{io} = 1$ $\sum_{j=1}^{m} \mu_j y_{jk} - \sum_{i=1}^{r} v_i\, x_{ik} \leq 0, \forall$ k μ_j, $v_j \geq 0$; $\forall$i,j	Minimize Efo = $\sum_{i=1}^{r} v_i x_{io}$ (3) (μ, v) Subject to: $\sum_{j=1}^{s} \mu_j\, y_{jo} = 1$ $\sum_{j=1}^{s} \mu_j y_{jk} - \sum_{i=1}^{r} v_i\, x_{ik} \leq 0, \forall$ k μ_j, $v_j \geq 0$; $\forall$i,j
Decision variables: weights μ_j and v_i	

The dual form of linear programming, denominated envelopment model, is now presented. In the output-oriented model, the technical efficiency, represented by the Greek letter Φ, is bigger than the unity.

<table>
<tr><td colspan="2">The dual form of linear programming (envelopment model)</td></tr>
<tr><td>CRS Input oriented model

Minimize θ (4)

θ is the scale whose value is the technical efficiency of DMUo, such that $0 \leq \theta \leq 1$
(θ, λ)

Subject to:
$\theta \, x_{io} - \sum_{k=1}^{n} \lambda_k \, x_{ik} \geq 0$; ∀i i=1,2,…,r
$\sum_{k=1}^{n} \lambda_k \, y_{mk}$ -y_{mo} ≥ 0; ∀m m=1,2,…,s
$\lambda_k \geq 0$; ∀k k=1,2,…,n</td><td>CRS output-oriented model

Maximize Φ (5)

scale whose value is the technical efficiency of DMUo, such that $1 \leq \theta \leq 0$
(Φ, λ)

Subject to:
$x_{io} - \sum_{k=1}^{n} x_k \, \lambda_{ik} \geq 0$; ∀i i=1,2,…,r
$\sum_{k=1}^{n} y_{mk} \; \lambda_k$-$\Phi y_{mo}$ ≥ 0; ∀m m=1,2,…,s
$\lambda_k \geq 0$; ∀k k=1,2,…,n</td></tr>
<tr><td colspan="2">Where: y (outputs), x (inputs), λ (weighs)
Decision variables: θ, Φ (scalar) and λ (weighs)</td></tr>
</table>

Where: y (outputs), x (inputs), λ (weighs). At the first model, the decision variables are the weights μ_j and v_i, while at the envelopment model, the decision variables are the θ and the weighs $\lambda_{k.}$ Therefore, at the envelopment model, the efficiency measure is represented by the scalar θ and Φ.

At the model (2) and (4), the focus is on identifying the technical inefficiency of the DMU, through the proportional reduction of the use of inputs, this is, input-oriented models. However, one can also obtain efficiency measures, known as output-oriented models, with proportional increases of outputs. Such measures allow the identification of the maximum output that can be generated by a fixed quantity of inputs and are presented at the models (3) and (5).

The BCC model generalizes the CCR model, considering technologies with constant, increasing, and decreasing return to scale (Ferreira and Gomes, 2009). For the BCC model, the formulation is as follows.

<table>
<tr><th colspan="2">Linear VRS programming form</th></tr>
<tr><td>VRS Input-oriented model</td><td>VRS output-oriented model</td></tr>
<tr><td>Maximize Efo = $\sum_{j=1}^{m} \mu_j y_{jo}$ (2)

(μ, v)

Subject to:

$\sum_{i=1}^{r} v_i \, x_{io} = 1$

$\sum_{j=1}^{m} \mu_j y_{jk} - \sum_{i=1}^{r} v_i \, x_{ik} \leq 0, \forall$ k

μ_j, vj ≥ 0; ∀i,j</td><td>Minimize Efo = $\sum_{i=1}^{r} v_i x_{io}$ (7)

(μ, v)

Subject to:

$\sum_{j=1}^{s} \mu_j \, y_{jo} = 1$

$\sum_{j=1}^{s} \mu_j y_{jk} - \sum_{i=1}^{r} v_i \, x_{ik} \leq 0, \forall$ k

μ_j, v_j≥ 0; ∀i,j</td></tr>
</table>

For CRS: To add, $\mu_0 = 0$ For VRS: To add, μ_0 livre For NIRS (non-increasing return to scale): To add, $\mu_0 \leq 0$ For NDRS (non-decreasing return to scale): To add, $\mu_0 \geq 0$	For CRS: To add, $\mu_0 = 0$ For VRS: To add, μ_0 livre For NIRS: To add, $\mu_0 \geq 0$ For NDRS: To add, $\mu_0 \leq 0$
Decision variables: weights μ_j and v_i	

In the dual form, the models are as follows.

The dual form of VRS linear programming (envelopment model)	
VRS Input-oriented model	VRS output-oriented model
Minimize θ (8) (θ, λ) Subject to: $\theta\, x_{io} - \sum_{k=1}^{n} \lambda_k\, x_{ik} \geq 0; \forall i \quad i=1,2,\ldots,r$ $\sum_{k=1}^{n} \lambda_k\, y_{mk} - y_{mo} \geq 0; \forall m \quad m=1,2,\ldots,s$	Maximize Φ (9) (Φ, λ) Subject to: $x_{io} - \sum_{k=1}^{n} x_k\, \lambda_{ik} \geq 0; \forall i \quad i=1,2,\ldots,r$ $\sum_{k=1}^{n} y_{mk}\, \lambda_k - \Phi y_{mo} \geq 0; \forall m \quad m=1,2,\ldots,s$

For CRS: To add, $\lambda_k \geq 0$; ∀k k=1,2,…,n For VRS: To add, $\sum_{k=1}^{n} y_k = 1$ For NIRS: To add, $\sum_{k=1}^{n} y_k \leq 1$ For NDRS: To add, $\sum_{k=1}^{n} y_k \geq 1$	For CRS: To add, $\lambda_k \geq 0$; ∀k k=1,2,…,n For VRS: To add, $\sum_{k=1}^{n} y_k = 1$ For NIRS: To add, $\sum_{k=1}^{n} y_k \leq 1$ For NDRS: To add, $\sum_{k=1}^{n} y_k \geq 1$

The added restriction is related to the rule of the technical efficiency score in the CRS model is smaller or equal to the VRS efficiency score (Ferreira and Gomes, 2009).

Regarding the sample size (DMUs), when the sample is representative, the bigger the size, the better the investigation of the inputs and outputs relation. If the sample size is small, there is a tendency to allocating a huge quantity of DMU as efficiently (Anjos, 2005). A rule is that the quantity of DMU should be at least two times higher than the considered number of input and output. In this way, the larger the number of inputs and outputs, the bigger the requested sample size. However, ones should also consider that the larger the sample size (or number of DMU analyzed), the bigger the heterogeneity, which increases the possibility of the result being affected by external factors (Golany and Roll, 1989). Another rule is the Golden Rule of Banker et. al (1989) which states that the number of DMUs should be at least three times the sum of the number of involved variables (inputs and outputs) or at least equal to the product of the number of input variables and the number of output variables, adopting the criterion associated to the greater number of required DMUs. Khezrimotlagh et al. (2018) proposed a new framework to significantly decrease the required DEA calculation time in comparison with the existing methodologies when a large set of DMUs (e.g., 20,000 DMUs or more).

Golany and Roll (1989) indicate the existence of three main steps for applying as efficiency study based on DEA: (i) definition and selection of DMU to enter analysis, (ii) determination of input and output factors which are relevant and suitable for assessing the relative efficiency of the selected DMU, and (iii) application of the DEA model.

Selecting the variables (inputs and outputs) of interest may generate a large number of factors, which would result in a large portion of the differences among DMUs and a large number of DMU in the efficiency score. Ones recommend introducing initially a limited number of carefully variables, seeking to accentuate the basic difference among DMU (Golany and Roll, 1989).

2.2.1.2. Implementation Steps

Emrouznejad and Witte (2010) propose the COOPER-framework which guides non-parametric analysis, encompassing a systematic checklist with the required phases to assess performance. The aim is to make efficiency analysis less costly, more reliable, more repeatable, more manageable, and faster. The framework includes a step-by-step to evaluate large and unexplored datasets, as the effort of implementing DEA increases significantly when the available data are growing. The suggested framework (see Figure 8) contains six phases which have numerous feedback loops, they are (1) Concepts and objectives, (2) On structuring data, (3) Operational models, (4) a Performance comparison model, (5) Evaluation, and (6) Results and deployment.

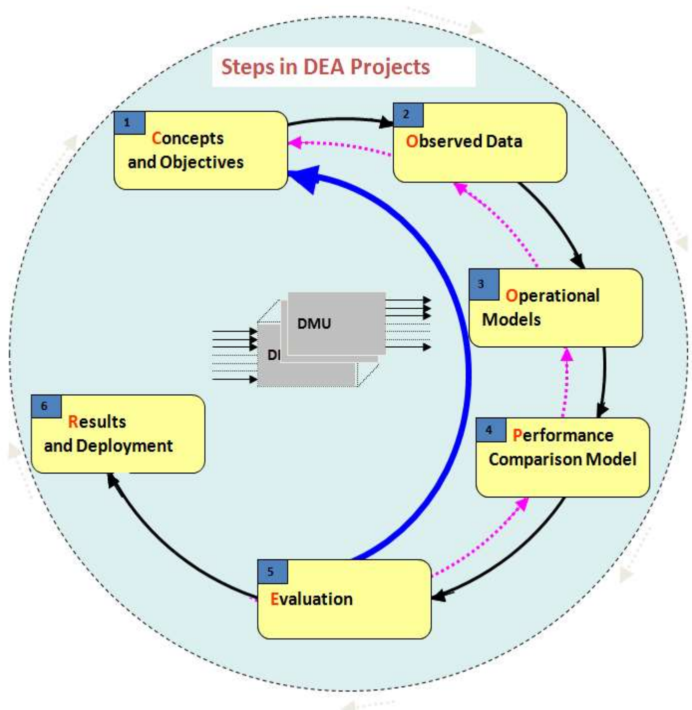


Figure 8 - Cooper framework
Source - Emrouznejad and Witte (2010)

2.2.1.3. Super-Efficiency

Some authors indicate that a weak point of the DEA model is that a considerable number of units typically are characterized as efficient. Therefore, DEA does not allow for a ranking of the efficient units themselves (Esmaeilzadeh and Hadi-Vencheh, 2015; Kao, 2017; Bogetoft and Otto, 2011). The model proposed by Anderson and Petersen (1993) presents the most popular concept to rank DMU, called super-efficiency, helping them to discriminate among frontier firms.

The term “supper-efficiency” is related to the DEA model in which the firms can obtain an efficiency score higher than one. In cases when the standard DEA model results in a score of 1 for various companies, the use of supper-efficiency can be useful to differentiate these frontier firms, as they obtain supper-efficiency scores that are greater than one. The efficiency score of the non-efficient firms does not change from the efficiency to the supper-efficiency model, as they were not part of the original DEA frontier (Coelli et al., 2005).

The Andersen and Petersen (1993) proposal is to eliminate the focal DMU to construct the frontier from the remaining (n-1) DMUs to calculate the supper-efficiency index. The data of the DMU analyzed is removed from the model constraints. This method enables the ranking to efficient DMUs, only. Since the DMUs being eliminated are the efficient ones, they will fall outside of the region encompassed by the new frontier, and their efficiency scores calculated based on this frontier will be greater than one. That is why this efficiency index is called “super-efficiency” (Kao, 2017; Ferreira and Gomes, 2009). Indeed, using “supper-efficiency” is interesting to differentiate among the firms with traditional efficiency scores of 1 (Bogetoft and Otto, 2011).

Assuming a VRS input orientation model, Figure 9 presents the graphic demonstration of the supper-efficiency score from firm C, which is 0C”/ 0C. An index for 1.2, for example, means that the DMU is better than the one with a smaller score because the former is further ahead of its peers.

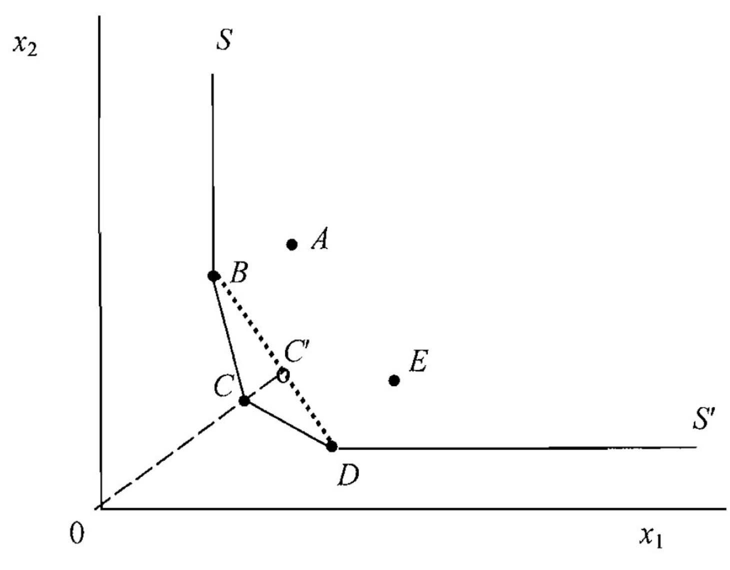


Figure 9 - Supper-efficiency graphic demonstration
Source - Coelli et al. (2005)

The mathematical representation of the supper-efficiency dual VRS model, with input orientation, is as follows.

Minimize θ (10)

(θ, λ)

Subjected to:

$$\theta\, x_{io} - \sum_{k=1,k\neq 0}^{n} \lambda_k\, x_{ik} \geq 0;\ \forall i \qquad i=1,2,\ldots,r$$

$$\sum_{k=1,k\neq 0}^{n} \lambda_k\, y_{mk} - y_{mo} \geq 0;\ \forall m \qquad m=1,2,\ldots,s$$

$$\sum_{k=1,k\neq 0}^{n} y_k = 1$$

2.2.2. SFA (Stochastic frontier analysis)

Unlike the DEA, the SFA (Stochastic Frontier Analysis) is a parametric approach, in which the form of the production function assumes to be known or is estimated statistically (Coelliet al., 2005). The SFA is motivated by the idea that organizations can be inefficient for a variety of reasons, and some of them may not be the organization's responsibility. Deviations that are not common to all organizations are called the stochastic term (Trigo, 2010; Chen et al., 2015).

An illustration of the SFA model is presented, which considers the same companies of the illustration developed for the DEA. The frontier shown in Figure 10 is based on the maximum likelihood estimation of β parameters, and the observations, therefore, deviate from the frontier because of the combined effect of sample noise and inefficiency. The constant term β_0 indicates that there is a minimum input required for any output to be produced (Chen et al., 2015).

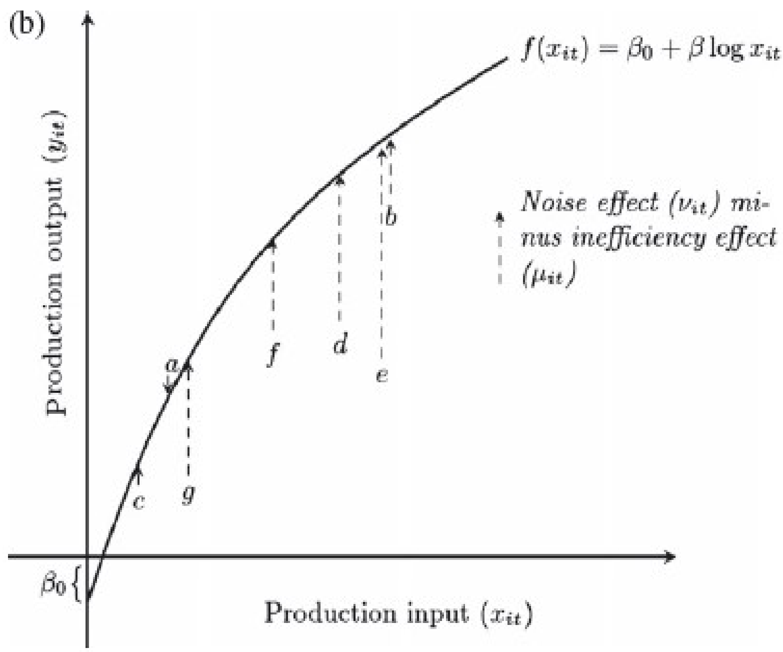


Figure 10 - SFA frontier
Source - Chen et al. (2015)

For the firm 'a' the effect of inefficiency and noise is positive, and consequently, 'a' is above the frontier *f* (Xit). For the other companies, the effect is negative, and thus, these are below the frontier, representing inefficiency *i* over a period of time t.

3. RESEARCH DESIGN

The research design of this study aims at the development of a procedural model to identify the performance efficiency frontier within the operations strategy context. Once the performance frontier estimation methodologies are proposed by literature, this study focus on the use of such methodologies, as well as multivariate statistical analysis, in the context of operations strategy. The output is a conceptual, procedural, and prescriptive framework to define operations strategy performance frontier. The following phases of the research design better explore this context.

Figure 11 presents the inputs required for each research technique, as well as the output provided for each one. The steps are presented sequentially, in the order in which they are executed.

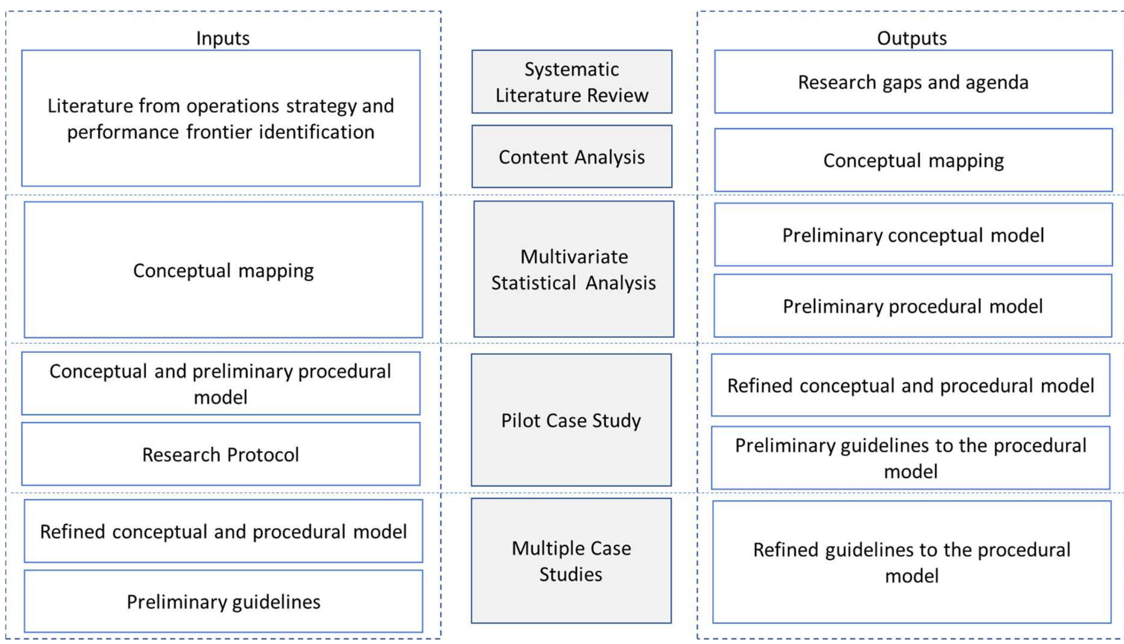


Figure 11 - Research design

Table 6 relates the research techniques with the specific research objectives, as well as the chapter structure.

Table 6 - Research Design

RO	RO Description	Deployment	ResearchTechnique	Results	Chapter
RO 01	To map the literature related to performance efficiency frontier analysis and Operations Strategy	To define the research proposal, making clear the novelty issue	Systematic Literature Review	Research Gaps Defined	1
		To provide a conceptual basis for the research development	Simple Literature Review	Basic Concepts understanding	2
		To position the research theme face to the existing literature	Systematic Literature Review	Research agenda defined	4
			Content Analysis	Conceptual Mapping	4
RO 02	To propose a conceptual framework to translate the concept of operations strategy into the performance efficiency frontier methodology	To develop a preliminary conceptual framework	Multivariate Statistical Analysis of HPM data	Conceptual framework	4
		Empirically implement the conceptual framework	Pilot Case Study	Refined conceptual framework	4
RO 03	To propose a procedural framework to asses and improve the operations strategy performance, employing performance efficiency frontier methodology.	To develop a preliminary procedural framework	Multivariate Statistical Analysis/ Frontier analysis methodology	procedural framework	4
		To develop a test protocol for the empirical test	Pilot Case Study	Research Protocol	3
		Empirically implement a procedural framework		Refined procedural framework	4
RO 04	To develop guidelines contemplating the steps for the application of the procedural framework.	To define implementation steps based on an empirical implementation	Pilot Case Study	Implementation Guidelines	4
		To expand the application of the refined procedural framework, including the guidelines to the application of the procedural framework	Multiple case study	Refined Implementation Guidelines	4

Each phase and the respective steps of the research design are described in the next sections.

3.1. DESCRIPTION OF THE RESEARCH APPROACH

The overall method for this research is promoted with four main methods: Systematic literature review and content analysis, multivariate statistical analysis, pilot case study, and multiple case studies. The research methods used in this study are detailed in the next subsections.

3.1.1. Systematic literature review

The Systematic Literature Review uses an adaptation of the Knowledge Development Process - Constructivist (ProKnow-C) instrument developed by the Multicriteria Decision Support Laboratory - LabMCDA - Federal University of Santa Catarina, Brazil, developed by Ensslin et al (2010).

The ProKnow-C process helps in accumulating knowledge of the intended research area. The process identifies a bibliographic portfolio aligned with the subject of study, weight the most relevant articles, authors, and journals in the bibliographic portfolio, evaluate the portfolio's articles according to the researcher's preferences; and highlight the strengths of those articles and how they can be improved (Rosa et al., 2012).

The process consists of four steps: (a) selection of a portfolio of articles on the research theme; (b) portfolio bibliometric analysis; (c) systemic analysis; and, (d) definition of the research question and research objective (Ensslin et al., 2013).

The systematic literature review of this research study approaches an adaptation of ProKnow-C, which process is presented in Figure 12.

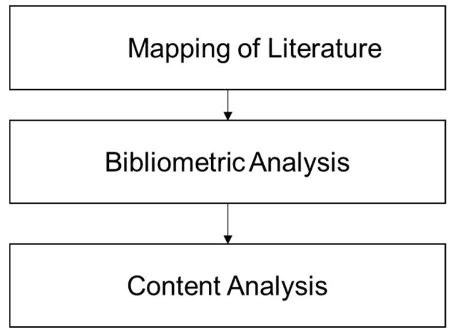


Figure 12 - Systematic literature review main steps

The mapping of literature seeks to identify a bibliographic portfolio coherent with the theme of operations strategy and performance frontier analysis, simultaneously. To do so, the approach follows several filter steps, including different procedures to papers with and without scientific recognition.

The bibliometric analysis was developed on two fronts: a bibliometric analysis of the bibliographic portfolio and bibliometric analysis of bibliographic portfolio references. The aim at this stage is to identify a research pattern, including the main research area authors, keywords and journals.

Then the content analysis explores the content of bibliographic portfolio papers seeking to identify the main research contribution as well as the research gaps. At this stage, a bibliographic review with the portfolio papers is done generating the research agenda mapping. By the end, a conceptual mapping is developed to relate the concept of operations strategy and performance efficiency frontier analysis.

The SLR can be depicted according to the following steps:

1) Mapping of Literature
   a) Relevant papers selection
   b) Search term definition
   c) Database and search criteria definition
   d) Preliminary search results analysis
   e) Search term refinement (inclusion of new keywords)

f) Portfolio papers selection

g) Paper scientific recognition identification

h) Bibliographic portfolio definition

2) Bibliometric analysis (Portfolio papers and References of portfolio papers)

a) Bibliographic Portfolio Bibliometric Analysis

b) Bibliometric Analysis of the Bibliographic Portfolio References

3) Content analysis

a) Portfolio papers bibliographic review

b) Research agenda mapping

c) Conceptual Mapping

This research proposes a framework to identify the superior frontier of performance within the context of operations strategy. This theme can be segregated in the following axes:

Technical axes - Border Analysis

Context axes - Manufacturing Strategy

3.1.2. Multivariate statistical analysis

This study deals with multiple performance measures and therefore, is based on multivariate statistical analysis to ground decisions over the proposed framework. Multivariate data analysis refers to techniques that simultaneously evaluate multiple measures regarding objects under investigation. For being classified as multivariate, the variables must be random and interrelated in such a way that their effects cannot be significantly interpreted separately (Hair et al., 2009).

The multivariate techniques encompass a range of research aims. There are techniques already established in the literature as well as emergent ones. This study is grappling with the following concepts and techniques: (i) descriptive statistics, (ii) Cronbach's alpha and (iii) principal component analysis.

(i) Descriptive statistics

(ii) Cronbach's alpha is a reliability measure for data (Cronbach, 1951; Hair et al., 2009).

(iii) Principal component analysis can be used to analyze the interrelation within a huge number of variables and explain such variables in terms of their inherent common dimensions, or factors. Therefore, PCA allows the original variables to be expressed as linear combinations of the factors and is useful when the objective is to reduce the number of variables (Rencher and Christensen, 2012; Hair et al., 2009).

The multivariate statistical analysis is performed to establish the conceptual and the procedural, as well as the implementation guidelines. All of them are tested on a third-part data repository within the mentioned techniques.

3.1.2.1. HPM Secondary Data

The selection of variables was based on High-Performance Manufacturing data (HPM) round 4. The HPM project seeks to identify the practices adopted by high-performance organizations and applies a survey with companies in 15 countries. The survey includes 1597 questions in 12 categories: Accounting, Downstream Supply Chain Management, Environmental Affairs, Human Resources Management, Information System Management, Plant Management, Process Engineering, Product Development, Production Control, Quality Management, Supervision, and Upstream Supply Chain Management. The database includes information from 330 companies. They are answered by different people inside these organizations. The HPM includes machinery manufacturers, vehicle component manufacturers, and electronics manufacturers companies with at least 100 employees (Flynn al., 1997). Round 4 was held between 2013 and 2018 (Park and Paiva, 2018, Phan et al. 2019).

The availability of reliable data is an important assumption for this research, as the processual model will further require benchmarking data. The competitive environment to promote the benchmarking is also based on the HPM dataset.

3.1.3. Case study

A case study is defined as a research strategy to empirically investigate a phenomenon in real contexts. Questions of type “how” may be explored in the case of studies, as they have an explicative character. Also, the case study is preferred during the examination of contemporary events, but when relevant behaviors cannot be manipulated (Yin, 2015). A case study typically uses multiple methods, qualitative or quantitative, and tools to collect data from through direct observation (Meredith, 1998).

The case study approach is conducted in this research to perform the frameworks for performance efficiency frontier identification. Once the models were defined using multivariate statistical analysis, a specific context application is promoted using case study methodology. This is primarily of importance to guarantee the proposed frameworks replication and therefore the model vigor. According to Voss et al. (2002), case research has been a powerful research method in operations management, especially in the development of new theory. Figure 13 - Case study protocol 13 shows the steps of the protocol applied to the case studies.

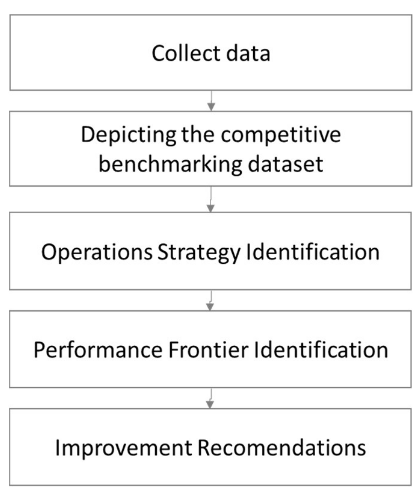


Figure 13 - Case study protocol

Step 1) Mapping the organization Operations Strategy. Before the beginning of the proposed procedural framework implementation, it is necessary to understand the operations strategy of the organization that will be studied, whether the operations strategy is formal or not.

Step 2) Collect data of the organization. The next step is to figure out the performance of the organization that will be the focus of the case study. The performance should be identified in each of the input and output variables defined at the proposed conceptual model. The data collected in this step can be promoted through the analysis of available documents and records or a questionnaire application. Both sorts of data may be applied because the data availability can vary from one organization to another.

Step 3) Execute the procedural framework. At this stage, the procedural framework is performed using the organization data collected at step 02, as well as the third-part database (HPM). The aim is to position the company studied at a case study face to its competitors.

Step 4) Provide a critical analysis regarding the company operations strategy and market positioning. Once the market behavior is understood, in terms of importance given to each input to achieve the desired output, it is possible to figure out whether the operations strategy of the studied company is successful or not.

Step 5) Provide a recommendation about strategies to enhance competitive organization position. The last stage is to draw suggestions for acting at key inputs to improve outputs and consequently competitive position. This stage development is supported by Focus Group methodology.

4. RESULTS AND DISCUSSION

This topic presents the results of the research steps described in chapter 3. Results are presented to each intended research objective of this thesis: Systematic literature review, conceptual framework, procedural framework, and prescriptive model.

4.1. SYSTEMATIC LITERATURE REVIEW

The systematic literature review can be summarized in the steps of mapping literature, bibliometric analysis, and content analysis. Each of the steps will be detailed in the next subsections.

4.1.1. Mapping of literature

The main literature mapping steps are in Figure 14.

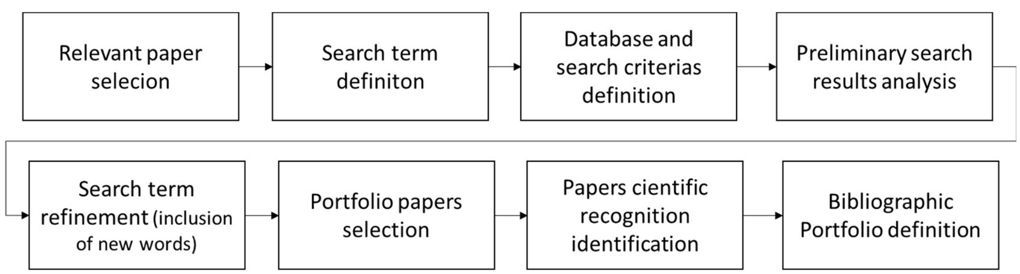


Figure 14 - Mapping of main literature steps

All the steps' results are briefly described.

Relevant paper selection

Seven paper related to operations strategy and performance efficiency frontier identification is randomly selected to identify keywords and to define the search term. This set of articles is a denominated *control group.*

Search term definition

According to the research objective, two study axes were defined; they are described in Table 7.

Table 7 - Study axes

Axes	Scope
Axes 1	Technical axes that cover the methodology that will be used to carry out the study, which focuses on the identification and analysis of performance frontier
Axes 2	Context axis related to the operations strategy, a concept used as the structuring basis of the work

The reading of the selected works allowed the identification of keywords and search terms for each axis.

Databases and search criteria definition

The defined databases are Scopus and Web of Science. The Web of Science was selected as the main database for testing the search term since it is a more restrictive database. The search criteria assigned in the web of science and Scopus include a period of fewer than 20 years (between the years of 1997 and 2017) and all papers in the English language.

Preliminary search results analysis

A search term was defined considering key-words in each of the axes. The first search term version generated 439 results at Web of Science.

Search term refinement

Based on the previous results, the search term was refined. It was noticed that the term 'capabilit' returns many results that are not aligned with the proposed theme, thus, to generate more precise results, the context of this term was further specified, using 'competitive capabilities' and 'operations capabilities'. The refined search term generated 114 results at Web of Science and 1374 results at Scopus.

Preliminary search results analysis

To validate the proposed search term, it was identified if the previously selected articles, denominated *control group*, were pointed out in the results generated by Scopus and Web of Science. One can notice that paper 01, 03 and 05 were missing in some or both results (see Table 8).

Table 8 - Search term validation results

	ISI JCR impact factor (2 years)	ISI JCR impact factor (5 years)	Scimago JCR impact factor (H Index)		Is it part of the result?	
					Web of Science	Scopus
Paper 01	3.297 (Q1)	3.582	2.505 (Q1)	JAYANTHI, Shekhar; KOCHA, Bart; SINHA, Kingshuk K. Competitive analysis of manufacturing plants: An application to the US processed food industry. European Journal of Operational Research 118 (1999) 217±234.	No	Yes
Paper 02	Not listed		0.436 (Q2)	BULAK, MuhammetEnis; TURKYILMAZ, Ali; Satir, Metin; Shoaib, Muhammad; Shahbaz, Muhammad. Measuring the performance efficiency of Turkish electrical machinery manufacturing SMEs with frontier method. Benchmarking: An International Journal Vol. 23 No. 7, 2016 pp. 2004-2026	Yes	Yes
Paper 03	3.339 (Q1)	4.211	2.191 (Q1)	NAND, Alka Ashwini; SINGH, Prakash J.; POWER, Damien. Testing an integrated model of operations capabilities An empirical study of Australian airlines. International Journal of Operations & Production Management Vol. 33 No. 7, 2013 pp. 887-91	No	No

Table 8 (continuation) - Search term validation results

	ISI JCR impact factor (2 years)	ISI JCR impact factor (5 years)	Scimago JCR impact factor (H Index)		Is it part of the result?	
					Web of Science	Scopus
Paper 04	1.396 (Q3)	2.515	0.613 (Q2)	ABBASI, Mehdi; KAVIANI, Mohamad Amin. Operational efficiency-based ranking framework using uncertain DEA methods an application to the cement industry in Iran. Management Decision. Vol. 54 No. 4, 2016 pp. 902-928	Yes	Yes
Paper 05	1.95 (Q3)	2.549	3.163 (Q1)	JACOBS, Brian W.; KRAUDE, Richard; NARAYANAN, Sriram. Operational Productivity, Corporate Social Performance, Financial Performance, and Risk in Manufacturing Firms. Production and Operations Management. Vol. 25, No. 12, December 2016, pp. 2065–2085	No	Yes
Paper 06	Not listed		0.363 (Q3)	HEMMATI, Maryam; FEIZ, Davood; JALILVAND, Mohammad Reza; KHOLGHI, Iman. Development of fuzzy two-stage DEA model for competitive advantage based on RBV and strategic agility as a dynamic capability. Journal of Modelling in Management Vol. 11 No. 1, 2016 pp. 288-308	Yes	Yes
Paper 07	4.029 (Q1)	4.671	3.674 (Q1)	SAMOILENKO, Sergey; OSEI-BRYSON, kweku-Muata. Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system. Omega 41 (2013) 131–142.	Yes	Yes

Search term refinement

The keyword adherence test reflected the lack of results from the control group's work; thus, new keywords were included. The inclusion of the new words resulted in a new search term.

TS=((“frontier analysis” OR “frontier approach*” OR “efficiency evaluation” OR “technical efficiency” OR “Data Envelopment Analysis” OR “Stochastic Frontier Analysis” OR “Operational Competitiveness Ratings Analysis” OR Coob-Douglas OR estimation NEAR/3 frontier* OR “frontier production function” OR “Operating frontier” OR “performance frontier*”) AND (“operation* strateg*” OR “manufacturing strateg*” OR “competitive priorit*” OR “competitive dimension*” OR “performance criteria*” OR “competitive criteria*” OR “performance dimension*” OR “Decision area*” OR “Resource-Based View” OR “competitive capabilit*” OR “operation* capabilit*”))

This search term generates 126 results at Web of Science. At Scopus, the search term is as follows.

(ALL ("frontier analysis") OR ALL ("frontier approach*") OR ALL ("efficiency evaluation") OR ALL ("technical efficiency") OR ALL ("Data Envelopment Analysis") OR ALL ("Stochastic Frontier Analysis") OR ALL ("Operational Competitiveness Ratings Analysis") OR ALL (coob-douglas) OR ALL (estimation AND near/3 AND frontier*) OR ALL ("frontier production function")) AND (ALL ("operation* strateg*") OR ALL ("manufacturing strateg*") OR ALL ("competitive priorit*") OR ALL ("competitive dimension*") OR ALL ("performance criteria*") OR ALL ("competitive criteria*") OR ALL ("performance dimension*") OR ALL ("performance criteria*") OR ALL ("Decision area*") OR ALL ("Resource-Based View") OR ALL ("competitive capabilit*") OR ALL ("operation* capabilit*")) AND PUBYEAR > 1996 AND (LIMIT-TO (LANGUAGE , "English"))

This search term generates 1385 results at Scopus.

To validate the proposed new search term, the same test was conducted again to identified whether the articles previously selected, called *control group,* were pointed out in the search result. Now all items in the control group were presented in the search term result.

Portfolio papers selection

At this point, some exclusion action was taken to eliminate works. First, works in duplicity were eliminated. EndNote X8 supported this action. At this stage, a result of 1.511 was felled to 1.403. Next, works that are not papers were eliminated as The Proknow-C methodology advocates the selection of scientific articles. In this way, works of other natures books and book chapters have been eliminated, generating then 1.211 papers. The title was them read, and papers with misaligned titles were also eliminated. The results of these exclusion steps are presented in Table 9.

Table 9 - SLR first filtering results

Stage 01: Raw work base	Web of Science: 126 Scopus: 1.385 Total: 1.511
Stage 02: Basis of work without duplicity	1.403 works
Stage 03: Articles base (deletion of non-article)	1.211 papers
Stage 04: Basis of articles without duplicity and with aligned title	426 papers

Papers scientific recognition identification

The next step in selecting the key references for the understanding state of the art in the topic is the filtering of articles according to their scientific recognition. To do this, a spreadsheet in Excel is organized with the list of articles and information of author/date, article title, and journal. In this, the information related to the JCR impact factor from 2016 and the number of citations of each of the articles extracted from the Scopus database is included and organized in descending order. At this stage, an adaptation of the Proknow-C methodology is promoted, which indicates the use of academic google as a source of the number of citations.

The result of the Pareto analysis of the number of citations reflects that 1.41% of articles (6 articles) are responsible for 25.41% of the total number of citations. 156 articles, representing 36.62% of the articles, contributed 90.09% of the total number of citations (see Table 10).

Table 10 - SLR Pareto Analysis results

Number of articles (Cumulative)	Cumulative percentage of the number of articles	Cumulative number of citations
6	1.41%	25.41%
156	36.62%	90.09%
426	100.00%	100.00%

Based on the analysis, it was defined that the articles of the first two groups, 156 articles, are part of those with confirmed scientific recognition. While the remaining 270 articles are those with unconfirmed scientific recognition.

The next step is the evaluation of the papers abstract to verify their adherence to the research theme. To make this phase feasible, there was a selection of the articles that will be submitted to the abstract evaluation. Different procedures were adopted for articles with confirmed scientific recognition and those with unconfirmed scientific recognition.

The abstracts of the 156 papers were analyzed, and it was identified that only 24 papers had the abstract aligned. These authors composed the repository A. The authors of the works that compose the repository A were listed, forming a database of reference authors (see Figure 15).

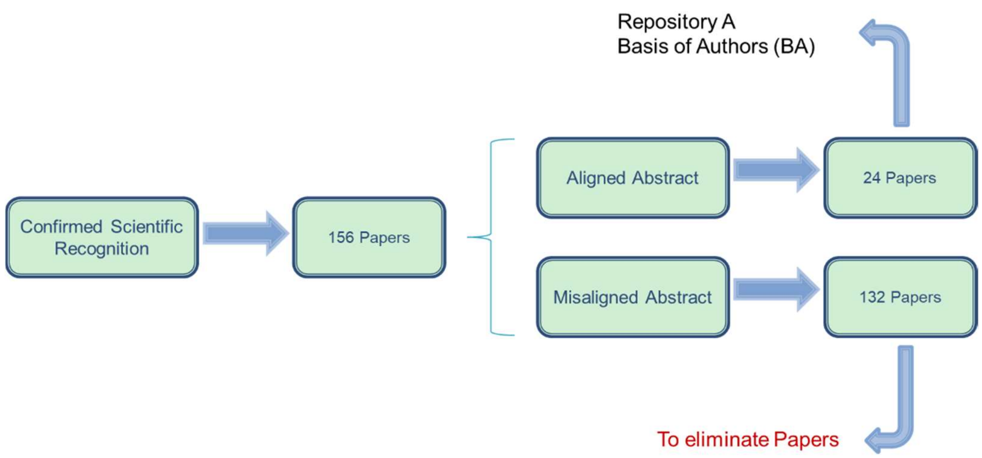


Figure 15 - Paper with confirmed scientific recognition

The papers classified as without scientific recognition (270 papers) were analyzed, taking into account the year of its publication. Recently published articles, with less than 2 years of publication, from 2015 through 2017, had their abstracts analyzed to check adherence to the research topic. This procedure was taken since the recent articles might have a lack of scientific recognition due to the short period in which they are exposed to the academic community.

The papers with more than two years of publication were evaluated about their authors. Those articles developed by the authors that are included in the Basis of

Authors (BA) were selected for the abstract reading, while the works developed by other authors were eliminated from the database. This process is shown in Figure 16.

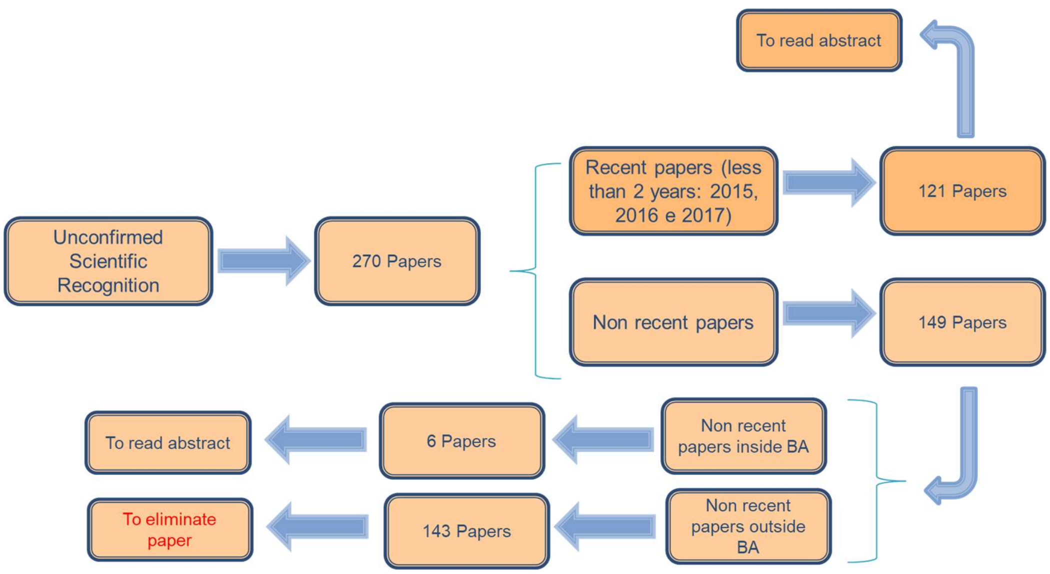


Figure 16 - Process for the paper without scientific recognition

127 articles proceeded to the abstract evaluation stage; that is, they were read. 121 of them were recent papers and 6 were non-recent but authored by someone from the Basis of Authors (BA).

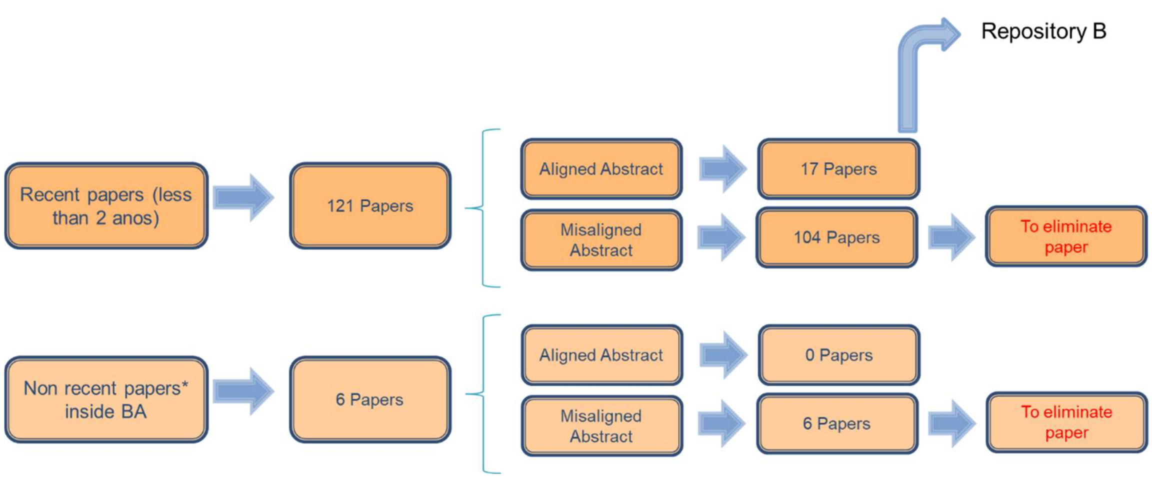


Figure 17 - Results of analysis of papers without scientific recognition confirmed

As a result, at this stage, 17 articles with aligned abstracts were identified, composing the repository B.

Bibliographic portfolio definition

To identify the references which would be included in the bibliographic portfolio, a full analysis of the content of all the remaining articles was promoted. Of the 42 articles with abstract alignment, 24 from Repository A and 17 from Repository B, 37 were available. From this set of articles, 19 papers were aligned to the research theme, which composes the bibliographic portfolio of the research. The whole screening process is summarized in Figure 18.

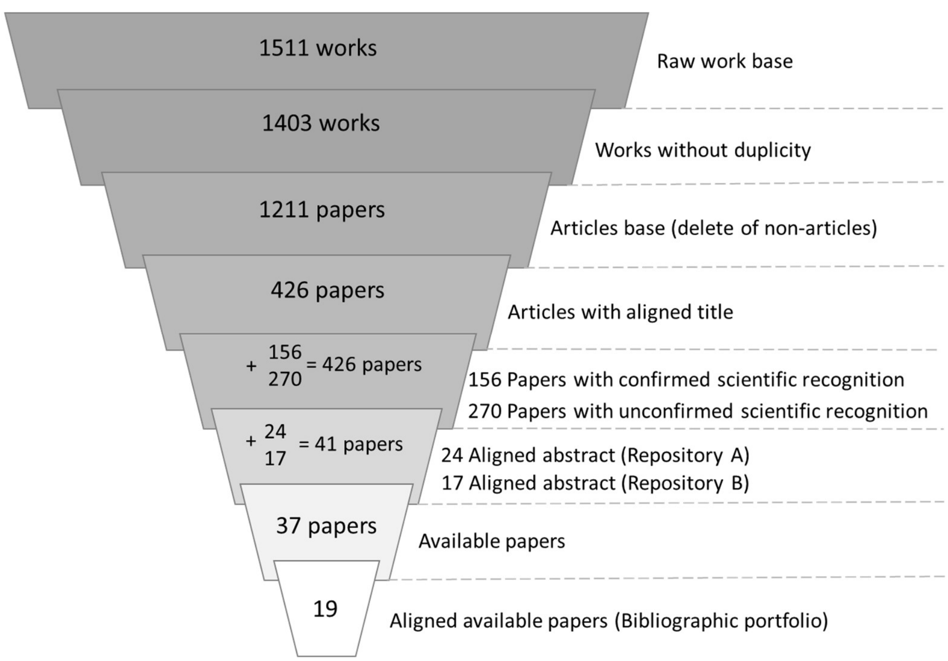


Figure 18 - SLR screening process

Table 11 presents the detail of the references that compose the bibliographic portfolio

Table 11 - Bibliographic portfolio

Authors	Title	Journal	Year
Abbasi, M. and Kaviani, M. A.	Operational efficiency-based ranking framework using uncertain DEA methods An application to the cement industry in Iran	Management Decision	2016
Achillas, C.; Aidonis, D.; Iakovou, E.; Thymianidis, M. and Tzetzis, D.	A methodological framework for the inclusion of modern additive manufacturing into the production portfolio of a focused factory	Journal of Manufacturing Systems	2015
Ahmed, M. U.; Kristal, M. M., and Pagell, M.	Impact of operational and marketing capabilities on firm performance: Evidence from economic growth and downturns	International Journal of Production Economics	2014
Akdeniz, M. B.; Gonzalez-Padron, T. and Calantone, R. J.	An integrated marketing capability benchmarking approach to dealer performance through parametric and nonparametric analyses	Industrial Marketing Management	2010
Bulak, M. E.; Turkyilmaz, A.; Satir, M.; Shoaib, M and Shahbaz, M.	Measuring the performance efficiency of Turkish electrical machinery manufacturing SMEs with frontier method	Benchmarking- an International Journal	2016
Cai, S. H., and Yang, Z. L.	On the relationship between business environment and competitive priorities: The role of performance frontiers	International Journal of Production Economics	2014
Chang, H.; Fernando, G. D. and Tripathy, A.	An Empirical Study of Strategic Positioning and Production Efficiency	Advances in Operations Research	2015
Dutta, S.; Narasimhan, O. and Rajiv, S.	Conceptualizing and measuring capabilities: Methodology and empirical application	Strategic Management Journal	2005
Hemmati, M.; Feiz, D.; Jalilvand, M. R. and Kholghi, I.	Development of fuzzy two-stage DEA model for competitive advantage based on RBV and strategic agility as a dynamic capability	Journal of Modelling in Management	2016
Jacobs, B. W.; Kraude, R. and Narayanan, S.	Operational Productivity, Corporate Social Performance, Financial Performance, and Risk in Manufacturing Firms	Production and Operations Management	2016
Jayanthi, S.; Kocha, B. and Sinha, K. K.	Competitive analysis of manufacturing plants: an application to the US processed food industry	European Journal of Operational Research	1999
Mahmood, I. P.; Zhu, H. and Zajac, E. J.	Where can capabilities come from? network ties and capability acquisition in business groups	Strategic Management Journal	2011
Miller, S. R., and Ross, A. D.	An exploratory analysis of resource utilization across organizational units - Understanding the resource-based view	International Journal of Operations & Production Management	2003
Nath, P.; Nachiappan, S. and Ramanathan, R.	The impact of marketing capability, operations capability and diversification strategy on performance: A resource-based view	Industrial Marketing Management	2010
Nevo, S.; Wade, M. R. and Cook, W. D.	An examination of the trade-off between internal and external IT capabilities	Journal of Strategic Information Systems	2007
Ramanathan, R.; Ramanathan, U. and Zhang, Y.	Linking operations, marketing, and environmental capabilities and diversification to hotel performance: A data envelopment analysis approach	International Journal of Production Economics	2016
Samoilenko, S. and Osei-Bryson, K. M.	Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system	Omega-International Journal of Management Science	2013
Seol, H.; Lee, S. and Kim, C.	Identifying new business areas using patent information: A DEA and text mining approach	Expert Systems with Applications	2011
Yu, W.; Ramanathan, R. and Nath, P.	The impacts of marketing and operations capabilities on financial performance in the UK retail sector: A resource-based perspective	Industrial Marketing Management	2014

4.1.2. Bibliometric analysis

The bibliometric analysis was developed on two fronts: a bibliometric analysis of the bibliographic portfolio and bibliometric analysis of bibliographic portfolio references.

4.1.2.1. Bibliographic Portfolio Bibliometric Analysis

In this stage, the information on the 19 bibliographic portfolio papers was collected. To do this, a spreadsheet in Excel is organized. First, an identification of the key words was made and from this, a diagram of affinities aiming to identify the subjects most approached by the authors. Table 12 indicates the name assigned to the topic in the first column, and in the second, the keywords, as quoted by the authors while the following chart shows the topics most approached, as a proposed grouping.

Table 12 - Bibliographic portfolio papers key words

Topic name	Kew Word (as indicated by the author)	Incidence
Capabilities	Operations capability / Operations capability/ Operations capability / capability / Operational capability / Capabilities / Marketing capability / Marketing capability / Marketing capability / Marketing capability / Marketing capability / IT Capability	12
Methods for technical efficiency calculation	Data envelopment analysis / Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis / Stochastic frontier analysis / Stochastic frontier analysis / Operational Competitiveness Ratings Analysis (OCRA)	10
Performance Management	Performance management / Performance measurement / Performance / performance / Performance measurement (quality) / Financial performance / corporate social performance / financial performance	8
Environments Specification	Economic downturns / Dynamic environments / emerging economy / New business areas / Uncertainty/ Transaction cost economics / Additive manufacturing / buyer-supplier ties	8
Sector specification	Electrical machinery industry / Retail / 3D printing / Dealership network / high-technology markets / Logistics / Processed food industry / IT consultants	8
RBV	Resource-based-view / Resource-based-view / Resource-based-view / Resource-based-view / resources	5

Table 12 (continuation)- Bibliographic portfolio papers key words

Topic name	Kew Word (as indicated by the author)	Incidence
Competitive Advantage	Competitive advantage / Competitive advantage / Competitive advantage / Competitive advantage / Competitive priority	5
Methods	Fuzzy logic / Multicriteria analysis / Data mining / Clustering / Text mining	5
Efficiency	Efficiency / Efficiency / Efficiency / productivity	4
Operations Strategy	Operations strategy / operations strategy / manufacturing strategy / content analysis	4
Frontier Analysis	stochastic frontier estimation / Operating frontier / Asset frontier	3
Decision Making	Decision making / Decision Support System	2
Region Specification	Turkish SMEs / UK	2
Others	Innovation / innovation and R&D / Patent information / Model-based approach of competitive analysis / financial risk / financial market reaction / Diversification / Management / Strategic agility / Technological strength / Functional importance / Benchmarking / network / Institutional theory / Resilience / business group	16

The next step was the identification of the involved authors. Two researchers participated in the authorship of more than one study (Ramanathan, R. and Nath, P.), the others had only one incidence. Then, the analysis of the most used journals was promoted. Figure 19 shows the graph with the incidence of publications by journals.

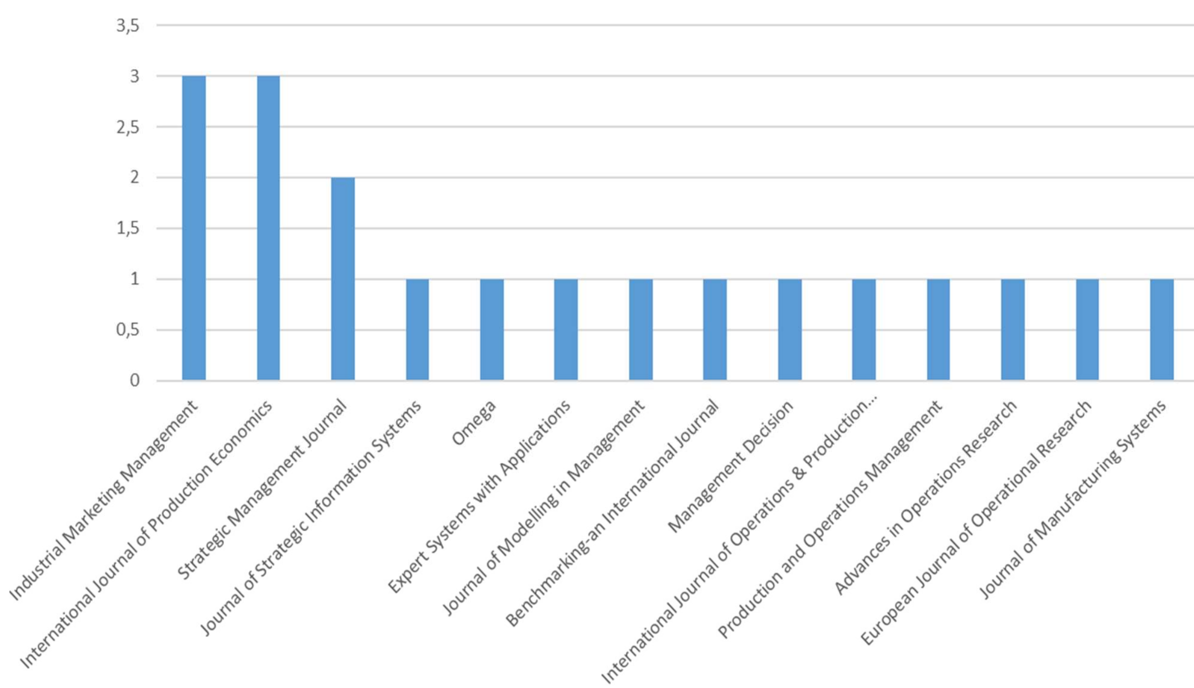


Figure 19 - Journal incidence

One can note that *Industrial Marketing Management* and the *International Journal of Production Economics* were the most used, with three incidences, followed by the Strategic Management Journal with two occurrences. The evolution of journal incidence over time is presented in Figure 20.

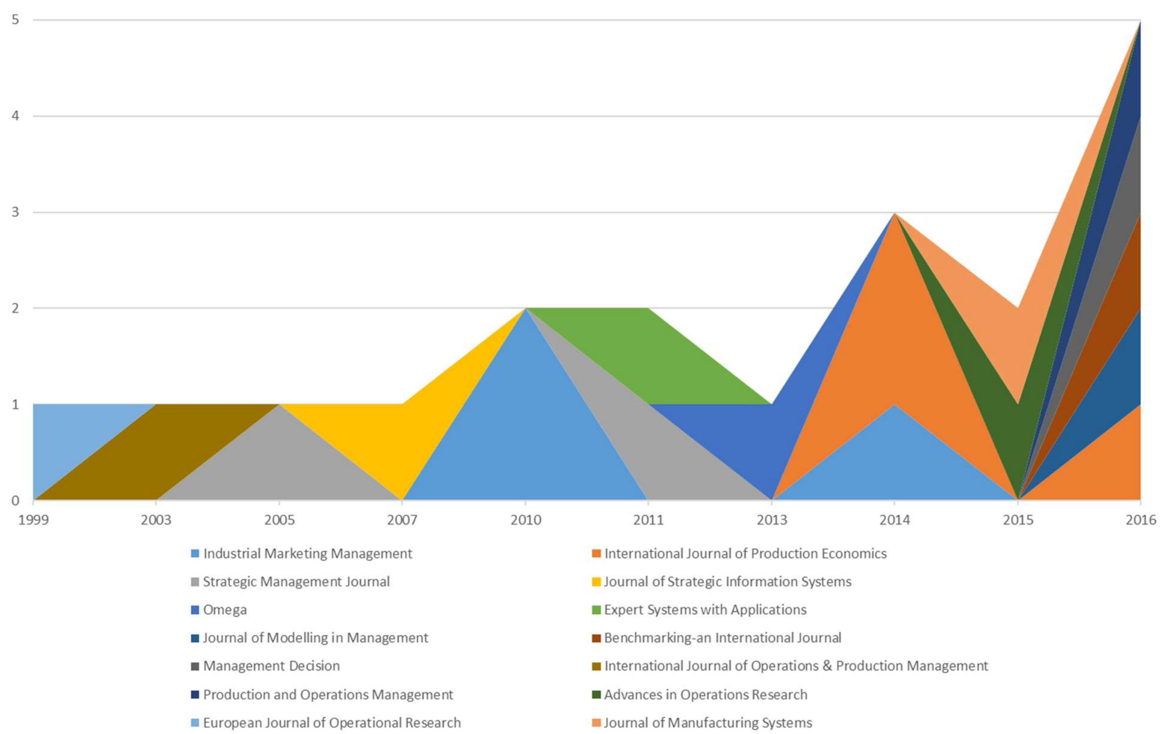


Figure 20 - Journal incidence over time

4.1.2.2. Bibliometric Analysis of the Bibliographic Portfolio References

At this step, the references of the 19 papers of the bibliographic portfolio were analyzed. Firstly, an analysis of the main authors who were involved in these works was promoted. In total, 820 main authors were involved, in 1.185 papers. Table 13 shows the main author more approached in the references of the bibliographic portfolio. The table only shows authors with more than 5 incidences.

Table 13 - Main author more approached in the references of bibliographic portfolio

First author-name	Incidence	First author-name	Incidence
Barney, J. B.	21	Vorhies, D. W.	8
Charnes, A.	13	Song, M.	8
Banker, R. D.	11	Day, G. S.	8
Wernerfelt, B.	10	Porter, M.	7
Peteraf, M. A.	10	Cook, W. D.	7
Dutta, S.	10	Teece, D. J.	6
Hayes, R. H.	10	Yu, W.	6
Amit, R.	9	Kao, C.	6

A similar study was promoted, considering all the authors involved in the work, not only the main one. The most cited authors are represented in Table 14. Only authors with more than 8 incidences are presented.

Table 14 - Author more approached in the references of bibliographic portfolio

Author name	Incidence	Author name	Incidence
Cooper, W. W.	26	Schoemaker, P. J. H.	9
Barney, J. B.	24	Rajiv, S.	9
Charnes, A.	21	Amit, R.	9
Wernerfelt, B.	14	Zhu, J.	8
Peteraf, M. A.	12	Vorhies, D. W.	8
Banker, R. D.	12	Rhodes, E.	8
Dutta, S.	11	Droge, C.	8
Song, M.	10	Day, G. S.	8
Narasimhan, O.	10		
Hayes, R. H.	10		

The next step was to identify the most used journals, the *Strategic Management Journal* used in 135 works, followed by *Management Science* with 53 references and the *Journal of Operations Management*, with 48. See table 15.

Table 15 - 20 more incident journals in the bibliographic portfolio references

Journal name	Incidence
Strategic Management Journal	135
Management Science	53
Journal of Operations Management	48
Journal of Marketing	45
Omega	36
Journal of management	35
International Journal of Production Economics	32
European Journal of Operational Research	32
Academy of Management Review	24
Harvard Business Review	24
Expert Systems with Applications	23
Industrial Marketing Management	23
Journal of Business Research	21
International Journal of Production Research	19
Production and Operations Management	19
Academy of Management Journal	19
International Journal of Hospitality Management	18
Administrative Science Quarterly	18
Journal of Marketing Research	18
International Journal of Operations and Production Management	16

Figure 21 shows the standard of the journal incidence over time, only for the 20 journals with higher participation.

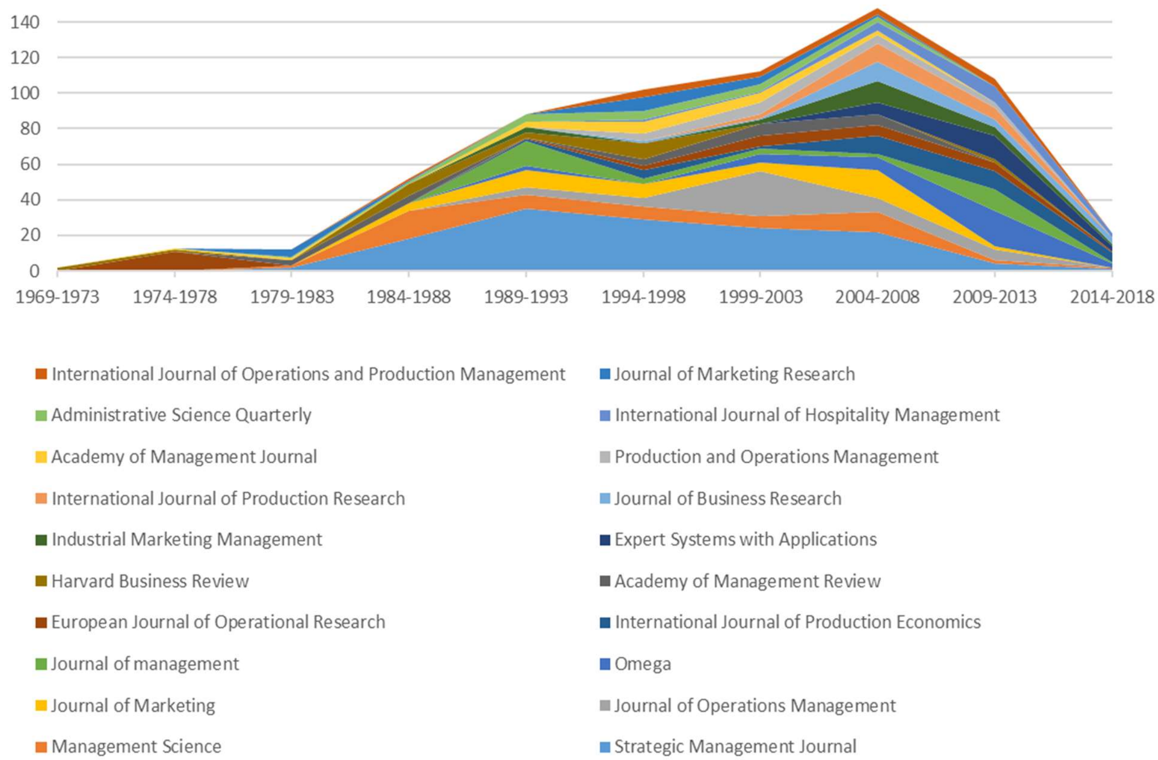


Figure 21 - More incident journals in the bibliographic portfolio references over time

4.1.3. Content analysis

The content analysis is promoted in three steps demonstrated in Figure 22. Portfolio papers bibliographic review section is going to approach main concepts and proposals covered by papers included in the portfolio. Second Section presents a research agenda mapping to identify gaps of literature. Finally, a conceptual map is developed to clarify mainly concepts of interaction.

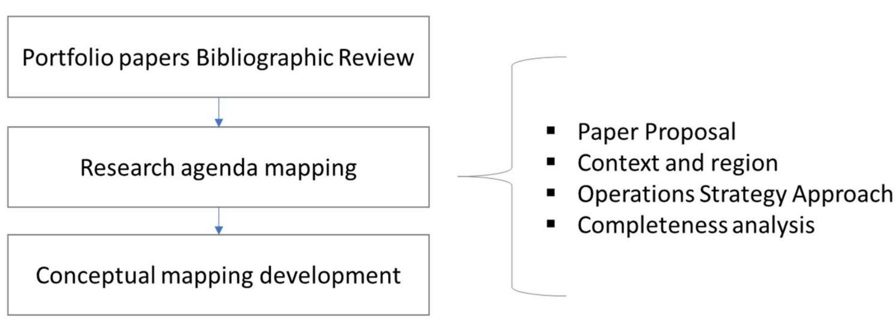


Figure 22 - Content analysis main steps

4.1.3.1. Portfolio papers bibliographic review

This topic summarizes the empirical work from the 19 papers of the bibliographic portfolio. The analysis of these papers content sustains the first version of the conceptual framework.

From the bibliographic portfolio set of papers, several authors use the resource-based view (RBV) concept as background for performance frontier study, since its theory link superior performance to firm resources and capabilities. Capabilities are the ability of a company to transform a set of inputs (resources) into certain outputs (objectives) for sustainable advantage (Akdeniz et al, 2010; Dutta et al., 2005; Ahmed et al., 2014). The RBV designates how an individual firm's resources (e.g. tangible and intangible assets and organizational capabilities) affect its financial performance (Barney, 1991; Wernerfelt, 1984; Peteraf, 1993, Prahalad and Hamel, 1990).

Dutta et al. (2005) exemplify the measurement of R&D capabilities in the semiconductor and computer equipment industries. Akdeniz et al. (2010) work discuss benchmarking marketing capabilities as a source of sustainable advantage through the DEA and SFA application. The study is applied at the business-to-business office furniture industry context and is grounded on three theoretical perspectives of benchmarking, which are the resource-based view of the firm, market orientation, and organizational learning.

Some papers focus on marketing and operations capabilities (Yu et al., 2014; Ahmed et al., 2014; Ramanathan et al., 2016). Ahmed et al. (2014) look at the impact of attributed importance given to operations and marketing function impact on capabilities and consequently, firm performance. Also, explore capabilities behavior in different economic conditions. Operational capability is understood as the integration and coordination of a complex group of tasks. The proposed framework looks at the firm capacity to expanding value throng enhancing cost efficiency or incomes. Value, from RVB theory, is the difference between the maximum price customers are willing to pay and the production cost. Yu et al. (2014) also look at financial performance and investigate the relationship among marketing capabilities, operational capabilities and financial performance within retail UK firms. Similarly, Nath et al. (2010) seek to identify the impact of functional marketing and operations capabilities and diversification strategies on the organization's financial results. According to the authors, the alignment between marketing and operations functions is the primary importance of consumer satisfaction. The proposed framework considers that the capability is the ability of the organization to develop resources (inputs) to achieve the desired objectives (outputs), using the efficiency frontier function to understand the optimal conversion of input to output. Inputs and outputs were selected to measure marketing and operations capabilities.

Ramanathan et al. (2016) include environmental capability and diversification strategy in their study. The authors analyze the impact of marketing capability, operational capability, environmental capability, and diversification strategy on performance. The scenario is the Hotel Industry in the UK. The impact of the moderating role of efficiency is evaluated throng regression analysis and the capabilities are assessed through DEA.

Hemmati et al. (2014) develop a framework based on RBV and dynamic capabilities theory. Specifically, strategic agility is used as a dynamic capability. The aim is to reach a competitive advantage. Data are gathered through the Fuzzy two-stage DEA model and considers strategic agility indicators as intermediates and competitive advantage indicators as outputs. While internals drivers - from RBV - are taken as inputs. Data are gathered through a set of questionnaires. The general hypothesis supports that that firm resources affect its competitive advantage through strategic agility. The results support that there are significant relationships between firm resources, strategic agility and competitive advantage. Miller and Ross (2017) explore the RBV concept investigating why resource utilization differs within a firm. The scenario is a petroleum firm. DEA is applied to examine resource input congestion of its distribution center. Managerial implications are discussed as well as the impact at the corporate level.

Samoilenko and Osei-Bryson (2013) propose and test a DEA Centric Decision Support System (DSS) that seeks to asses and manage the relative performance of organizations. The framework is developed based on internal (RBV) and external organization environment. They suggest that the DDS model includes externally-oriented and internally-oriented functionality. The first one regards the external competitive environment as well as identifying the organization state face its competitors. While the internal approach is about the productivity level of organization and issues that impact its aim. The DDS embraces parametric and non-parametric data and techniques such as DEA, Cluster Analysis, Decision Tree, Neural Networks, and Multivariate Regression.

Another stream of empirical literature looks at evaluating the contribution of specifics elements to production efficiency. Chang et al. (2015) approach the relationship between strategic positioning - cost leadership and differentiation - and production efficiency. This is relevant because firms that focus on cost leadership give more importance to production efficiency, while companies with differentiation strategy rely on innovation, brand development, marketing, and so forth to achieve competitive advantage. The authors' framework uses the DEA model and seeks to identify the importance given by firms to production efficiency base on its strategic positioning. Results confirm that companies with a cost leadership strategy give more importance to production efficiency.

Jayanthi et al. (1999) work brings a model-based approach for competitive analyses of manufacturing firms. They propose the application of Operational Competitiveness Rating Analysis (OCRA) to measuring competitiveness through relative inefficiency. The presented conceptual framework identifies and classifies the competitiveness drivers in structural terms (e.g. plant size, capacity, age of equipment, etc.) and infrastructural ones (e.g. policies, the introduction of new products, variety of products, etc.). The framework is applied to the US processed food industry. OCRA is a nonparametric method that seems to circumvent such a restriction. Framework inputs were Labor (annual expenditures on direct and indirect labor and salaried employees), Materials (annual expenditures on raw material and packaging suppliers), Capital (annual depreciation cost of facilities and equipment) and Energy (annual cost of energy and utilities). Output was revenue.

Other authors approach the concept of operations strategy and analysis of the performance frontier in more specific contexts. Seol et al. (2013) use DEA as a foundation to identify new business opportunities. It is based on the evaluation of the technological strength of firms among potential business opportunities. Input variables are the value of patents. Nevo et al. (2007) compare the impact of internal and external IT capabilities on productivity. Achillas et al. (2015) work within the field of additive manufacturing, in which the objective is to propose a methodological model that combines multi-criteria decision aid (MCDA) and DEA for determining the optimum operations strategy aligned to focused factory concept.

The market-based view (MBV) orientation is less explored within performance frontier studies. Abassi and Kaviani (2016), Bulak et al. (2016) and Cai and Yang (2014) are an example of the few pieces of research that are market-oriented, exploring the concept of competitive priorities. Abassi and Kaviani (2016) suggest a performance evaluation framework for appraising and ranking the organizations based on the effectiveness of their operations strategies. To this end, uncertain DEA is used as an approach, which embraces fuzzy DEA, imprecise DEA and Grey DEA. The authors' four-stage operational framework are: determining the basic DEA model, Data gathering, Ranking DMUs' operations strategies using uncertain DEA models and Generating the final ranks of DMUs' operations strategies. Input variables are the operations strategy performance objectives or competitive priorities. While the output variables include financial indicators (ROA and ROI) and non-financial indicators (market share). This model is shown in Figure 23.

Figure 23 - Frontier analysis proposed model for cement factory

Source - Abbasi and Kaviani (2016)

Bulak et al. (2016) measure and evaluates the efficiency of Turkey's electrical small and medium machinery manufacturing. Authors use output-oriented CCR data envelopment analysis methodology. The study aims to determine whether competitive priorities, defined as inputs, maximizes firm performance, or outputs. The output variables are defined through a SWOT analysis from the Turkish Machinery Industry sector based on the Ministry of Economy Report. Figure 24 presents the model as well as the inputs and outputs variables. The input variables approach major competitive priorities (cost, delivery, quality, and flexibility) and all the priorities (excluding cost) are measured with multiple related variables. Regardless of outputs, they embrace financial and non-financial performance measures.

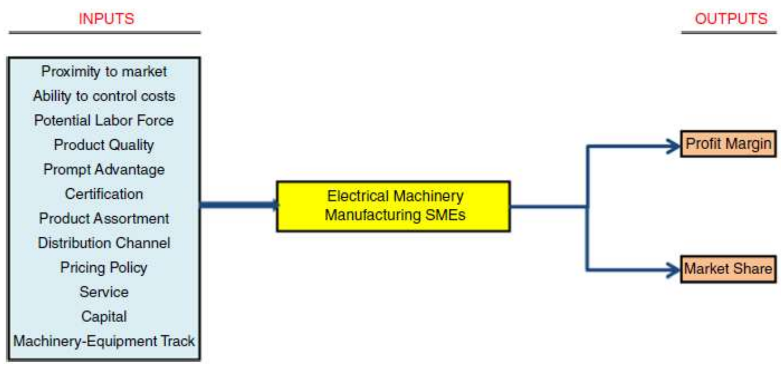


Figure 24 - Frontier analysis proposed model for electrical machinery manufacturing SMEs
Source - Bulak et al. (2016)

Cai and Yang (2014) in their turn, explore the link between business environment and competitive priorities which are based on the manufacturing strategy concept. The study considers the effect of asset frontier and operating frontier, as well as trade-offs across competitive priorities. The authors take a different perspective, detailing how the asset frontier affects the operating frontier, which subsequently affects competitive priorities. The asset frontier can also affect competitive priorities, and the business environment can affect both frontiers. The authors' model is shown in Figure 25.

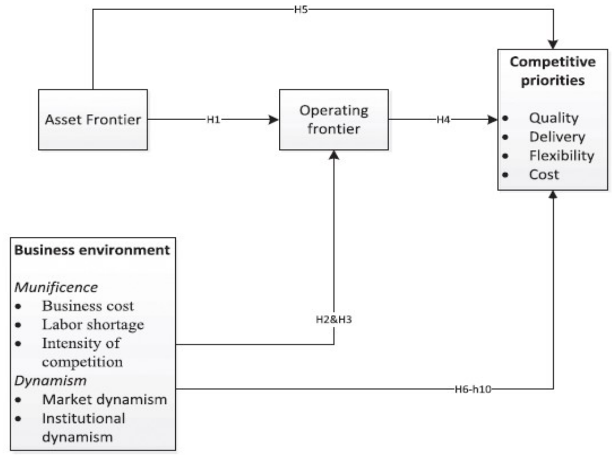


Figure 25 - Research framework
Source - Cai, and Yang (2014)

By the end, some papers indirectly approach the operations strategy concept. Jacobs et al. (2016) examine the relationship between Operational Productivity, Corporate social performance, financial performance, and risk. These relationships are important to the operations management area due to the focus on productivity and enhancing concern about corporate social performance. Mahmood et al. (2011) also bring an approach indirectly related to operations strategy within a contingency approach, an item little explored by other works. The authors study how the type of ties between businesses can affect the development of capabilities, specifically research and development. For this, they use the non-parametric approach of SFA.

The next topic presents conceptual mappings to compare the bibliographic portfolio set of papers.

4.1.3.2. Research agenda mapping

The second stage includes the content analysis, which is developed through the investigation of some elements of the works that compose the bibliographic portfolio; they are work proposal, context, and region of the empirical application if it exists; operations strategy approach and completeness analysis, based on Pettigrew's (1987) proposal.

Pettigrew (1987) proposes a framework to analyze the strategic change of a company based on the notion of formulating the context, content, and process. The context can be internal or external; the internal is related to structure, organizational culture, politics, among others; while the external context is linked to the economic, political and competitive environment in which the organization operates. The content is related to the organizational objectives and the organizational area in transformation, such as technology, hierarchical structure, products, geographic positioning, culture, among others. Finally, the process analysis contemplates the actions, reactions, and interactions of the various stakeholders that are part of the changing process from the current state to a future state.

Based on the papers' content analysis, conceptual mappings for each element are presented. There were identified three main work proposals objectives: Examine the relationship of some element with productivity, to measure productivity or to propose a framework for supporting decision making. In the first stream of study, the evaluation shows that many of the authors work in the context of Capabilities (eg. Ramanathan et al., 2016; Nath et al., 2010; Nevo et al., 2007; Yu et. al., 2014; Ahmed et al., 2014; Akdeniz et. al., 2010; Hemmati et al., 2014; Dutta et al., 2005; Mahmood et al., 2011). Some of them relate the impact of one or more capabilities on business performance while others explore how some elements influence capabilities building. Most authors specify the context of the business and the region where the studies are promoted. There are also some authors with similar objectives, but they do not work with the concept of capabilities; instead, they seek to raise the drivers of organizational performance, not restricting to capabilities. In these cases, organizational performance is measured by financial measures or not (Chang et al., 2015; Jacobs et al., 2016; Miller and Ross, 2003; Jayanthi et al., 1999; and Cai and Yang, 2014). Figure 26 presents a summary of the paper's purpose.

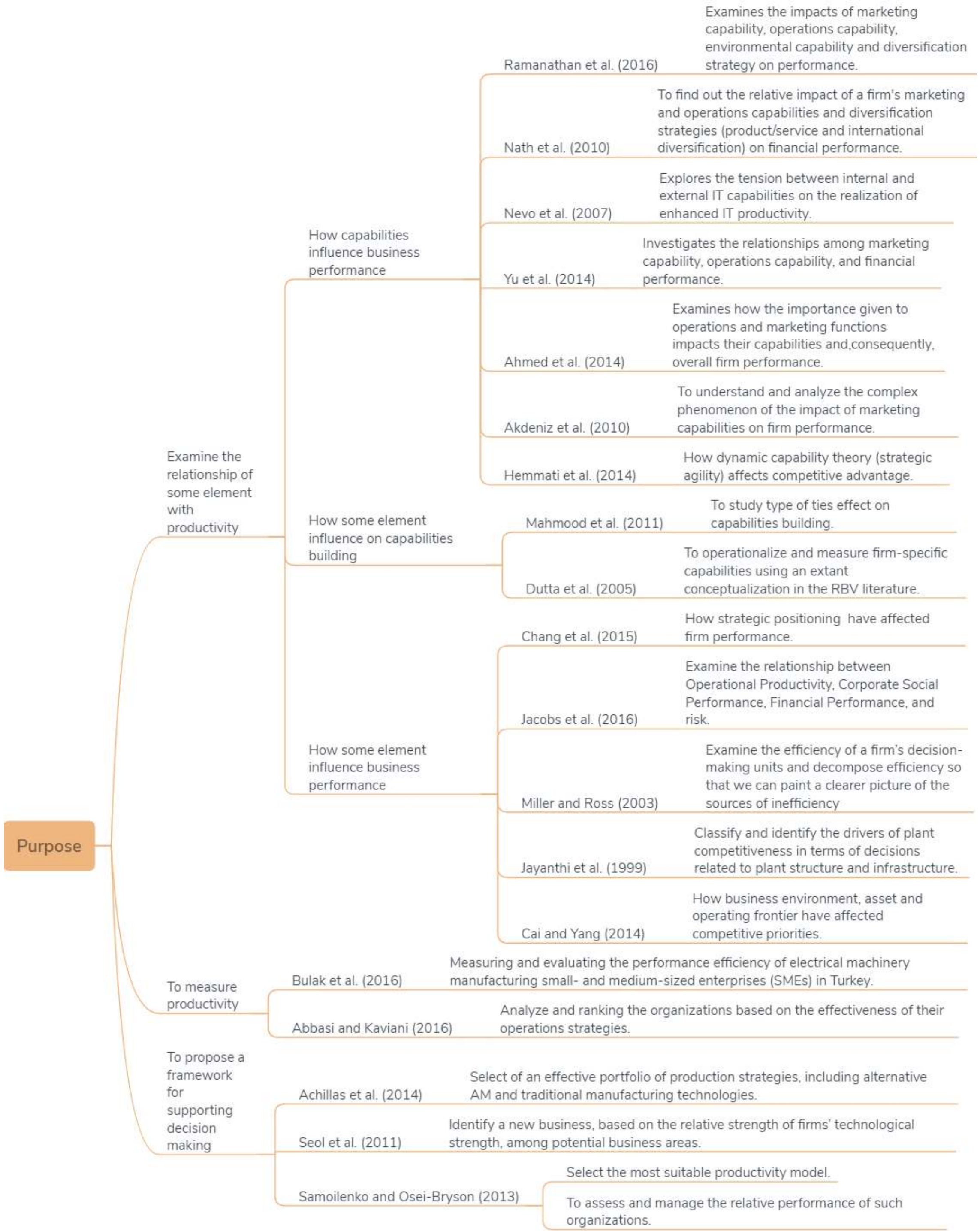


Figure 26 - Summary of bibliographic portfolio papers purpose

In general, the authors select a context and a region for the estimation of the performance frontier. The most explored context is manufacturing companies, while the region is the United States (see Figure 27).

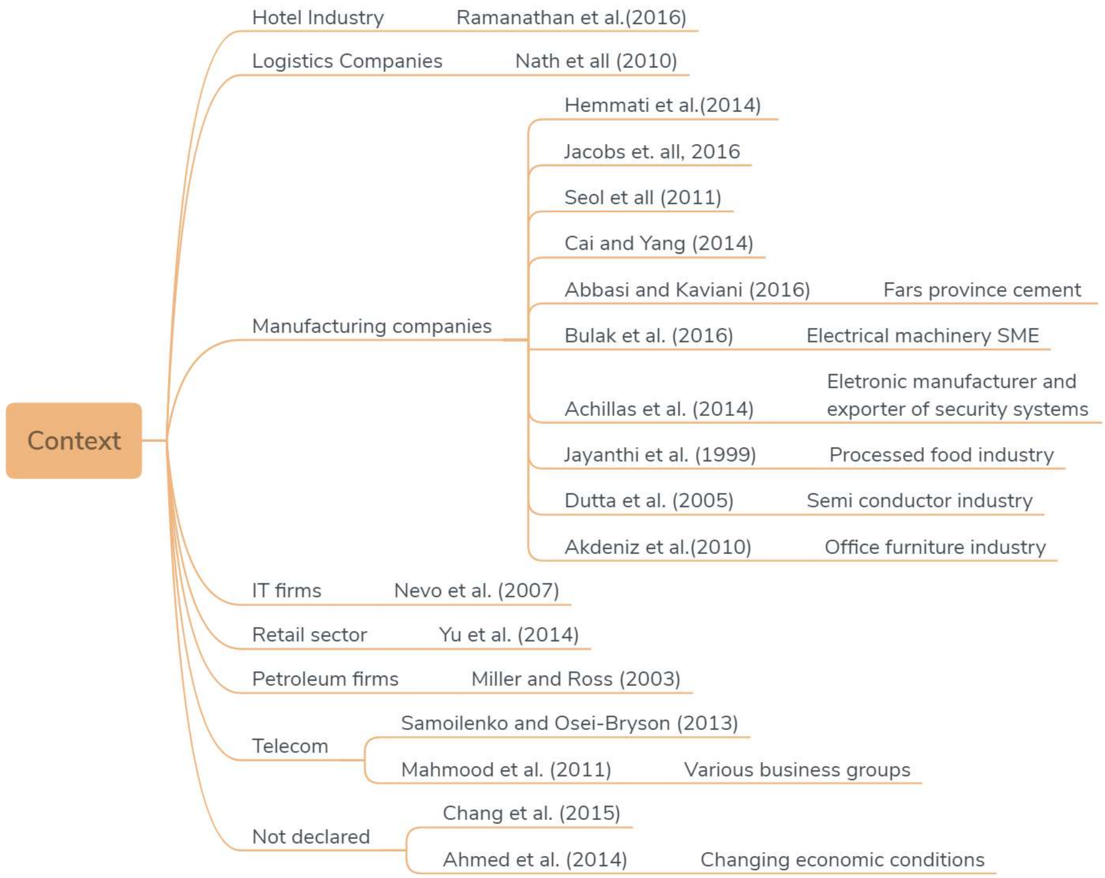


Figure 27 - Summary of bibliographic portfolio papers context

It is noticed that Brazil was not the focus of any of the studies. See Figure 28 which presents the vision of the region where the study proposal was implemented.

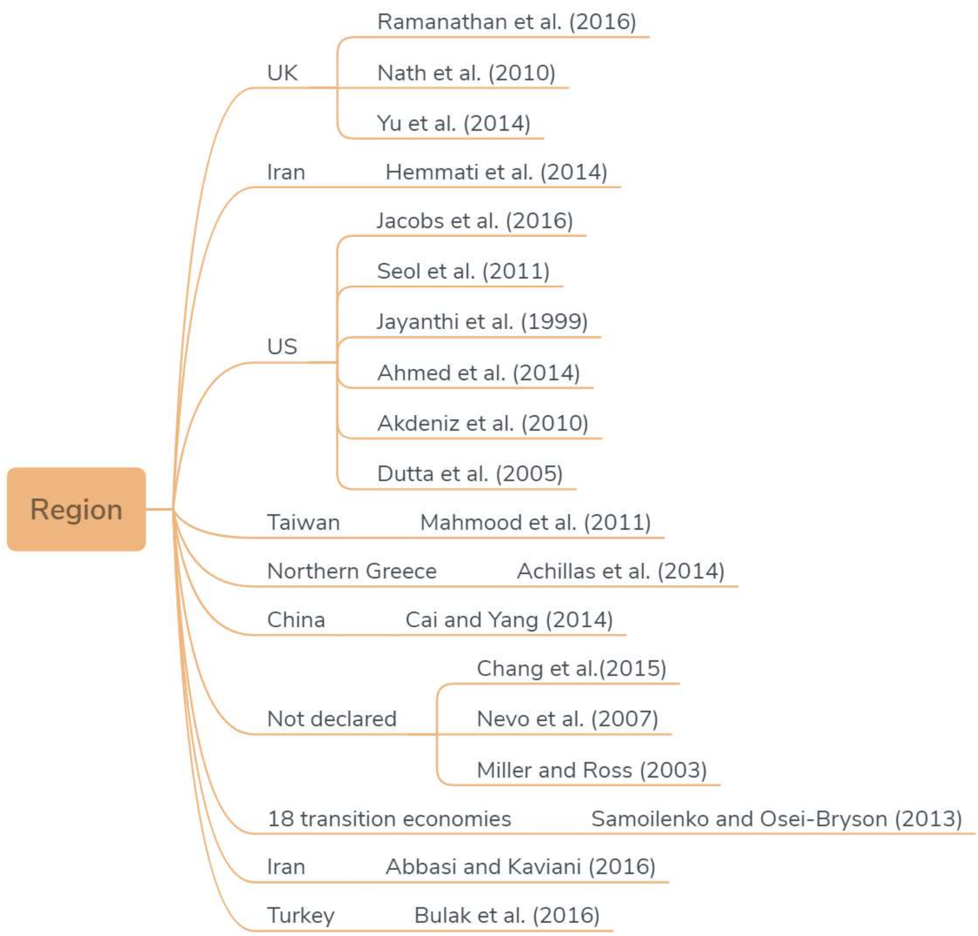


Figure 28 - Summary of bibliographic portfolio papers region

As the requirement of bibliographic portfolio work content, they should have addressed the topic of performance frontier analysis and operations strategy. It is noticed that the focus of most of the works is in the resource-based view operations strategy approach, working with the capabilities. Some authors work with the focus on competitive priorities, such as Cai and Yang (2014); Abbasi and Kaviani (2016) and Bulaket al. (2004). While Jayanthi et al. (1999) focus on the structural and infrastructural decision areas. Some authors indirectly approach the operations strategy concept in their papers, such as Chang et al. (2015); Jacobs et al. (2016) and Samoilenko and Osei-Bryson (2013). Figure 29 presents a summary of the operations strategy approach.

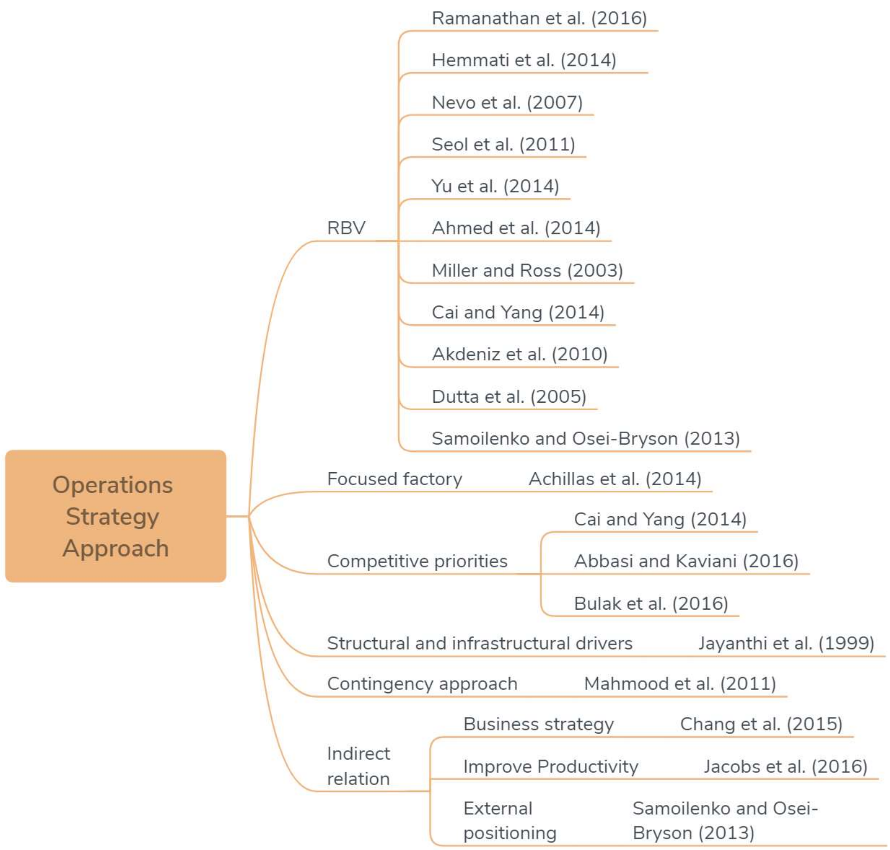


Figure 29 - Summary of the operations strategy approach of the bibliographic portfolio papers

Finally, the completeness analysis, in Figure 30, identifies the paper focus, being context, content or process analysis.

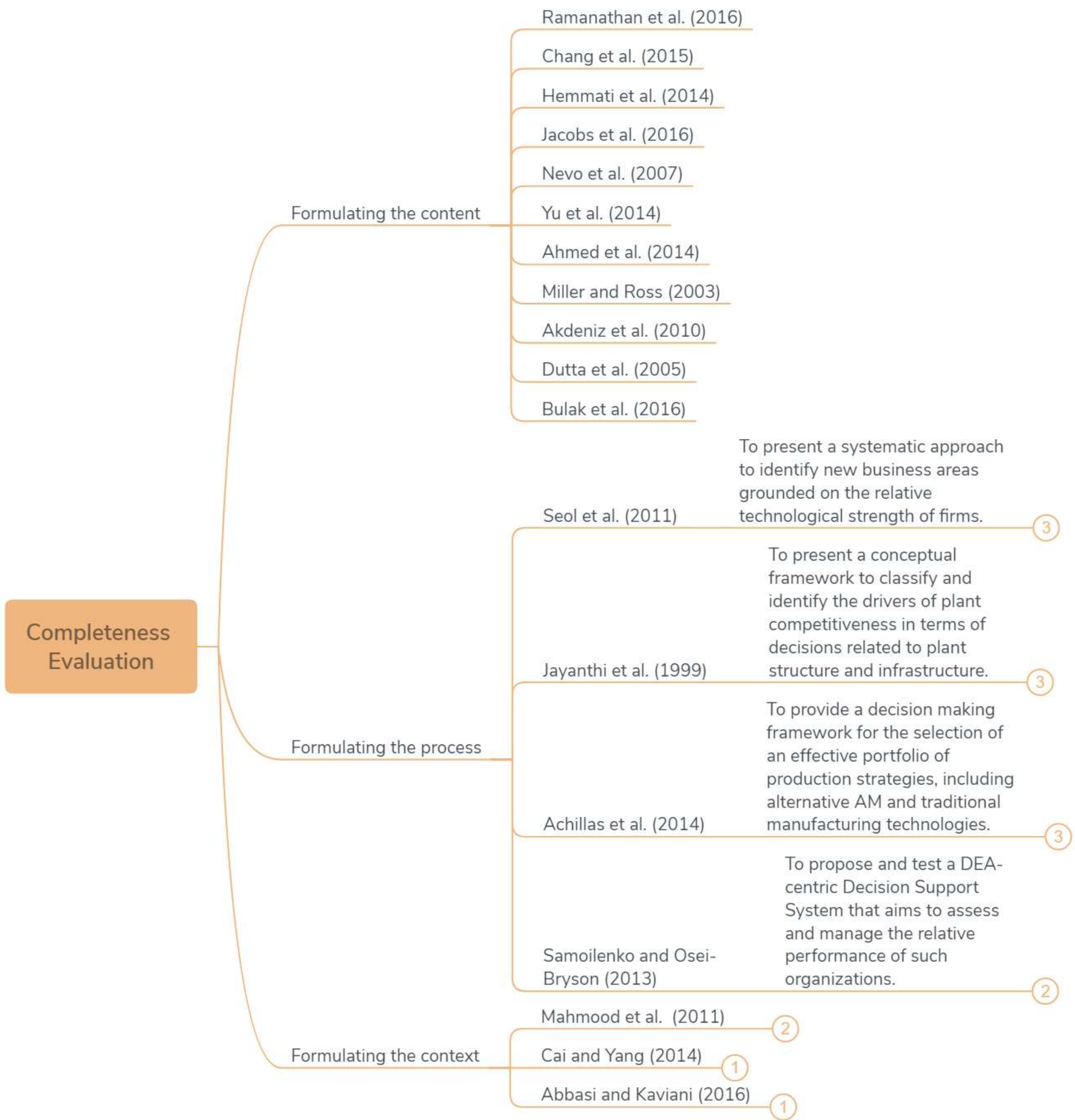


Figure 30 - Summary of the completeness evaluation of the bibliographic portfolio papers

It is noticed that most of the papers are focused on the content analysis, seeking to identify the performance drivers or to estimate the frontier. There are articles focused on the context, seeking to classify the target organization within an external context. A process-oriented paper generally proposes frameworks for specific purposes. Seol et al. (2011) aim to identify potential new business areas based on each company's technology strengths. Jayanthi et al. (1999) seek to identify the drivers of competitiveness based on the decisions regarding the infrastructure and structure of the organization. Achillas et al. (2014) work in the specific context of additive manufacturing. Samoilenko and Osei-Bryson (2013) propose a model for decision-making.

Although papers are focusing on process analysis, none of them are market-oriented, addressing the concept of competitive dimensions and promoting the integration of them within the organizational performance. Besides, prescriptive models, which may be important for the replication of frontier estimation by other organizations, are not proposed. The weakness of the papers that approach the process is pointed out in Figure 31.

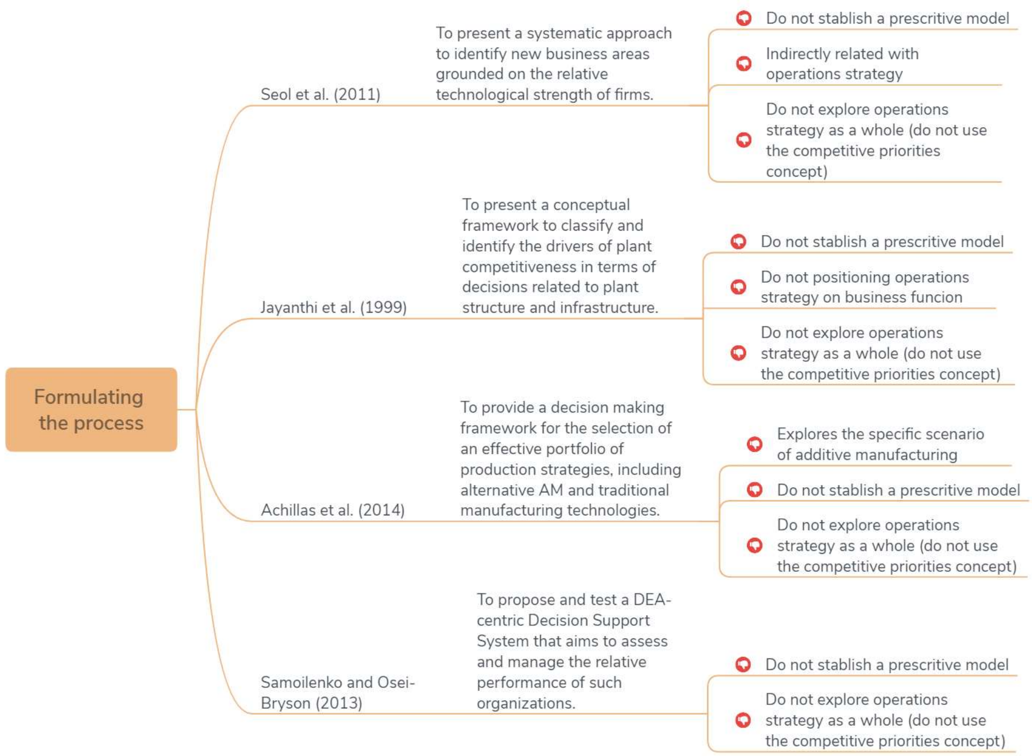


Figure 31 - Weakness of the process literature

The presented content analysis reveals a research opportunity to work with a market-oriented processual model, to propose a way to estimate the maximum performance frontier, within the context of the operations strategy, driving the increase of the competitiveness of the business.

The connection between operations strategy and firm performance frontier is not exhaustively explored in literature, as a comprehensive approach. Some papers integrated both concepts as Abassi and Kaviani (2016), Bulak et al. (2016), Ramanathan et al. (2016), Cai and Yang (2014), Hemmati et al. (2016); Yu et al. (2014), Ahmed et al. (2014), Akdeniz et al. (2010), Nath et al. (2010), Nevo et al. (2007), Dutta et al. (2005). However, many of these works are based on capabilities concept from resource-based view theory, as could be seen in the works of Miller and Ross (2003), Maslen (1997), Prahalad and Hamel (1990), Barney (1991), and Wernerfelt (1984). Unquestionably, the capabilities approach can help in leading through operations effectiveness. However, it encompasses one research stream of the operations strategy, the resource-based view, only. The present research develops its contribution to the gap of the market-based view approach to study the operations strategy in the leans of frontier analysis methodologies, to do so, it explores the concept of the competitive priorities.

The dearth in exploring the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. For Okoshi et al. (2019) and Phusavat and Kanchana (2008), the appropriate choice of competitive priorities reflects on the future direction of a firm and has a fundamental importance in achieving the competitive advantage which may lead to business performance improvement.

4.1.3.3. Conceptual Mapping

Another stage of content analysis was the understanding of the key concepts for the proposal under development and the relationship between them. The bibliographic portfolio papers were adopted as a research source, seeking to identify the relationship between the concepts related to the operations strategy and the performance efficiency frontier analysis. The conceptual map obtained as a result of this analysis is presented in Figure 32.

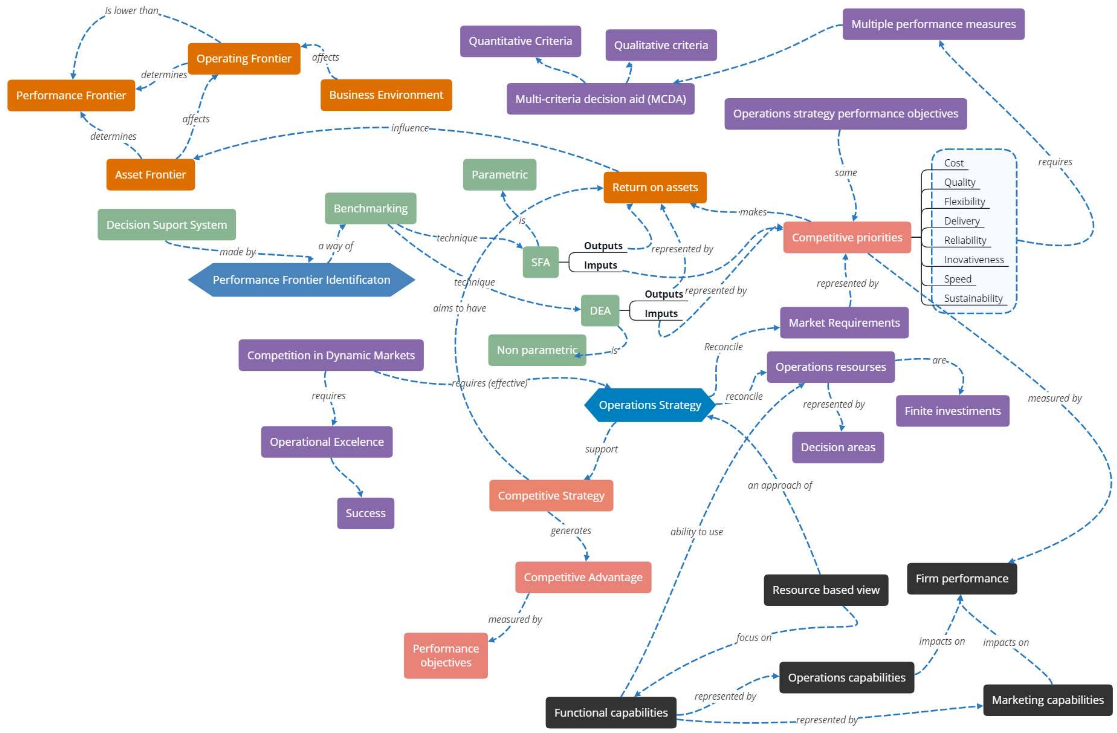


Figure 32 - Conceptual mapping of the relationship between operations strategy and performance frontier analysis

The conceptual mapping makes clear that the performance frontier identification is a decision support system, through benchmarking, and there are some methodologies already proposed in the literature to perform it. The methodologies can be parametric or non-parametric and the most known are stochastic frontier analysis (SFA) and data envelopment analysis (DEA). Both are based on the measurement of inputs and outputs (See green boxes).

On the other hand, operations strategy reconciles market requirements as well as operations resources, which are finite investments and therefore, limit the potential of its organizational function. The operations resources are represented by the decision areas while the market requirements can be translated to operations function employing the competitive priorities (cost, quality, speed, dependability, innovativeness, sustainability, and so on). The competitive priorities, in a recent competitive scenario, requires multiple performance measures, enhancing the complexity of the decision making. These competitive priorities are operations strategy performance objectives. The operations strategy is even more important when competing in dynamic and competitive markets, in this scenario, operational excellence is a need (See purple boxes). A very recognized approach of operations strategy is the resource-based view which works with the concept of capabilities to enhance operations strategy results (See black boxes).

Operations strategy supports the competitive strategy that, in its turn, seeks the achievement of competitive advantage, measured by performance objectives. Therefore, it is possible to establish a relation between the competitive priorities and the competitive strategy (See red boxes).

When we look at performance efficiency frontier identification, seeking to enhance competitive advantage through operations strategy, the competitive priorities should be analyzed as an input, to evaluate its capacity of enhancing the outputs, represented by some metric related to the return on assets, a way of identifying competitive strategy effectiveness. The return on assets, influence the assent frontier, which, in its turn, determines the performance efficiency frontier, and affect operating frontier, which is also affected by the business environment (See orange boxes).

4.2. CONCEPTUAL FRAMEWORK

In the face of the presented conceptual mapping, one notices that the concept of operations strategy and performance efficiency frontier are closely related. The conceptual framework formalizes how the operations strategy concept can be connected in a framework that enables performance efficiency frontier analysis. Two stages of the conceptual framework are proposed. The first stage conceptual framework has been proposed based on the insights obtained by the content analysis of the bibliographic portfolio.

4.2.1. First stage conceptual framework

The operations strategy is deployment from the corporate strategy and aims to achieve excellent performance in the key competitive priorities; this is achieved through acting in the so-called decision areas. While the concept of efficiency frontier is a function that indicates the maximum level of result attainable for a corresponding quantity of inputs, the frontier is estimated based on the observation of inputs and outputs of a population of companies (or a representative sample).

Outputs are understood as the desired result of the business, in financial and non-financial terms, which are defined through corporate strategy. These results are achieved through action in operations, represented by functional strategies. The operations function has its strategy composed of the competitive priorities, supported by the action in the decision areas. In this way, inputs are defined by competitive priorities. Figure 33 shows the relationship between the concepts of operations strategy and the performance efficiency frontier.

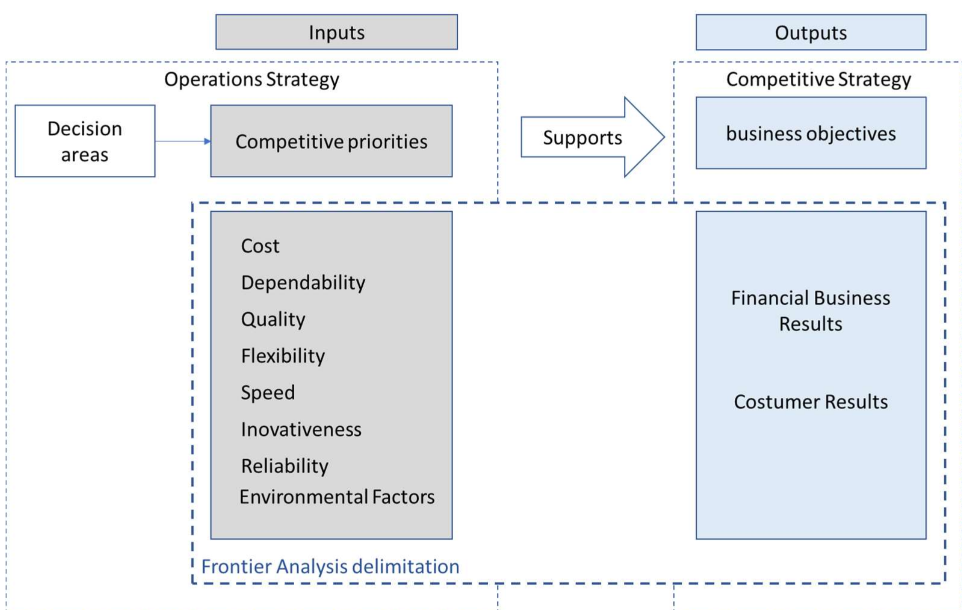


Figure 33 - First stage conceptual framework

This figure is grounded on the content analysis of the bibliographic portfolio, summarized in the previous conceptual mappings. This conceptual framework gives a different picture to Schmenner and Swink (1998), who establish the competitive priorities are outputs to employ the performance efficiency frontier concept to operations strategy. The proposed framework, therefore, provides a wider approach, seeking to explore how the operations strategy contributes to the business results. Bringing, therefore, a different approach to some empirical applications (Dutta et al., 2005; Abbasi and Kaviani, 2016; Hemmati et al., 2014). Next, the input and output variables are defined.

4.2.2. Definition of framework variables

To represent the inputs of the conceptual model, the selected competitive priorities in this research work include quality, cost, flexibility, dependability, reliability, speed, innovativeness, and environmental affairs.

There are several approaches to defining the most important competitive dimensions. According to Slack and Lewis (2018), the five most common performance objectives are quality, cost, dependability, flexibility, and speed. These five generic performance objectives have meaning for all types of operations and are related to satisfying customer requirements. Beyond the traditional competitive priorities, recent literature has dealt with other criteria due to the current dynamic context as a reflex of the businesses' digital transformation, and a socioeconomic paradigm based on sustainable development. Innovativeness is recognized as a new competitive priority to compete in global markets (Laosirihongthong et al., 2014; Hult et al., 2004; Bouranta and Psomas, 2016; Khin and Ho, 2019; Ferreira et al., 2019; Vial, 2019). Environmental affairs are also bringing as a recent concern and included together with the classical competitive priorities (Wang, 2019; Díaz-Garrido et al., 2011; Vivares-Vergara et al., 2016). Reliability is approached as a criterion detached from quality by some authors. Narkhede (2017) indicates that reliability is an important approach mainly for the USA, Europe, Japan, and India, being explored by various authors in manufacturing practices. This research includes innovativeness, reliability, and environmental factors as important competitive priorities in the current dynamics of competition.

4.2.2.1. Data source

Once the relationship between the concepts of operations strategy and performance efficiency frontier analysis is defined, the variables on behalf of inputs (competitive priorities) and outputs (organizational results) are then selected. The selection of variables was based on 'High-Performance Manufacturing data (HPM)', round 4. The availability of reliable data is an important assumption for this research, as the processual model will further require benchmarking data.

The HPM project seeks to identify the practices adopted by high-performance organizations and applies a survey with companies in 18 countries. The survey includes 1597 questions in 12 categories: Accounting, Downstream Supply Chain Management, Environmental Affairs, Human Resources Management, Information System Management, Plant Management, Process Engineering, Product Development, Production Control, Quality Management, Supervision, and Upstream Supply Chain Management. They are answered by different people inside the organization. The HPM includes machinery manufacturers, vehicle component manufacturers and electronics manufacturers companies with at least 100 employees (Flynn et al., 1997). The 4th round was realized between 2012 and 2018 (Park and Paiva, 2018; Phan et al., 2019).

The first step of variables definition is the questionnaire understanding seeking to choose those that evaluate competitive priorities as well as organizational results (financial and client's perspective). At this step, only variables with less than 30% of missing data were included. That's because it is possible to remediate missing data until 30% (Hair et al., 2009).

The questions selected in this first stage are presented in Appendix B. Due to the existence of questions posed both positively and negatively, it was necessary to transform the results to allow comparison. Such transformation occurred by reversing the scale of responses (using the least-squares method).

4.2.2.2. Sample definition

At this time, we have 304 participants companies, seeking a bigger sample we have considered to this analysis the three kinds of companies: machinery manufacturers, vehicle component manufacturers, and electronics manufacturers companies. But, even implementing the exclusion of variables and samples with more than 30% of missing values, the one in which less than 30% of missing values were still in the database. Next, a procedure was established to evaluate whether cutting off all the samples with missing data would endanger compliance with the minimum criterion of sample size, as the number of cases without missing data should be sufficient for the selected analysis technique (Hair et al., 2009). The sampling size per category was analyzed, and two actions could be promoted: eliminate the sample with remaining missing data or establishing a corrective procedure to replace missing data. Corrective actions to replace missing data should be taken in the cases where the removal of samples with missing values harmed the sampling size criterion of having at least 100 samples and an average of 10 samples per variable (Hair et al., 2009; Nunnally and Bernstein,1994; Rencher and Christensen, 2012). In cases where the sampling size criterion was not affected by removing samples with missing data, the removal was preceded. By doing this, the adopted procedure to replace missing data will not interfere with the result. So, the samples with missing data were only removed if the sampling size criterion still fulfilled in each category. Figure 34 shows the procedure flowchart for checking the suitability of the sample size.

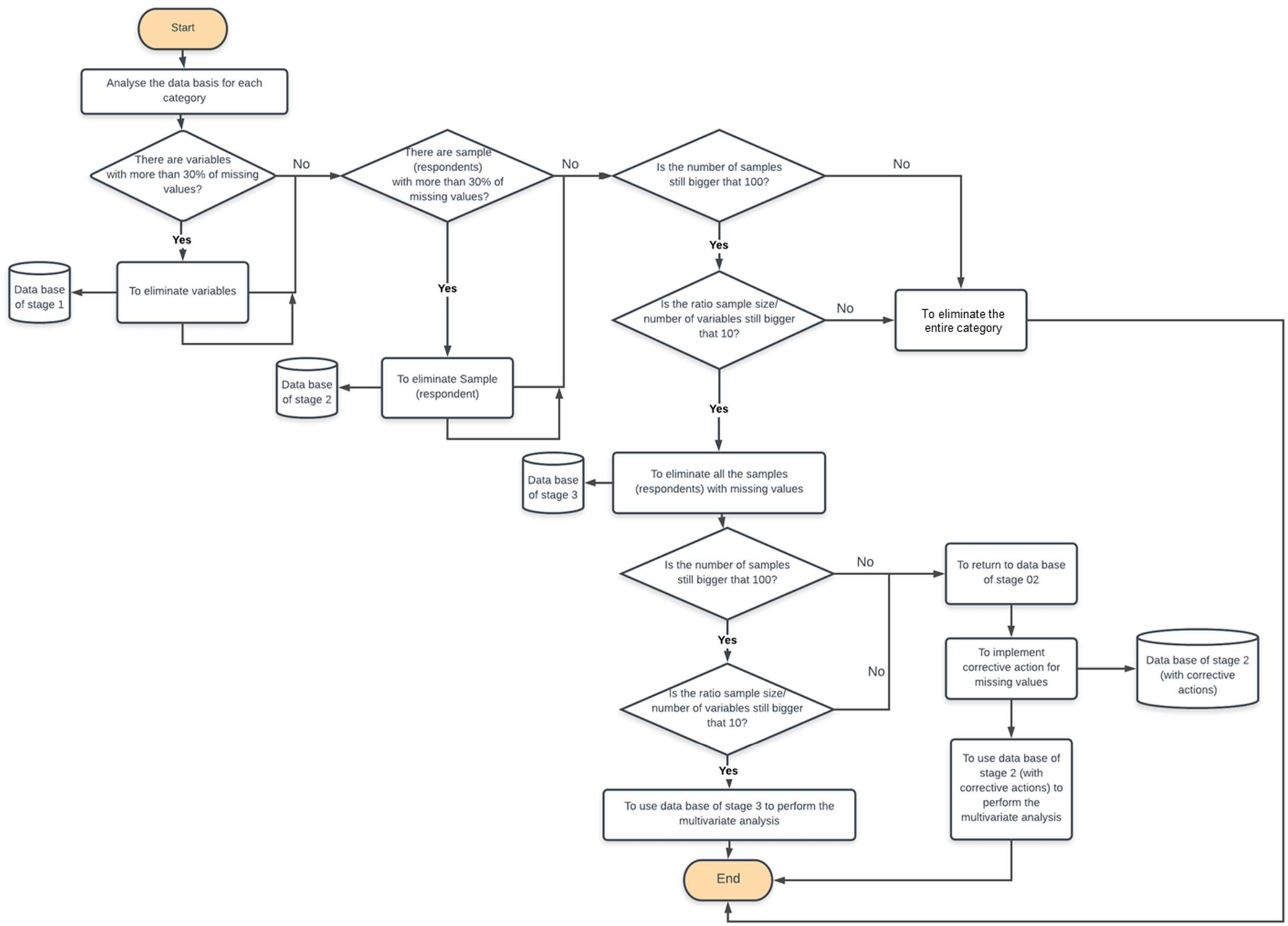


Figure 34 - Sample selection procedure

As a result of the implementation of the procedure, all the criteria meet the sample size requirement, even with the elimination of the samples with less than 30% of missing data, and no corrective action was taken at this step. Table 16 shows the results of the defined sample size (SS) criterion (database of stage 3).

Table 16 - Sample size

Category	Number of variables/questions	Sample Size	Ratio SS/ Variable
Cost	9	117	13.0
Dependability	6	241	40.2
Environmental factors	10	249	24.9
Flexibility	18	212	11.8
Innovativeness	13	202	15.5
Quality	19	210	11.1
Reliability	4	261	65.3
Speed	7	181	25.8
Clients Results	10	241	24.1
Financial Results	1	271	271

It is possible to recognize that most of the criteria have a huge quantity of questions (variables), which can be a constraint in the procedural model. According to Alder and Golany (2001) and Alder and Yazhemsky (2010), an excessive number of input/output variables in a DEA model results in a large number of efficient DMU, not allowing to differ the superior performed companies. To consistently reduce the number of variables, another multivariate statistical analysis was conducted – Principal Component Analysis (PCA).

The accurate specification of the DEA model is important to not disturb the efficiency estimation (Smith, 1997; Ruggiero, 2005; Nataraja and Johnson, 2011). However, according to Smith (1997), the main weakness of DEA is that the choice of input and output variables depends on the judgment of the researcher, as there is no support to help the user determine wheatear or not the chosen model is appropriate. Nataraja and Johnson (2011) indicate that the four most used approaches to guide variables specification in DEA is efficiency contribution measure (ECM), principal component analysis, a regression-based test, and bootstrapping for variable selection. The authors don't recommend the use of bootstrapping. And suggest the use of PCA to small data set (less than 300 observations) with a high correlated degree (greater than 0.8). To larger data sets or data with low correlation levels (smaller than 0.2), both ECM or regression-based tests are indicated.

Bootstrapping aims to allow for heterogeneity in the structure of efficiency, by the estimation of the bias and variance and construction of confidence intervals. The method can be used to asses uncertainty about distance to the true production frontier from a small number of points in the production set (Simar and Wilson, 1998; Simar and Wilson, 2000). The ECM was proposed by Pastor et al. (2002). The authors propose a statistical test to help in deciding about the incorporation or the exclusion of a variable into a given DEA model.

Ruggiero (2005) proposes a statistical procedure based on a regression-based test to the selection of inputs variables utilizing simulation analysis. In Ruggiero's (2005) proposal an initial measure of efficiency is obtained from a set of known production variables. Efficiency is then regressed against a set of candidate variables; if the coefficients in the regression are statistically significant, the variables are relevant to the production process and should be retained.

Usually, the input and output variables are correlated, therefore, the variables should be selected taking the knowledge of the variables. Ueda and Hoshiai (1997) proposed a way of weighting DEA model variables and summarizing parsimoniously them instead of simply selecting them. Alder and Golany (2001) also apply PCA to overcome the difficulties that DEA faces when there is a huge number of variables.

4.2.2.3. Principal Component Analysis

As the more variables are added - and this is inherent in multivariate data analysis techniques - more and more correlation (or overlapping) occurs between the variables. As the variables become correlated, the researcher needs alternatives to manage them, grouping highly correlated variables. PCA allows the identification of correlations in many variables and defines strongly interrelated groups, which define the factors. In this way, the objective of the factor analysis techniques is to summarize several original variables in a smaller group of new dimensions composed of statistical variables, called factors, with a minimum loss of information (Hair et al., 2009). The goal is, therefore, to reduce a set of p observed variables to a set of m new variables ($p>m$) (Velicler and Jackson, 1990). Factor analysis describes a broad category of approaches to determining the structure of relations among measures (Nunnally and Bernstein, 1994). Factor analysis may be exploratory or confirmatory.

Both confirmatory and exploratory factor analysis is based on the common factor model and aims to represent the structure of correlation among measured variables using a small set of constructs. Exploratory factor analysis (EFA) is primary database and provides procedures to determine an appropriate number of factors, while confirmatory factor analysis (CFA) requires the research to specify a specific number of factors. EFA is suitable when the research has a little theoretical or empirical basis for developing solid assumptions about how many factors exist (Fabrigar et al., 1999). Some authors defend that CFA supplants EFA; however, there is the support of using them as a complementary approach (Velicler and Jackson, 1990).

The design of a factor analysis includes three steps: (1) verify the adequacy of the database, (2) determine the extraction method and the number of factors to be extracted and (3) decide the method of factor rotation (Filho and Júnior, 2010).

The factor analysis is usually performed with metric variables. Concerning the sample size, most of the recommendations involve determining the sample size based on the number of measured variables included in the analysis (the more the number of variables the bigger the sample size). Sometimes some recommendations also include the sample size, regardless of the number of measured variables. However, the recommendations given by existing literature vary dramatically (Fabrigar et al., 1999). According to Hair et al. (2009), it is difficult to carry out an analysis with less than 50 observations. Preferably, the sample size should include more than 100 observations. Beyond that, the number of observations must be at least 5 times greater than the number of variables. Being positive, a ratio of 10 observations to a variable. Nunnally and Bernstein (1994) also recommend at least a ratio of 10 to 1. However, there is a limitation in these guidelines because the determination of the adequate sample size is not a function of the number of measured variables; instead, it is more appropriate to consider the extent to which factors are overdetermined and the level of communalities of the measured variables. To an overdetermined factor (e.g. At least three or four measured variables represent each factor) and the communalities are high (e.g. an average of 0.7 or higher) a sample size of 100 might provide accurate estimates of population parameters (McCallum et al., 1999). In more moderate conditions a sample size of at least 200 might be needed (Fabrigar et al., 1999).

Another point is the multicollinearity, measured by VIF (Variance Inflation Factor), which is desired as the aim is to identify interrelated sets of variables. In general, the stronger the data, the smaller the sample required for an accurate analysis. In factor analysis, strong data means high communalities without cross-loadings and several variables with strong loads on each factor (Costello and Osborne, 2005).

The communality of a variable is the estimation of its shared variance between the variables as presented by the obtained factors (Hair et al., 2009). A low communality among a group of variables is an indication that they are not linearly correlated and therefore should not be included in the factor analysis (Filho and Júnior, 2010; Fabrigar et al., 1999).

Assuming that the conceptual requirements for the variables included in the analysis have been ensured, then it is necessary to guarantee that the variables are sufficiently intercorrelated to produce representative factors. First, the correlations need to be higher than 0.30. The anti-image correlation matrix (generated by SPSS software) gives the negative value of the partial correlation. A high partial correlation is one with practical and statistical significance represented by a result bigger than 0.70. Another method for determining the appropriateness of factor is using the entire correlation matrix, the Bartlett test of sphericity. It provides the statistical significance that the correlation matrix has significant correlations among at least some of the variables (Hair et al., 2009). A third measure to quantify the degree of intercorrelation among variables is the measure of sampling adequacy (MSA), the index that varies from 0 to 1, reaching 1 when each variable is perfectly predicted without error by the other variables (Hair et al., 2009).

The next step is to determine the factor extraction method and the number of factors to be extracted. To determine the technique of factor extraction some basic characteristics of the relations between the variables need to be clarified. At this point, it is important to understand the difference between common factors and principal component analysis (PCA). Both techniques aim to generate a linear combination of the variables that capture the maximum variance of observed variables (Filho and Júnior, 2010). PCA considers the total of variance and derives factors that contain a small proportion of unique variance and, in some cases, error variances. PCA does not discriminate between shared and unique variance (Hair et al., 2009; Costello and Osborne, 2005). Meanwhile, the analysis of the common factors reflects only the shared variance, if both are unique and error variance are not of interest in defining the structure of the variables (Hair et al., 2009).

The EFA deal with several model-fitting methods or factor-extraction procedures. They differ on the parameters estimative (factor loading and unique variances) of the common factor model (Fabrigar et al., 1999). The ones included at SPSS version 21 are unweighted least squares, generalized least squares, maximum likelihood (ML), principal axis factoring, image factoring, and alpha factoring.

The linear combination of variables in factor analysis may be defined to optimize some aspect of the expected relation between a sample and a population, this approach is summarized by the maximum likelihood (ML), unweighted least squares (ULS) and generalized least squares (GLS), which are all based upon common factor model. ML is the most popular (Nunnally and Bernstein, 1994); however, a limitation of ML is its assumption of multivariate normality (Fabrigar et al., 1999). The major difference between ML, GLS, and ULS are in the loss function that they minimize. ULS is more suitable than ML or GLS for highly non-moral data (Nunnally and Bernstein, 1994). The principal axis factoring is also commonly used and does not require the normality assumption (Laros, 2012).

PCA is preferred when the objective is to reduce data, while EFA is recommended when the research aims to detect the data structure (Costello and Osborne, 2005; Fabrigar et al., 1999). Many researchers wrongly believe that PCA is a type of exploratory factor analysis (Fabrigar et al., 1999). At SPSS statistical package the principal component analysis is presented as an extraction method of the exploratory factor analysis. However, some authors argue that the execution steps of both, PCA and EFA, are the same, and they can present similar solutions in the function of the data structure; there are some contexts in with this is not the big cases (Fabrigar et al., 1999; Nunnally and Bernstein, 1994). Differences in results are most likely when communalities are lower than 0.4, and there are a modest number of measured variables (e.g., three) per factor (Widaman, 1993).

For practical purposes, however, the choice of method is not a decision that will greatly affect empirical results. Other decisions, such as the number of factors to be retained or the rotation method, are more critical (Velicler and Jackson, 1990). In this research, the main objective is to reduce dimensionality.

The number of factors to be extracted should be determined, since some of the factors may explain a substantial of the total variance across all variables. This is an important step since both over-extraction and under-extraction of factors retained for rotation can have harmful effects on the results (Costello and Osborne, 2005). There are several criteria cited in the literature to conduct such an analysis (Hair et al., 2009), and no consensus among authors is found (Filho and Júnior, 2010). Determining the number of factors to be included in the model requires the researcher to balance the need for parsimony (a model with relative few factors) against the need for plausibility (a model with enough number of common factors to adequately account for the correlations among measured variables) (Fabrigar et. al, 1999).

One criterion is the Kaiser Criterion, which considers the eigenvalues, only those factors that have eigenvalues greater than 1 are considered significant, the others should be discarded (Rencher and Christensen, 2012; Hair et al., 2009). This is the default procedure in most statistical software; however, this is among the least accurate method for selecting the number of factors (Laros, 2012, Costello and Osborne, 2005;

Nunnally and Bernstein, 1994). Frequently, there is over-extraction when using the Kaiser criterion (Laros, 2012; Velicler and Jackson, 1990).

Alternate tests for factor retention include the scree test, Velicer's MAP criteria, and parallel analysis. Unfortunately, the latter two methods, although accurate and easy to use, are not available in some used statistical software (Costello and Osborne, 2005).

The scree test used to identify the optimum number of factors that can be extracted before the amount of unique variance being to dominate the common variance structure. The scree test is determined by plotting eigenvalues to the number of factors in their extraction order. The resulting curve is used to evaluate the cutoff point (Hair et al., 2009). The researcher should look for the natural bend or breakpoint in the data where the curve flattens out. The number of data points above the "break" (not including the point at which the break occurs) is usually the number of factors to retain (Costello and Osborne, 2005). While the Kaiser criterion employs absolute values of the eigenvalues, the scree rule uses a relative change in these values. The scree plot typically suggests fewer factors than Kaiser rule when the average level of correlation is low and/or several variables are high (Nunnally and Bernstein, 1994).

The Parallel analysis was proposed by Horn (1965) and is based on the generation of random variables for estimating the component that needs to be subtracted. The proposition is that the number of common factors should not be determined using the eigenvalues bigger than one. The parallel analysis determines the number of common factors by selecting the number of the eigenvalues of a correlation matrix that were greater than or equal to those provided by data computer-simulated with known characteristics. The idea is to generate random data of similar size and calculate the latent roots and vectors of these random data to provide a criterion tailored to the data set being analyzed (Horn,1965).

Only factors that correspond to empirical eigenvalues, which exceed the mean values of the eigenvalues obtained randomly, would be extracted. Empirical eigenvalues less than or equal to the random eigenvalues would be due to the random sample variance (Laros, 2012). An advantage of the parallel tests model is that its assumptions make it easy to grasp useful conclusions about how individual items relate to the factors or latent variables, based on our observations of how the items relate to one another (DeVellis, 2003).

A third criterion is the percentage of the total variance. No absolute threshold has been adopted for all applications (Hair et al., 2009; Rencher and Christensen, 2012; Nunnally and Bernstein, 1994). Hair et al. (2009) consider that 60% is satisfactory in social sciences studies, Rencher and Christensen (2012) recommend 80%. But this value depends heavily upon average correlation; consequently, this rule is inapplicable as advice to determinate the number of factors (Nunnally and Bernstein, 1994).

Factor rotation simplifies the structure of factor loads and often makes the factors more clearly distinguishable and easy to interpret. In this way, step 3 consists of deciding the type of rotation of the factors, which can be orthogonal or oblique. Unrotated factor loads are often difficult to interpret. The simplest case of rotation is orthogonal. The type of rotation most commonly used is varimax, which has been very successful as an analytical approach to obtain an orthogonal rotation of factors (Hair et al., 2009). A factor with fewer than three items is generally weak and unstable; 5 or more strongly loading items (.50 or better) are desirable and indicate a solid factor (Costello and Osborne, 2005).

The analysis considered 'Principal Component Analysis' as the method to extract the factor and the varimax as the rotation method, as the main objective is the dimensionality reduction. The PCA was performed for each set of variables representing the competitive priorities as well as the outputs. The following subtopics present the results of the PCA in each category. The input category of environmental factors and the output category of financial issues do not require the factor analysis as they have only three and one variables, respectively, and therefore are not necessary to reduce the number of variables. The steps used in PCA for each category, as well as the objective, are presented in Figure 35.

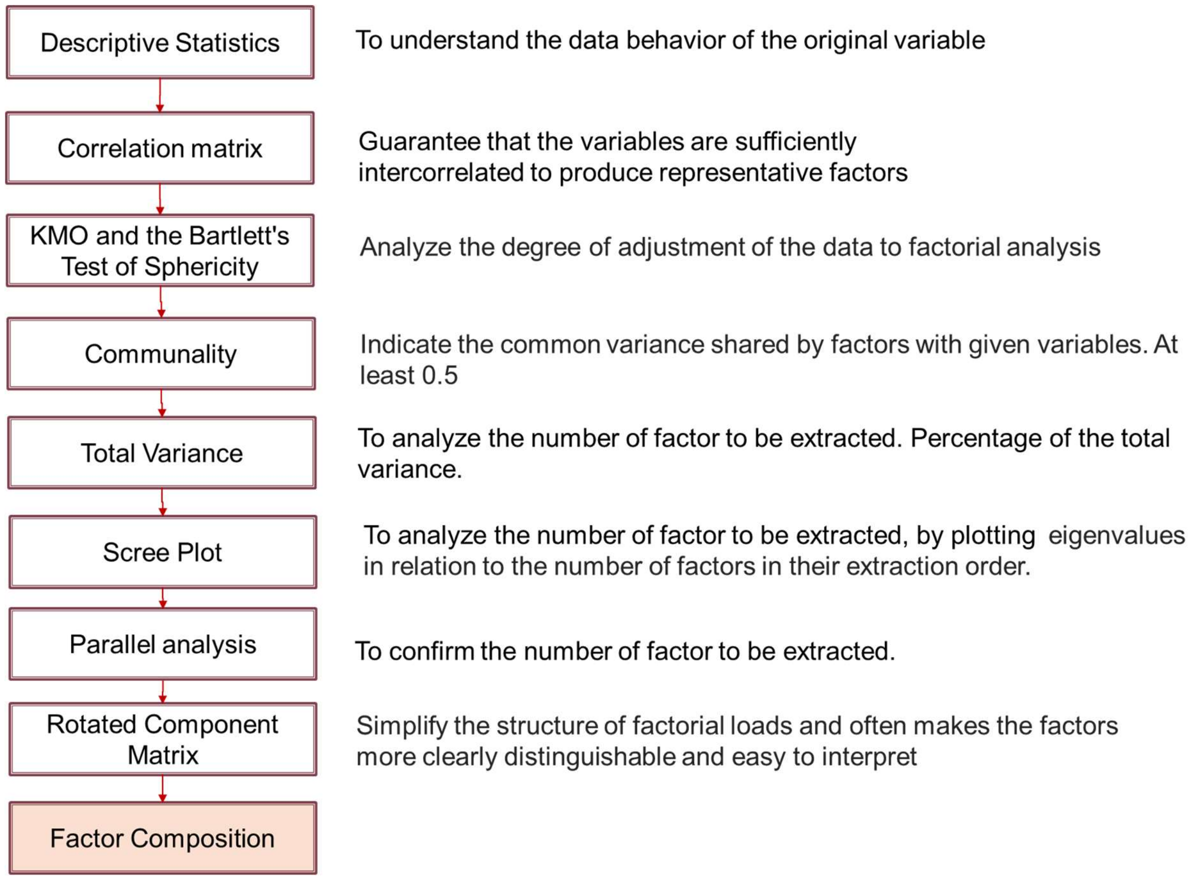


Figure 35 - Principal component analysis steps

Each of these steps is developed in detail to each input (cost, dependability, environmental factors, flexibility, quality, reliability, and speed) and output categories (customer results). The exceptions are the output category of financial issues and the input innovativeness category. The results are next summarized.

Descriptive Statistics

The descriptive statistics of the original variables used to begin the PCA development for each criterion are presented in appendix C.

Correlation Matrix

The correlation matrix reveals the significance of the Pearson correlation values tests. Based on this result an exclusion variables procedure was promoted to some criteria, as some of the original variables presented a low correlation value within the other ones. In this case, it is recommended to exclude the variable (Hair et al., 2009). Only one variable to cost was excluded due to a low correlation in the PCA. To the innovativeness category, the correlation matrix exposed a low correlation between many of the variables, not allowing the PCA promotion.

KMO and Bartlett's Test of Sphericity

The Bartlett test of sphericity provides the statistical significance that the correlation matrix has significant correlations among at least some of the variables (Hair et al., 2009). The null hypothesis of the Bartlett sphericity test states that there is no correlation between the initial variables. Therefore, values greater than 0.1 indicate that the null hypothesis cannot be rejected and that the data are not suitable for treatment. Therefore, a p-value of less than 0.1 is desired, which rejects the null hypothesis (Filho and Júnior, 2010). Another measure to quantify the degree of intercorrelation among variables is the measure of sampling adequacy (MSA), the index that varies from 0 to 1, reaching 1 when each variable is perfectly predicted without error by the other variables. This test is promoted utilizing Kaiser-Meyer-Olkin (KMO) at SPSS software. Results bigger than 0.80 is meritorious, 0.70 or above is middling, 0.60 or above, mediocre, 0.50 or above, miserable and bellow 0.50 is unacceptable (Hair et al., 2009).

The KMO as well as the significance level of Bartlett's Test of Sphericity, at the beginning of the PCA, to each category are presented in Table 17.

Table 17 - KMO and Bartlett's test of sphericity

Category	KMO	Test of Sphericity (Sig)
Cost (C)	0.749 (middling)	0.000
Dependability (D)	0.646 (mediocre)	0.000
Environmental factors (E)	0.852 (meritorious)	0.000
Flexibility (F)	0.735 (middling)	0.000
Innovativeness (I)	Not applicable	Not applicable
Quality (Q)	0.844 (meritorious)	0.000
Reliability (R)	0.572 (miserable)	0.000
Speed (S)	0.799 (middling)	0.000
Financial results (FO)	Not applicable	Not applicable
Clients results (CO)	0.775 (middling)	0.000

KMO results ranged from mediocre to meritorious, but all categories have enough indication of sampling adequacy for the PCA method. Bartlett's Test of Sphericity test has also determinate conformance.

Communality

The communality of a variable is the estimation of its shared variance between the variables as presented by the obtained factors (Hair et al., 2009). Usually, the minimum acceptable value is 0.50. Therefore, if the researcher finds any communality below this threshold, the variable must be excluded, and the PCA must be performed again. Since a low communality among a group of variables is an indication that they are not linearly correlated and therefore should not be included in the PCA (Filho and Júnior, 2010; Fabrigar et al., 1999). The variables with communalities smaller than 0.5 were also excluded from the study. Table 18 demonstrates the variables with low communality in the first run of the PCA.

Table 18 - Excluded variables for low communality

Category	Excluded variables for low communality
Cost (C)	COSTCN03
Dependability (D)	GLOBLX11, LINKCN02, ONTIMN04
Environmental factors (E)	CPADVN08
Flexibility (F)	DESCHGN02, RECNFGN06, RECNFGN04
Innovativeness (I)	N.A.
Quality (Q)	POSTNX04, SATISN04, SATISR06
Reliability (R)	None
Speed (S)	NPDPFX13
Financial results (FO)	N.A.
Clients results (CO)	POSTNX05, SATISN03

Total Variance and Scree Plot

The Kaiser Criterion is the default procedure in the SPSS software to define the number of factors to be extracted. However, it is considered the least accurate method for selecting the number of factors for some authors (Laros, 2012, Costello and Osborne, 2005; Nunnally and Bernstein, 1994) which states that frequently there is over-extraction when using the Kaiser criterion. So, the parallel analysis was also performed. Table 19 compared the recommendation of the number of factors to be extracted with both methods.

Parallel analysis

The parallel analysis was promoted using syntax by Brian O'Connor (O'Connor, 2018) and this criterion prevailed to define the number of factors to be extracted.

Table 19 - Recommendation of the number of factors to be extracted

Category	Kaiser Criterion	Parallel Analysis
Cost (C)	2	2
Dependability (D)	1	1
Environmental factors (E)	2	2
Flexibility (F)	6	3
Innovativeness (I)	N.A.	N.A.
Quality (Q)	5	2
Reliability (R)	2	2
Speed (S)	2	1
Financial results (FO)	N.A.	N.A.
Clients results (CO)	2	2

For flexibility variables, the Kaiser criterion recommended six factors and the parallel analysis only three. For quality variables, the Kaiser criterion recommended five factors and the parallel analysis only two. For Speed variables, the total variance recommended two factors to be extracted while the parallel analysis indicated only one. Based on the parallel analysis results, PCA has performed again with the fixed number of factors recommended by parallel analysis. For some variables, the parallel analysis confirmed the results given by Kaiser Criterion. The cost, environmental factors, and reliability variables had two factors extracted as well as the client results variables. Dependability variables had one factor extracted.

Rotated Component Matrix

PCA was performed with a varimax rotation method. The Rotated component matrix was performed to identify the factorial loads of each variable concerning the extracted components. Based on these results the weight of each variable to compose the component was established, which are proportional to the given component load. Table 20 indicates the number of interactions in the rotated matrix, the number of original and new variables.

Table 20 - Number of iterations

Category	Number of iterations to the converged rotation	Number of original variables	Number of factors or new variables
Cost	3	9	2
Dependability	-	6	1
Environmental factors	3	10	2
Flexibility	4	18	3
Innovativeness	N.A.	13	N.A.
Quality	3	19	2
Reliability	3	4	2
Speed	-	7	1
Financial results	N.A.	1	N.A.
Clients results	3	10	2

Factor/Component Composition

Table 21 summarizes the initial eigenvalues (EV), as well as the cumulative percentage of the total variance that the component can explain (TV) through the 'Rotation Sums of Squared Loadings'.

Table 21 - Component composition

Cat.	Component	EV	TV
C1	Manufacturing cost	3.21	45.92
C2	Manufacturing cost - recently launched products	2.06	75.33
D1	Dependability performance	1.97*	65.62*
E1	Capacity of environmental practices positively influence results	4.00	44.43
E2	Overall environmental performance	1.98	66.39

* Extraction Sums of Squared Loadings

Table 21 (continuation) - Component composition

Cat.	Component	EV	TV
F1	Customer vision about flexibility	2.20	27.52
F2	Changing mix/ volume Capacity	1.90	51.27
F3	Product customization	1.70	71.55
I1	Process technology innovativeness	N.A.	N.A.
I2	Equipment technology innovativeness	N.A.	N.A.
I3	Product innovativeness	N.A.	N.A.
Q1	Quality performance compared to competitors	3.72	41.36
Q2	Quality in recently launched products	2.11	64.8
R1	Reliability performance	1.74	43.55
R2	Recently launched products reliability	1.74	86.96
S1	Speed performance	2.71*	67.63*
FO1	Financial Performance	N.A.	N.A.
CO1	Market Share recently launched products	3.09	44.16
CO2	Customer satisfaction	1.99	72.55

* Extraction Sums of Squared Loading

To the innovativeness category, the correlation matrix exposed a low correlation between many of the variables, as can be seen in Table 22.

Table 22 - Correlation Matrix for innovativeness variables

		KNOWLN04	PROCSR01	DESTCHN02	DESTCHN05	ANTICN03	DESTCHN03	PROCSX05	EQUIPN04	YPREVN02	EQUIPN06	EQUIPN01	GLOBLX12	PRDCTX04
Correlation	KNOWLN04	1.000	.114	.110	.199	.216	.207	.061	.139	.071	.088	.130	.120	-.020
	PROCSR01	.114	1.000	-.049	.094	-.079	-.095	.140	.014	-.115	.105	.113	-.140	.135
	DESTCHN02	.110	-.049	1.000	.217	.465	.435	.144	.333	.409	.210	.247	.031	-.121
	DESTCHN05	.199	.094	.217	1.000	.417	.250	.158	.251	.208	.378	.307	.164	.002
	ANTICN03	.216	-.079	.465	.417	1.000	.377	.202	.320	.306	.297	.382	.035	-.109
	DESTCHN03	.207	-.095	.435	.250	.377	1.000	.080	.295	.323	.126	.212	.167	-.153
	PROCSX05	.061	.140	.144	.158	.202	.080	1.000	.125	.124	.175	.141	.033	-.009
	EQUIPN04	.139	.014	.333	.251	.320	.295	.125	1.000	.495	.348	.477	.166	-.099
	YPREVN02	.071	-.115	.409	.208	.306	.323	.124	.495	1.000	.268	.333	.107	-.110
	EQUIPN06	.088	.105	.210	.378	.297	.126	.175	.348	.268	1.000	.576	.075	.118
	EQUIPN01	.130	.113	.247	.307	.382	.212	.141	.477	.333	.576	1.000	.015	.107
	GLOBLX12	.120	-.140	.031	.164	.035	.167	.033	.166	.107	.075	.015	1.000	-.258
	PRDCTX04	-.020	.135	-.121	.002	-.109	-.153	-.009	-.099	-.110	.118	.107	-.258	1.000
Sig.	KNOWLN04		.053	.059	.002	.001	.002	.192	.024	.159	.105	.033	.045	.388
	PROCSR01	.053		.245	.091	.132	.090	.023	.423	.052	.069	.054	.024	.028
	DESTCHN02	.059	.245		.001	.000	.000	.021	.000	.000	.001	.000	.332	.044
	DESTCHN05	.002	.091	.001		.000	.000	.013	.000	.001	.000	.000	.010	.490
	ANTICN03	.001	.132	.000	.000		.000	.002	.000	.000	.000	.000	.310	.062
	DESTCHN03	.002	.090	.000	.000	.000		.127	.000	.000	.036	.001	.009	.015
	PROCSX05	.192	.023	.021	.013	.002	.127		.038	.040	.006	.023	.323	.452
	EQUIPN04	.024	.423	.000	.000	.000	.000	.038		.000	.000	.000	.009	.079
	YPREVN02	.159	.052	.000	.001	.000	.000	.040	.000		.000	.000	.064	.059
	EQUIPN06	.105	.069	.001	.000	.000	.036	.006	.000	.000		.000	.145	.048
	EQUIPN01	.033	.054	.000	.000	.000	.001	.023	.000	.000	.000		.417	.066
	GLOBLX12	.045	.024	.332	.010	.310	.009	.323	.009	.064	.145	.417		.000
	PRDCTX04	.388	.028	.044	.490	.062	.015	.452	.079	.059	.048	.066	.000	

Denis (2019) argues that does not make sense to perform PCA if the analyzed variables are not at least to some degree correlated. Therefore, considering the low correlation level of Innovativeness, it is more coherent to classify the variables of this category as formative constructs as there is a set of exogenous variables. According to Hair et al. (2009) in this situation, the indicator causes the construct, whereas, in more conventional reflexive constructs the indicator is caused by the latent variable. The compression of the innovativeness variables was then promoted through semantic analysis, applying an affinity diagram. In this procedure, three groups of variables were defined; they are related to equipment technologies, process technologies, and product innovativeness.

Table 23 - Innovativeness variables groups

Affinity Group	Variable	Code
Process technology innovativeness	We quickly adopt new technologies by applying what we learn from our customers.	KNOWLN04
	We often fail to achieve the potential of new process technology.	PROCSR01
	As new technologies emerge, we modify our production technology.	DESTCHN02
	There are no substitutes for our production technology.	DESTCHN05
	Our plant stays on the leading edge of new technology in our industry.	ANTICN03
	Our current production technology is protected by patents.	DESTCHN03
	Posture toward new processes	PROCSX05
Equipment technology innovativeness	We frequently modify equipment to meet our specific needs.	EQUIPN04
	In order to improve equipment performance, we sometimes redesign equipment.	YPREVN02
	We produce a substantial amount of our equipment in-house.	EQUIPN06
	We actively develop proprietary equipment.	EQUIPN01
Product innovativeness	Product innovativeness	GLOBLX12
	Posture toward new products	PRDCTX04

The composition of new variables was formed based on the average of the original variables for each group.

4.2.2.4. Variables summary

The following tables include a summary of the procedure to reduce the number of variables in a meaningful way, promoted through the PCA. Table 24 includes a summary for input variables and 25 for the outputs one.

Table 24 - Summary of input variables

Category	Factor (New Variable)		Original variable	Previous Variable	Weight
Cost	1	Manufacturing cost	POSTNX01	Product selling price	17.45%
			GLOBLX01	The unit cost of manufacturing	18.93%
			GLOBLX23 and DISTIX12	Labor cost	42.47%
			GLOBLX27	Operating expense	21.15%
	2	Manufacturing cost - recently launched products	SUCCSX08	recently launched products success - Unit manufacturing cost	49.56%
			NPDPFX11	The unit cost of manufacturing of recently launched products	50.44%
Dependability	1	Dependability performance	CREDCN01	The promises that our plant makes to its customers are reliable	35.56%
			GLOBLX03	On-time delivery performance	29.74%
			ONTIMN03	Our customers can rely on us for punctual delivery	34.69%
Flexibility	1	Customer vision about company flexibility	FLEXCN02	Our customers select us because we deliver flexibility for their needs	32.56%
			FLEXCN03	Our customers can rely on us for flexibility	31.85%
			FLEXCN04	We are selected by our customers because of our reputation for flexibility	35.59%
	2	Production system capacity of changing production mix and volume in the vision of the plant manager	GLOBLX05	Flexibility to change product mix	49.43%
			GLOBLX06	Flexibility to change the volume	50.57%
	3	Product customization	MCUSTN03	Our setup cost, changing from one product to another, is very low - Process Engineering	24.05%
			MCUSTN01	We are highly capable of large-scale product customization	24.39%
			MCUSTN02	We can easily add significant product variety without increasing the cost	24.33%
			MCUSTN04	We can customize products while maintaining a high volume	27.23%
Innovativeness	1	Process technology innovativeness	KNOWLN04	We quickly adopt new technologies by applying what we learn from our customers.	14.29%
			PROCSR01	We often fail to achieve the potential of new process technology.	14.29%
			DESTCHN02	As new technologies emerge, we modify our production technology.	14.29%
			DESTCHN05	There are no substitutes for our production technology.	14.29%
			ANTICN03	Our plant stays on the leading edge of new technology in our industry.	14.29%
			DESTCHN03	Our current production technology is protected by patents.	14.29%
			PROCSX05	Posture toward new processes	14.29%

Table 24 - Summary of input variables (continuation)

Category	Factor (New Variable)		Previous Variable		Weight
Innovativeness	2	Equipment technology innovativeness	EQUIPN04	We frequently modify equipment to meet our specific needs.	25.00%
			YPREVN02	In order to improve equipment performance, we sometimes redesign equipment.	25.00%
			EQUIPN06	We produce a substantial amount of our equipment in-house.	25.00%
			EQUIPN01	We actively develop proprietary equipment.	25.00%
	3	Product innovativeness	GLOBLX12	Product innovativeness	50.00%
			PRDCTX04	Posture toward new products	50.00%
Quality	1	Quality performance compared to competitors – quality management vision	DIMENX08	Overall product quality perceived by customers	17.83%
			DIMENX04	Conformance to established standards	17.59%
			DIMENX01	Primary product performance characteristics	16.99%
			DIMENX02	Secondary options or features	15.62%
			DIMENX07	Aesthetics; how the product looks, feels, sounds, tastes or smells	15.77%
			DIMENX06	Serviceability; ease of repair	16.20%
	2	Quality performance compared to competitors in recently launched products	NPDPFX05	Conformance quality	29.27%
			NPDPFX01	Performance (functionality)	36.02%
			NPDPFX02	Features	34.71%
Reliability	1	Reliability performance compared to competitors – quality management vision'	NPDPFX03	Durability (life expectancy)	50.33%
			NPDPFX04	Reliability (time between failures)	49.67%
	2	Reliability performance compared to competitors in recently launched products	DIMENX05	Durability	50.16%
			DIMENX03	Reliability of the product	49.84%
Speed	1	Speed performance	GLOBLX04	Fast delivery - compared to competitors	24.82%
			GLOBLX09	Speed of new product introduction into the plant (development lead time) - compared to competitors	23.75%
			DISTIX11	Agile manufacturing	25.36%
			GLOBLX08	Cycle time (from raw materials to delivery)	26.06%
Environmental factors	1	The capacity of environmental practices positively influence other company's results	CPADVN01	Being environmentally conscious can lead to substantial cost advantages for our plant.	16.23%
			CPADVN02	Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	16.85%
			CPADVN04	Our plant can enter lucrative new markets by adopting environmental strategies.	17.63%
			CPADVN05	Our plant can increase market share by making our current products more environmentally friendly.	17.34%
			CPADVN06	Reducing the environmental impact of our plant's activities will lead to quality improvement in our products and processes.	14.48%
			CPADVN07	Better environmental performance can differentiate our plant from our competitors.	17.47%
	2	Overall environmental performance	OUTCMX01	Environmental performance	35.77%
			OUTCMX02	Regulatory performance	34.27%
			EPERFX01	Overall environmental performance - compare to others in your global industry on	29.96%

Table 25 - Summary of output variables

Category	Factor (New Variable)		Previous Variable		Weight
Financial Results	1	Financial Performance	GLOBLX25	Throughput: the rate at which the plant generates money through sales	100.00%
Clients Results	1	Market Share and customer satisfaction on recently launched products	NPDPFX10	Market share - recently launched products, compared to competitors	36.21%
			SUCCSX02	Market share - recently launched products	38.48%
			SUCCSX01	Customer satisfaction - recently launched products	25.32%
	2	Customer satisfaction	SATISN07	Our plant satisfies or exceeds the requirements and expectations of our customers	25.18%
			SATISN01	Our customers are pleased with the products and services we provide for them	26.36%
			SATISN05	Our customers have been well satisfied with the quality of our products, over the past three years	25.15%
			SATISN02	Our customers seem happy with our responsiveness to their problems	23.30%

The PCA conducted the reduction of 97 variables in 19 variables of 8 input and 2 output categories, allowing for the DEA study. The second level conceptual framework is a result of this data analysis.

4.2.3. Conceptual framework

The PCA provided a reduction in the number of variables, which is important to enabling replication of the model in later case studies.

According to the objective of the application of the PCA, the researcher can use one of the methods for reducing data (Hair et al., 2009). The purpose of conducting the PCA in this research extrapolates the objective to understand better the interrelationships between the variables and reducing the number of variables is of primary importance. It is sought to reduce the number of variables, to enable the replication of the data gathering in other companies that will be studied in case studies, as indicated in the research design chapter.

The procedure of replacing the original set of variables by a smaller number of new variables can be the factor score or multiple scales (Hair et al., 2009).

The conceptual framework developed after the factor results is presented in Figure 36 The framework identifies the input and output variables that will be used for the performance efficiency frontier purpose.

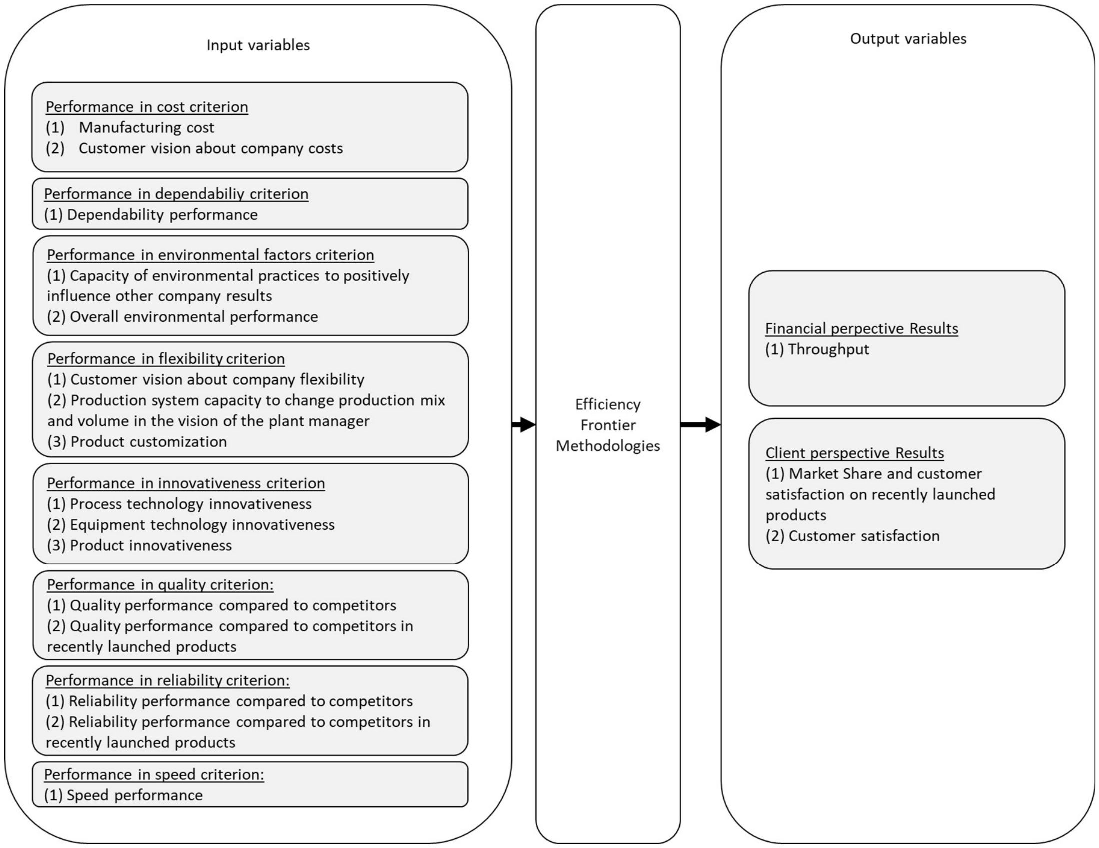


Figure 36 - Second stage conceptual framework

The conceptual framework presented the constructs to evaluate operations strategy in an input-output model allowing the development of performance efficiency frontier methodologies. The defined constructs are discussed in the next section.

4.2.3.1. Reliability analysis

Once the related question was identified, questionnaire comprehension can be tested. To do so, Cronbach’s alpha calculus was realized. Cronbach's Alpha is a reliability measure that varies between 0 and 1, being the most used coefficient to this end (Malhotra, 2010). Coefficient alpha is an appropriate reliability estimator for composite measures containing multiple components (Osburn, 2000). Values from 0.6 to 0.7 are considered the inferior limit of acceptance (Hair et al., 2009).

Cronbach's alpha analysis proceeded to the remain variables for each new variable. The Cronbach alpha examines the relationships among variables; therefore, it is important to find internal reliability within the factor variables. Table 26 presents the results for each of the factors generated or new variables.

Table 26 – Reliability Statistics Cronbach's Alpha for factor or new variables

Category	Component or not observed variable	Cronbach's Alpha
Cost	C1: Manufacturing cost	0.880
	C2: Customer vision about company cost	0.828
Dependability	D1: Dependability Performance	0.775
Environmental factors	E1: Capacity of environmental practices positively influence other company's results	0.899
	E2: Overall environmental performance	0.722
Flexibility	F1: Customer vision about company flexibility	0.818
	F2: Production system capacity of changing production mix and volume in the vision of the plant manager	0.775
	F3: Product customization	0.702
Innovativeness	I1: Process technology innovativeness	0.585
	I2: Equipment technology innovativeness	0.739
	I3: Product innovativeness	-0.692
Quality	Q1: Quality performance compared to competitors	0.876
	Q2: Quality performance compared to competitors in recently launched products	0.763
Reliability	R1: Reliability performance compared to competitors	0.851
	R2: Reliability performance compared to competitors in recently launched products	0.847
Speed	S1: Speed performance	0.839
Client Output	CO1: Market Share and customer satisfaction on recently launched products	0.751
	CO2: Customer satisfaction	0.882

Financial outputs are represented by single variables; therefore, no factors are formed. The components with results inferior of 0.70 are only the ones of the innovativeness category. Endorsing, therefore that they are not reflexive construct; therefore, the PCA as a variable selection procedure cannot be promoted, since it. The other categories generated by PCA, have an acceptable Cronbach alpha, as expected, confirming the consistency among variables inside the same component.

4.2.3.2. Descriptive Statistics for New Variables

At the descriptive statistics analysis values of kurtosis and skewness are presented. The Skewness coefficient allows distinguishing the asymmetric distributions. A negative value indicates that the tail on the left side of the probability density function is larger than the right side. A positive value for asymmetry indicates that the tail on the right side is larger than on the left side. A null value indicates that the values are distributed evenly on both sides of the mean. A normal distribution has the skewness coefficient equal to zero.

By making the quotient between the asymmetry coefficient and the standard error of the asymmetry, it is possible to obtain the Z score of asymmetries, which allows us to reject or not to suppose the asymmetry of the series. The asymmetry is present when the result in absolute value is bigger than 1.96 (Martins and Domingues, 2019), as demonstrated in Figure 37.

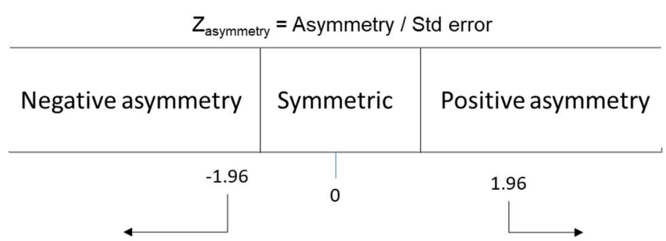


Figure 37 - Skewness reference
Source - Martins and Domingues (2019)

Kurtosis is a dispersion measure that characterizes the “tailedness" of the distribution function curve. By means of the excess kurtosis coefficient it is possible to determine the degree of this flattening and can be classified as platykurtic (kurtosis <0.00), mesokurtic (kurtosis = 0.00) or leptokurtic (kurtosis >0.00), as Figure 38.

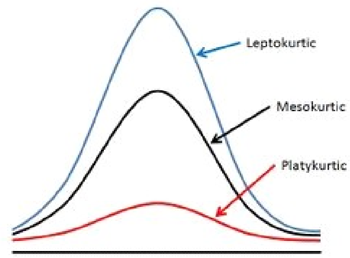


Figure 38 - Kurtosis analysis

Source - Martins and Domingues (2019)

Additionally, for its interpretation, it is possible to use, as in the case of asymmetry, the calculation of Z of kurtosis, which corresponds to the quotient between the kurtosis index and its standard error provided by SPSS, the reference is shown at Figure 39 (Martins and Domingues, 2019).

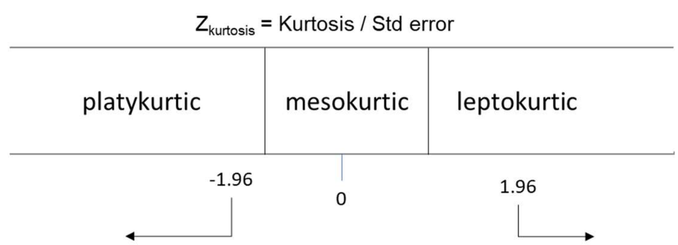


Figure 39 - Kurtosis reference

Source - Martins and Domingues (2019)

Table 27 summarizes the main descriptive data. The last column indicates the significance level of the Kolmogorov-Smirnov Normality test.

Table 27 - Summary of components descriptive

Category	Factor or not observed variable	N	Mean	Median	Std Deviation	Skewness	kurtosis Excess	Sig
Cost	COS_F1: Manufacturing cost, including operating expense	77	3.22	3.09	0.70	0.39	-0.68	0.581
	COS_F2: Customer vision about company cost	77	3.06	3.00	0.72	-0.07	-0.36	0.976
Dependability	DEP_F1: Dependability performance	77	4.06	4.05	0.65	-0.61	0.64	0.489
Environmental factors	ENV_F1: Capacity of environmental practices positively influence other company's results	77	3.41	3.39	0.79	-0.45	0.11	0.725
	ENV_F2: Overall environmental performance	77	4.11	4.04	0.58	-0.38	-0.49	0.193
Flexibility	FLE_F1: Customer vision about company flexibility	77	3.89	3.85	0.63	0.16	-0.45	0.084
	FLE_F2: Production system capacity of changing production mix and volume	77	3.82	3.99	0.71	-0.11	-0.25	0.190
	FLE_F3: Product customization	77	3.47	3.55	0.78	-0.72	0.86	0.279
Innovativeness	INO_F1: Process technology innovativeness	77	3.24	3.21	0.51	-0.17	0.11	0.709
	INO_F2: Equipment technology innovativeness	77	3.55	3.70	0.69	-0.27	-0.31	0.105
	INO_F3: Product innovativeness	77	3.86	3.80	0.66	0.02	-0.70	0.073
Quality	QUA_F1: Quality performance compared to competitors	77	3.76	3.79	0.51	-0.03	-0.65	0.520
	QUA_F2: Quality performance compared to competitors in recently launched products	77	3.89	3.83	0.53	0.22	0.15	0.039
Reliability	RE_F1: Reliability performance compared to competitors in recently launched products	77	3.80	3.75	0.61	0.34	-0.35	0.038
	RE_F2: Reliability performance compared to competitors – quality management vision'	77	3.83	3.82	0.66	0.20	-0.67	0.091
Speed	SPE_F1: Speed performance	77	3.65	3.47	0.65	0.69	-0.18	0.067
Client Output	CLI_F1: Market Share and customer satisfaction on recently launched products	77	3.61	3.56	0.72	-0.40	0.84	0.632
	CLI_F2: Customer satisfaction	77	3.94	3.92	0.63	-0.61	1.07	0.461
Financial Output	FIN_F1: Throughput: the rate at which the plant generates money through sales	77	3.60	3.55	0.86	-0.27	0.17	0.020

The database counted on 77 DMU for automotive companies HPM Dataset. The mean and the median are based on answers given by the 77 DMUs on 5 points Likert scale, where the bigger, the best.

The significance value reveals that most of the variables are normal. Only three components are non-normal, they are QUA_F2: Quality performance compared to competitors in recently launched products, RE_F1: Reliability performance compared to competitors in recently launched products and FIN_F1: Throughput: the rate at which the plant generates money through sales.

The non-normality of FIN_F1 could be expected since it is the original variable, and the process of new variable composition, grounded on Principal Component Analysis was not necessarily to this variable. The QUA_F2 and RE_F1 are non-normal components, even though their distribution behavior resembles a bell curve. The non-normality does not represent an issue to data envelopment analysis, as it is a non-parametric method.

4.3. PROCEDURAL FRAMEWORK

Five steps procedural framework is proposed to assess, measure and improve operations strategy, grounded on the calculation of the gap into the competitive criteria, based on the data of the best-performed companies. The proposed procedural framework, presented in Figure 40, encompasses first the data collection in the target DMU to identify both, operations strategy positioning and performance in the input and output variables. Second, the competitive scenario must be represented by benchmarking data; in this step, such a data is studied and interpreted. Next, the operations strategy of the target DMU is understood. The fourth step is about the performance efficiency frontier identification itself. To conclude, the final step indicates improvement recommendations concerning the operations strategy and performance frontier, focusing on improving the position among benchmarked companies.

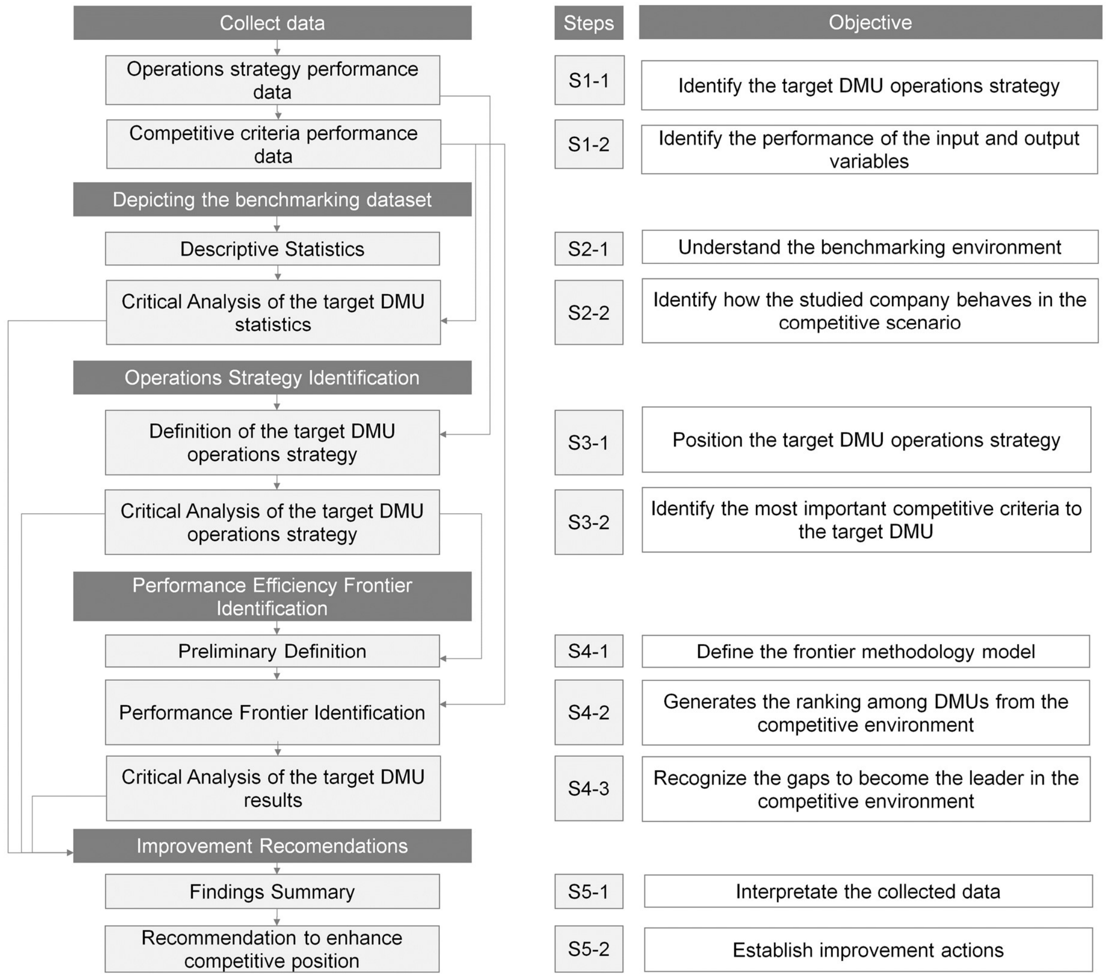


Figure 40 - Procedural framework steps

The framework demonstrates the steps in the sequence they must be performed, and the arrows indicate the relation between them. The operations strategy data, collected in the target DMU (S1-1), is later used to define its operations strategy positioning (S3-1). Step S3-1 in its turn allows the definition of the interest variables for the target DMU (S4-1). The competitive priority data collected in the target DMU (S1-2) is used first to compare the target DMU performance with the benchmarking dataset in the S2-2 and second, to perform the supper-efficiency estimation (S4-2). All steps feed the definition of improvement recommendation.

4.3.1. Data collection

As this study refers to the integration of two concepts, operations strategy and firm performance frontier, the data collection is made in two fronts. First, data to identify the operations strategy is required. Next, the performance in the studied performance dimensions needs to be framed. In doing so, two questionnaires are proposed. Both have to be answered by at least six people in the company: plant manager, downstream supply chain management, process engineering, product development, quality management, and environmental affairs. The respondent attribution is the same as the HPM project, to allow a homogeneous comparison.

The first questionnaire, of step S1-1, is based on the importance and performance matrix that allows the recognition of the relative importance of each of the manufacturing performance objectives according to clients' priorities, which should be aligned to manufacturing priorities. The matrix allows the assessment of the present performance achieved by the production function by comparing the performance of the organization with that of the competition. Therefore, it is possible to recognize the gaps between what is important to the operation and what performance is being achieved by classifying it into four zones. Identifying this gap provides the direction of choices and implementation of improvement plans (Slack et al., 2018).

The questions of the second questionnaire, of step S1-2, derivate from the 4th round of the HPM Project. A five-point Likert scale guides the answers, whereas the bigger the response index, the best. The scale content depends on the question. To collect the data, the original variables that compose the component (new variables) are used. Once the data of the original variables are collected, the index of the new variable is formed by calculating the weighted average. The questionnaires are found in appendix D.

4.3.2. Depicting the benchmarking dataset

This step aims to understand the competitive environment represented by the benchmarking data, and, from this, to identify how the studied company behaves in comparison with the competitors. The dataset depicting is promoted to the data regarding automotive companies, only. At this point, the database includes DMU data, with less than 30% of missing values. A total of 77 DMUs composes the sample. The reposition procedure by mean was applied for all remaining missing values.

Figure 41 presents the country composition of the 77 participants' DMUs. North Korea has 15.6%, Japan and Germany are both at 11.7%, Vietnam has 10.4%. Brazil participates with 9.1% of the companies.

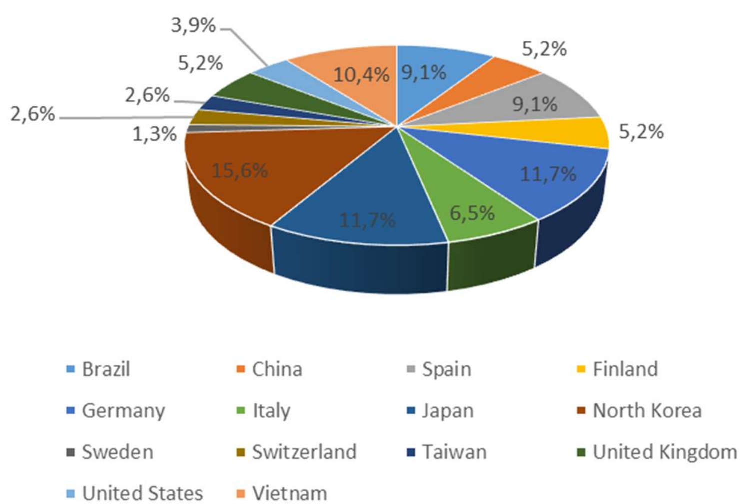


Figure 41 - Database country composition

The descriptive statistics (S2-1) were previously presented, in Table 27. By looking at the average performance of the benchmarked DMUs, it is possible to recognize the sector standard, e.g. in what variables the sector performs well and what are the critical ones. The studied automotive sector is good at overall environmental performance and dependability performance. On the other hand, it faces some issues about cost and process technology innovativeness.

In the S2-2, the studied company is compared with the average performance of the competitive data, to recognize detaching and poor performance. The variables are measured in 5 points Likert scale, whereas the bigger, the best. The analysis procedure calculates the gap from the target DMU performance and the average performance of benchmarking data. Gaps bigger than 20% should be brought to managerial attention. Positive values mean that the target company performs better than the sector average, likewise, negative values represent that the studied DMU is worse than the sector average.

4.3.3. Operations strategy identification

A detaching point of the proposed framework is being contextual driven, that is, the performance efficiency frontier analysis is developed to the variables that are important to the studied company. Therefore, each of the studied companies will have a particular frontier analysis method. The target DMU operations strategy is defined employing the average of both importance and performance indexes. The performance is classified as better, the same or worse than competitors and the importance of order-winning, qualifying or less important objectives. The order-winning criteria are those in which the company must seek to outperform its competitors to win customers. The qualifying criteria are those in which the organization must achieve the minimum level of performance accepted by the market to qualify to compete in it. Having a higher level of performance in the qualifying objectives does not contribute to the increase of its competitive power. Lastly, the least important criteria are those on which the customer is not based to make his purchasing decision (Corrêa and Corrêa, 2004).

4.3.4. Performance efficiency frontier identification

To perform the frontier identification, the frontier model must be specified (S4-1). At first, the DMUs under analysis should be defined. It is required homogeneity in terms of the period of analysis, type of business, and the number of employees.

The definition of the input and output variables was promoted in the conceptual framework previously developed in this work, through an in-dept statistical process for defining representative variables. At this stage, it is necessary to select which of the previously defined variables will be used in the analysis of the target company. The input variables include the order winning criteria identified in the foregoing step, since the objective of the model is to provide a benchmarking relative to the aimed DMU operations strategy, being context-driven or context-dependent.

This step deals with the selection of the target set of DMUs, as well as defining the DMU characteristics to control sample heterogeneity (period of analysis, type of business, number of employees, region, etc.). The dataset is the 4th round of the HPM Project, as this is the dataset used to statistically define the conceptual model.

The chosen frontier analysis method is the DEA with VRS (variable return to scale) and input orientation. This choice was made since the DEA model deterministic character; unlike the probabilistic stochastic frontier method, it is the technique that is closest to the possibility of comparing a producer with the group that is inserted (Anjos, 2005). The VRS (Variable Returns to Scale) or BCC (Banker, Charnes, and Cooper, 1984) assumes variable returns to scale and disregards the proportionality between inputs and outputs, covering a greater possibility of adaptation to the database.

The performance frontier is implemented through the supper-efficiency concept. The DEA model was performed, but a weakness addressed by some authors has materialized. A considerable number of units typically are characterized as efficient. Therefore, DEA does not allow for a ranking of the efficient units themselves (Esmaeilzadeh and Hadi-Vencheh, 2015; Kao, 2017; Bogetoft and Otto, 2011). Because of that, the super-efficiency Anderson and Petersen (1993) are performed to rank DMU and therefore allowing the discrimination between frontier firms. The term “supper-efficiency” is related to the DEA model in which the firms can obtain an efficiency score higher than one (Coelli et al., 2005).

The formulation below presents the SDEA (super-efficiency DEA) VRS dual model with input orientation, which is the base to the efficiency calculation of this study.

Minimize θ

(θ, λ)

Subject to:

$$\theta\, x_{io} - \sum_{k=1,\ k\neq 0}^{n} \lambda_k\, x_{ik} \geq 0;\ \forall i \qquad i=1,2,\ldots,r$$

$$\sum_{k=1,k\neq 0}^{n} \lambda_k\, y_{mk} - y_{mo} \geq 0;\ \forall m \qquad m=1,2,\ldots,s$$

$$\sum_{k=1,k\neq 0}^{n} y_k = 1$$

Where: y is the outputs, x is the inputs, λ the weighs. The decision variables are θ (scalar) and λ (weighs).

The ranking results allow the identification of the gaps into each of the competitive criteria, and from these, improvement recommendations are delineated.

4.3.5. Improvement recommendations

The higher ranked firms should improve the effectiveness of their operations in the competitive environment to hold their positions among the best practitioners of the market. The lower-ranked companies should benchmark the high ranked organizations to identify ways of improving their operational performance. This topic summaries the improvement opportunities concerning the operations strategy and the performance efficiency frontier analysis. The step S5-1 interprets the results from previous steps and seek to define improvement opportunities. The improvement recommendations can be detailed by the researcher together with the managerial team, in the S5-2.

4.3.6. Pilot case study

The procedural framework presented is implemented in a pilot case study to identify its applicability in a real context. The case study was realized in an automotive company located in Curitiba – Brazil, in June of 2019. The company will be mentioned in this study as Company A.

4.3.6.1. Data collection

The data were collected through the questionnaires of Appendix D. It is important to highlight that the analysis considered the main business of the target company since the strategic positioning varies according to the segment.

4.3.6.2. Depicting the benchmarking dataset

The benchmarking data was already presented in this dissertation. The graphs of Figure 42 compare the sector historical data with the target company performance.

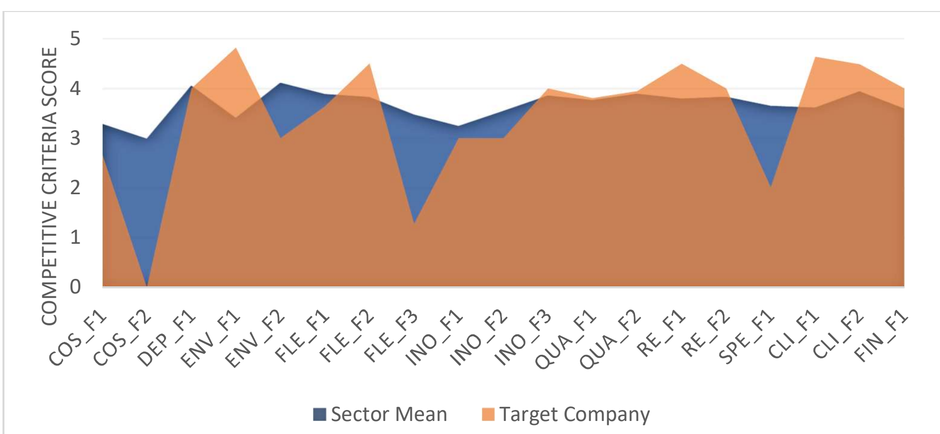


Figure 42 - Sector x target company performance variables (pilot case study)

It is possible to recognize that Company A is performing better than the sector average in half of the competitive priorities variables. To ‘ENV_F1: Capacity of environmental practices positively influence other company’s results’ Company A exceed in more than 1 point the industry average.

Company A is performing worse than the sector average to 8 of the 16 input variables. Whereas in two of those, Company A is more than 1.5 points weak than the industry average, they are: ‘FLE_F3: Product customization’ and ‘SPE_F1: Speed performance’.

Looking at the output variables, Company A is better positioned than the sector average to all of them, however, this is not a relevant difference, Company A exceeds the industry average by 22% (CLI_F1: Market Share and customer satisfaction on recently launched products), 12% (CLI_F2: Customer satisfaction) and 10% (FIN_F1: Throughput: the rate which plant generates money through sales).

4.3.6.3. Operations Strategy Identification

This topic presents the result of the answers gathered in the operations strategy questionnaire. The results demonstrate the strategic positioning of each of the competitive criteria. This is provided through the identification of two main elements (1) the importance is given by the customer to each of the competitive criteria at the time of the buying decision, and (2) the current performance of the studied company.

Definition of the target DMU operations strategy

About the Importance given by the customer, the results show that most of the criteria are ‘Order Winning,’ which means that the company must outperform its competitors to win customers, as this criterion is considered by customers in the buying decision. Only Environmental factors are considered ‘Qualifying’. The qualifying criteria are those in which the organization must achieve the minimum level of performance accepted by the market to qualify to compete in it. Having a higher level of performance in the qualifying objectives does not contribute to the increase of its competitive power.

Concerning the Performance, Company A is seeing as ‘Better than competitors’ in most of the criteria. Only in Flexibility, Speed and Cost, Company A is perceived as ‘The same as competitors. The results presented in Table 28 considered the mean of the participant's answers. The scale used is presented in appendix D.

Table 28 - Importance and performance indexes (pilot case study)

Operations Strategy Performance Criteria		Importance			Performance		
		Mean	Std Dvt	Classification	Mean	Std Dvt	Classification
1)	Cost	2.60	1.82*	Order-winning	6.29	1.11	The same as competitors
2)	Reliability	2.40	1.34	Order-winning	2.17	1.17	Better than competitors
3)	Flexibility	2.80	1.30	Order-winning	4.00	0.82	The same as competitors
4)	Innovativeness	3.80	1.30	Order-winning	3.57	1.72*	Better than competitors
5)	Quality	2.20	1.30	Order-winning	1.86	0.90	Better than competitors
6)	Speed	3.00	1.22	Order-winning	4.83	1.33	The same as competitors
7)	Environmental factors	5.80	1.79*	Qualifying	2.29	0.76	Better than competitors

* worse than the target result

The critical analysis is provided in two main views. First, the consistency among participants' answers is examined to avoid misinterpretation. Next, the operations strategy positioning concerning the competitive criteria performance and importance is presented. It is important to emphasize that the result is based on an opinion survey, and the answers can vary according to the participant's background. Even so, similar answers demonstrate the existence of a shared understanding of the company's strategic positioning.

Critical Analysis of the target DMU operations strategy

The answers are given by 7 representatives inside the company. There was found good concordance in answers to most criteria, but to some, there was a bigger variance of the answers, as can be seen in the standard deviation index. For analysis purposes, it is considered that a Standard deviation smaller than 1.5 represents a good answer standard. Looking at the importance scale results, it is possible to recognize that the criteria of 'Cost' and 'Environmental Factors' are the ones with smaller consensus among participants.

The analysis of the performance reveals a possible lack of consensus on the innovativeness variable, which presented a 1.72 standard deviation index. The consensus among participants is bigger to the performance scale than to the importance scale. A reasonable result since most of the participants does not have direct interaction with final customers.

Figure 43 presents a comparison of importance and performance classification in a graph form, where it is possible to identify if the company is performing behind or ahead of the required level of expectation from customers.

Figure 43 - Importance x performance radar graphic (pilot case study)

From the graphic, it is possible to identify that cost is important to customers (classification about 2.60 – usually considered by customers), but the company performance is not along with this importance (classification about 6.30 – often within striking distance of the main competitors). The same behavior, but more smoothly, occurs to speed criterion. The opposite behavior is found in environmental factors. To this, the customer doesn't attribute so much importance, but the organization's performance is exceeding expectations.

The matrix of Figure 44 presents the classification of Importance and performance all together from a different perspective. The matrix allows the recognition of the relative importance of each of the manufacturing performance objectives according to the clients' priorities, which should be the manufacturing priorities. On the other hand, the matrix also promotes the evaluation of the actual performance achieved by the production function, by comparing the performance of the organization with that of the competition. Therefore, it is possible to recognize the gaps between what is important to the operation (based on the client's perspective) and what performance is being achieved by classifying it into four zones. Identifying this gap provides the direction of choices and implementation of improvement plans.

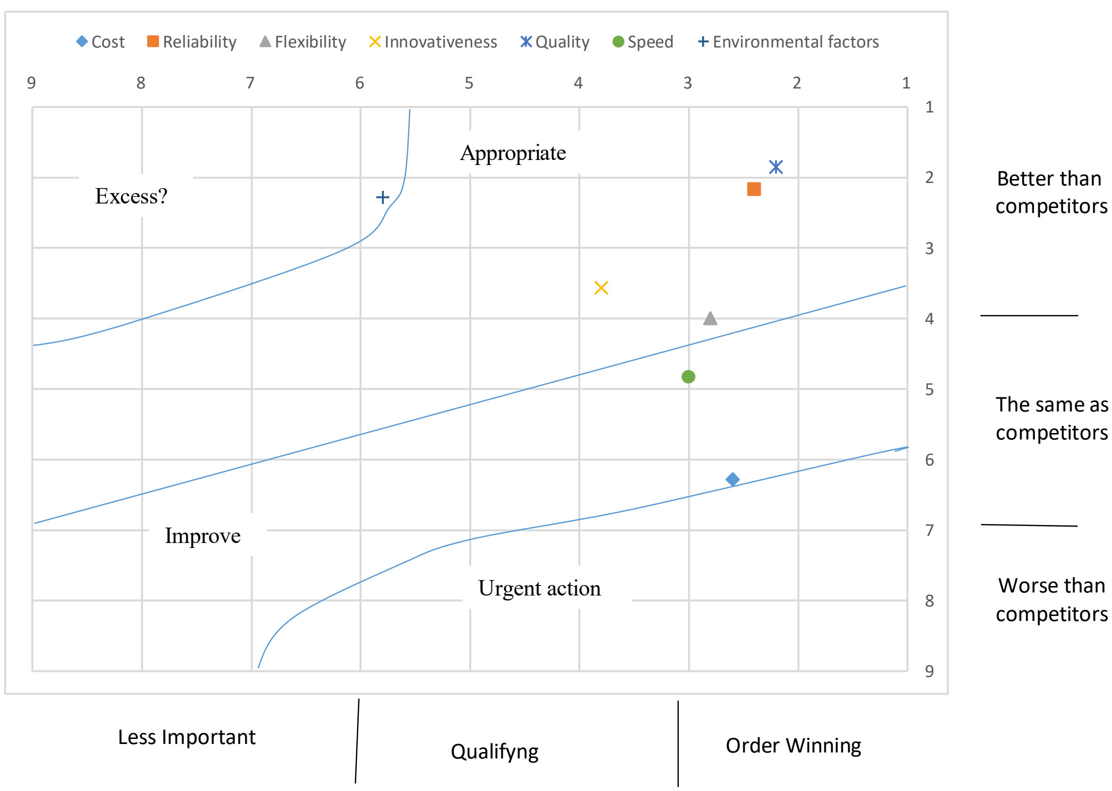


Figure 44 - Company A Importance x performance matrix (pilot case study)

Most of the criteria are in the 'appropriate zone,' which means that the performance is adequate from the customer perspective. Speed and cost are in the 'improve zone,' which covers the relevant improvement objectives but does not represent urgent cases. Both criteria are order-winning and have their performance at the same level as competitors. Therefore, there is an opportunity to establish actions to exceeds competitors. To cost the result is more critical since it is very close to the 'urgent action zone'. Still, it cannot be neglected to consider that the importance of attribution for the cost criterion had a dispersion above the expected. This fact may have influenced the result, so caution should be taken in assessing this criterion.

Environmental Factor is inside the 'excess' zone since it is perceived less importance from clients, but even so, Company A has an excellent performance. The company should analyze whether the resources devoted to achieving such a performance could be used elsewhere.

4.3.6.4. Performance Frontier Identification

This step is developed with data from the competitive criteria questionnaire (Appendix D).

Preliminary Definition

The performance efficiency frontier analysis is performed through the data envelopment analysis technique. Specifically, the variable return to scale dual model, with input orientation. It is considered the super-efficiency to rank DMU seeking to identify the best-performing companies. The performance efficiency frontier is calculated for automotive companies with 100 or more employees, considering the 4th round of the HPM database. The variables include the order winning criteria identified in the aforementioned step. To Company A, the model is as represented in Figure 45.

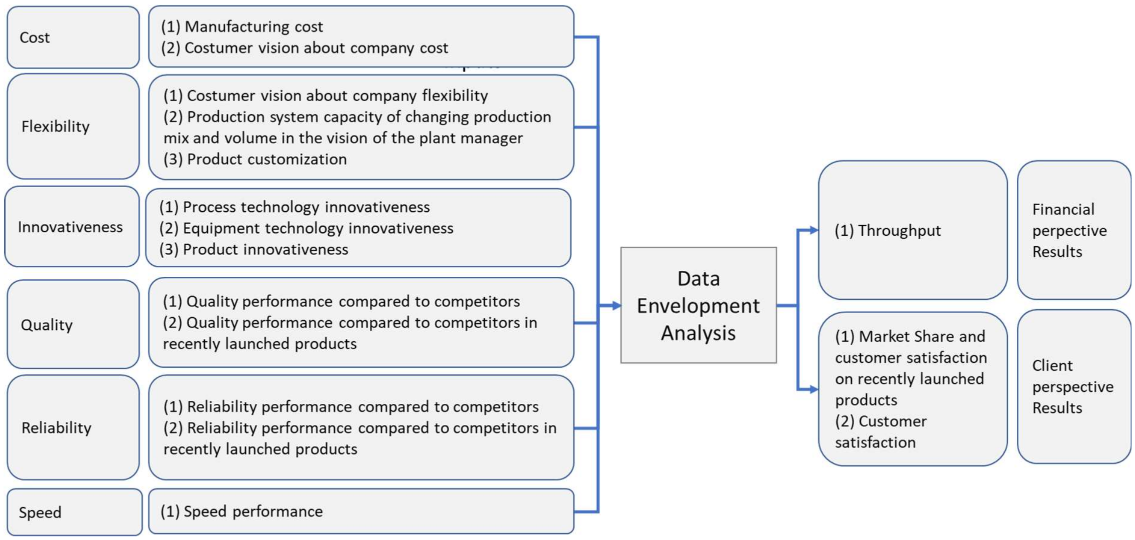


Figure 45 - Company A input and output variables (pilot case study)

Performance efficiency frontier identification

The ranking of the supper-efficiency model is indicated in Table 29. Company A is positioned on the thirty-second position of the ranking considering the supper-efficiency model oriented to input. The index means that 1304, which has a supper-efficiency index of 2.99 is better than the ones with lower scores because the former is further ahead of its peers.

Table 29 - Supper-Efficiency from DEA VRS dual input-oriented model

Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency
1	1304	2.9988006	27	315	0.997979561	53	905	0.676154501
2	1924	2.419353418	28	504	0.982055546	54	1216	0.673069146
3	1909	2.025320911	29	1809	0.981457949	55	606	0.66441412
4	502	1.9994003	30	1718	0.968497077	56	1204	0.662868203
5	922	1.744071829	31	407	0.966272242	57	813	0.658463051
6	1724	1.673833514	32	Company A	0.962906901	58	1328	0.649372588
7	1905	1.632851376	33	320	0.952724042	59	910	0.64603127
8	327	1.626218562	34	1709	0.943415281	60	411	0.641596656
9	703	1.550866367	35	714	0.918891495	61	920	0.640456181
10	1215	1.371144226	36	808	0.900205968	62	1207	0.632669512
11	330	1.366265484	37	814	0.888274516	63	0403	0.630503602
12	1904	1.310988096	38	702	0.875458321	64	1902	0.618691787
13	1801	1.25552192	39	805	0.863518812	65	1201	0.60726062
14	1920	1.250342589	40	807	0.841207608	66	903	0.603074252
15	816	1.2	41	803	0.839430199	67	921	0.601208544
16	822	1.17795428	42	409	0.827850589	68	1310	0.599172878
17	107	1.177595628	43	1723	0.823117574	69	415	0.596152557
18	1914	1.132325253	44	918	0.82264775	70	1704	0.594223218
19	902	1.059653269	45	914	0.796931137	71	904	0.591056628
20	1910	1.040926052	46	428	0.777361342	72	1327	0.559467855
21	106	1.04024011	47	101	0.768351813	73	926	0.502956972
22	503	1.032609087	48	406	0.746165885	74	1413	0.494230869
23	501	1.007132245	49	1220	0.734812626	75	421	0.468813493
24	1719	1	50	1211	0.690910937	76	810	0.463969115
25	901	1	51	1308	0.680711248	77	412	0.456660019
26	1716	1	52	1401	0.68045035	78	704	0.443849904

The improvement recommendations are given based on the three best-positioned DMUs: 1304, 1924 and 1909.

Critical Analysis of the target DMU results

Beyond the respondent's perception of the performance in each of the competitive criteria (operations strategy questionnaire), the second step of the data collection includes some specific questions related to each of the performance criteria (competitive criteria performance questionnaire). With those, it is possible to understand and confirm the index attributed to each criterion regarding their performance. The analysis of each of the competitive priorities is next presented.

Cost

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale
- Analysis procedure: Bigger, better
- Obtained punctuation: See radar graph below
- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points
- Analysis procedure: Smaller, better
- Obtained punctuation: 6.29 (Often within striking distance of the main competitors)
- Question: What is the company's performance compared to competitors?

Comparative analysis: *Strong Consistency*

Cost performance criterion was evaluated around 6 in performance scale (Often within striking distance of the main competitors). So, performance in cost, according to this scale, can be improved.

The specific questions confirmed this evaluation. The respondents considered cost much worse or somewhat worse than competitors to most of the topics.

Manufacturing costs, including operating expense	COS_F1	Topic	Question	1	2	3	4	5
Manufacturing Costs	POSTNX01	Product selling price	How do your plant's products compare to its leading competitors, on Product selling price?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Manufacturing Costs	GLOBLX01	Unit cost of manufacturing	How does your plant compare with its competitors in its industry, on a global basis, on Unit cost of manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Manufacturing Costs	GLOBLX23 and DISTIX12	Labor cost	How does your plant compare with its competitors in its industry, on a global basis, on Labor cost ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Manufacturing Costs	GLOBLX27	Operating expense	How does your plant compare with its competitors in its industry, on a global basis, on Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better

Environmental Factors

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale

- Analysis procedure: Bigger, better

- Obtained punctuation: See radar graph below

- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points

- Analysis procedure: Smaller, better

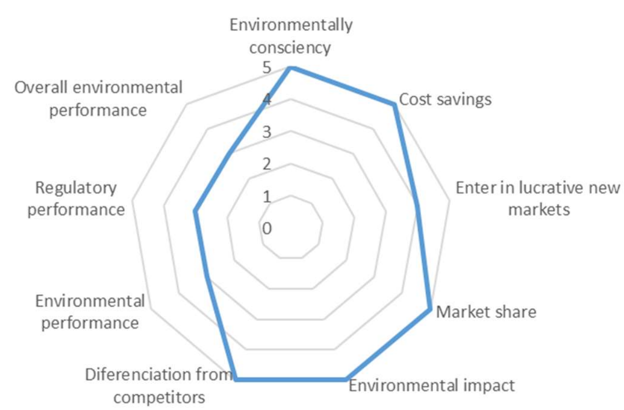
- Obtained punctuation: 2.3 (Consistently clearly better than competitors).

- Question: What is the company's performance compared to competitors?

Comparative analysis: *Strong Consistency*

Environmental Factors performance criterion was evaluated with an index of about 2.3 in performance scale (Consistently clearly better than competitors). So, performance in Environmental factors, according to this scale, is good.

The specific questions confirmed this evaluation since the answers were in the majority evaluated as much better. Some of the answers varied from Strongly agree with the good environmental performance or about the same as competitors.



Capacity of environmental practices positively influence other company's results'	ENV_F1	Topic	Question	1	2	3	4	5
Capacity of environmental practices positively influence other company's results	CPADVN01	Environmentally consciency	Indicate the extent to which you agree or disagree with each of the statement: Being environmentally conscious can lead to substantial cost advantages for our plant.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Capacity of environmental practices positively influence other company's results	CPADVN02	Cost savings	Indicate the extent to which you agree or disagree with each of the statement: Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Capacity of environmental practices positively influence other company's results	CPADVN04	Enter in lucrative new markets	Indicate the extent to which you agree or disagree with each of the statement: Our plant can enter lucrative new markets by adopting environmental strategies.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Capacity of environmental practices positively influence other company's results	CPADVN05	Market share	Indicate the extent to which you agree or disagree with each of the statement: Our plant can increase market share by making our current products more environmentally friendly.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Capacity of environmental practices positively influence other company's results	CPADVN06	Environmental impact	Indicate the extent to which you agree or disagree with each of the statement: Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Capacity of environmental practices positively influence other company's results	CPADVN07	Diferenciation from competitors	Indicate the extent to which you agree or disagree with each of the statement: Better environmental performance can differentiate our plant from our competitors.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Overall environmental performance	ENV_F2	Topic	Question	1	2	3	4	5
Overall environmental performance	OUTCMX01	Environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Environmental performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better
Overall environmental performance	OUTCMX02	Regulatory performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Regulatory performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better
Overall environmental performance	EPERFX01	Overall environmental performance	How does your plant compare to others in your global industry, in Overall environmental performance?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better

Flexibility

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale

- Analysis procedure: Bigger, better

- Obtained punctuation: See radar graph below

- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points

- Analysis procedure: Smaller, better

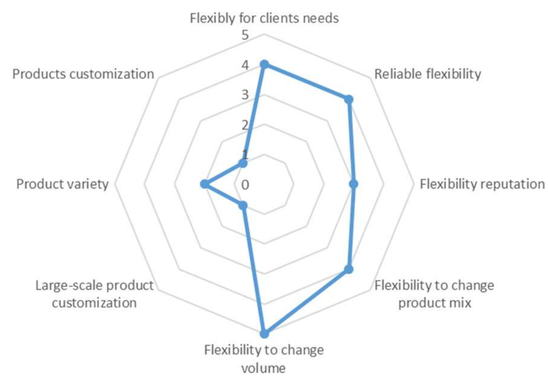
- Obtained punctuation: 4 (Often marginally better than competitors).

- Question: What is the company's performance compared to competitors?

Comparative analysis: *Consistency*

Flexibility performance criterion was evaluated around 4 in performance scale (Often marginally better than competitors). So, performance in flexibility is median.

The specific questions confirmed somewhat this evaluation. The customer vision about company flexibility and mix/volume flexibility was well evaluated, but the product customization had a poor performance perception.



Costumer vision about company flexibility	FLE_F1	Topic	Question	1	2	3	4	5
Costumer vision about company flexibility	FLEXCN02	Flexibly for clients needs	Indicate the extent to which you agree or disagree with each of the statement: Our customers select us because we deliver flexibly for their needs	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Costumer vision about company flexibility	FLEXCN03	Reliable flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Costumer vision about company flexibility	FLEXCN04	Flexibility reputation	Indicate the extent to which you agree or disagree with each of the statement: We are selected by our customers because of our reputation for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Production system capacity of changing production mix and volume in the vision of the plant manager	FLE_F2	Topic	Question	1	2	3	4	5
Production system capacity of changing production mix and volume in the vision of the plant manager	GLOBLX05	Flexibility to change product mix	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change product mixt ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Production system capacity of changing production mix and volume in the vision of the plant manager	GLOBLX06	Flexibility to change volume	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change volume?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Product customization	FLE_F3	Topic	Question	1	2	3	4	5
Product customization	MCUSTN01	Large-scale product customization	Indicate the extent to which you agree or disagree with The statement: We are highly capable of large scale product customization.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Product customization	MCUSTN02	Product variety	Indicate the extent to which you agree or disagree with The statement: We can easily add significant product variety without increasing cost.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Product customization	MCUSTN04	Products customization	Indicate the extent to which you agree or disagree with The statement: We can customize products while maintaining high volume.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree

Innovativeness

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale

- Analysis procedure: Bigger, better

- Obtained punctuation: See radar graph below

- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points

- Analysis procedure: Smaller, better

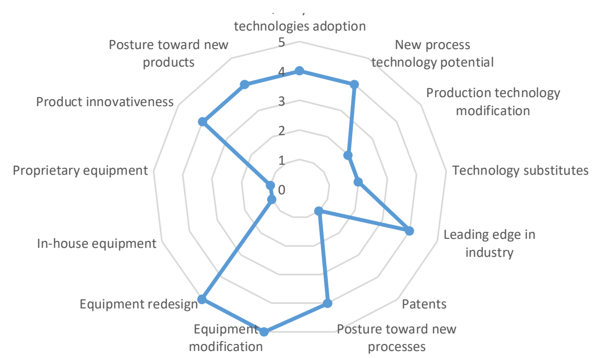
- Obtained punctuation: 3.57 (Often marginally better than most of the competitors).

- Question: What is the company's performance compared to the competitors?

Comparative analysis: *Consistency*

Innovativeness performance criterion was evaluated with an index of about 3.6 in performance scale (Often marginally better than most of the competitors). So, performance in Innovativeness is median.

The specific questions confirmed somewhat this evaluation. The innovativeness perception of good performance varies according to the variable. The product customization variable presented the lower innovativeness index.



Process technology innovativeness	INO_F1	Topic	Question	1	2	3	4	5
Process technology innovativeness	KNOWLN04	Quickly new technologies adoption	Indicate the extent to which you agree or disagree with the statement: We quickly adopt new technologies by applying what we learn from our customers.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Process technology innovativeness	PROCSR01	New process technology potential	Indicate the extent to which you agree or disagree with the statement: We often fail to achieve the potential of new process technology.	Strongly agree	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Strongly disagree
Process technology innovativeness	DESTCHN02	Production technology modification	Indicate the extent to which you agree or disagree with the statement: As new technologies emerge, we modify our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Process technology innovativeness	DESTCHN05	Technology substitutes	Indicate the extent to which you agree or disagree with the statement: There are no substitutes for our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Process technology innovativeness	ANTICN03	Leading edge in industry	Indicate the extent to which you agree or disagree with the statement: Our plant stays on the leading edge of new technology in our industry.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Process technology innovativeness	DESTCHN03	Patents	Indicate the extent to which you agree or disagree with the statement: Our current production technology is protected by patents.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Process technology innovativeness	PROCSX05	Posture toward new processes	Which term best describes the plant's posture toward new processes?	Never adopts new processes	Usually among the last to adopt new processes	Adopts new processes when it becomes more or less the general rule	Among the first to adopt new process, but not the leader	Leader in new processes
Equipment technology innovativeness	INO_F2	Topic	Question	1	2	3	4	5
Equipment technology innovativeness	EQUIPN04	Equipment modification	Indicate the extent to which you agree or disagree with the statement: We frequently modify equipment to meet our specific needs.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Equipment technology innovativeness	YPREVN02	Equipment redesign	Indicate the extent to which you agree or disagree with the statement: In order to improve equipment performance, we sometimes redesign equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Equipment technology innovativeness	EQUIPN06	In-house equipment	Indicate the extent to which you agree or disagree with the statement: We produce a substantial amount of our equipment in-house.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Equipment technology innovativeness	EQUIPN01	Proprietary equipment	Indicate the extent to which you agree or disagree with the statement: We actively develop proprietary equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree
Product innovativeness	INO_F3	Topic	Question	1	2	3	4	5
Product innovativeness	GLOBLX12	Product innovativeness	How does your plant compare with its competitors in its industry, on a global basis, on Product innovativeness?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Product innovativeness	PRDCTX04	Posture toward new products	Which term best describes the plant's posture toward new products?	Never adopts new products	Among the last to adopt new products	Adopts new products when it becomes more or less the general rule	Among the first to adopt new products, but not the leader	Leader in new products

Quality	
Competitive criteria performance questionnaire - Scale: 5 points Likert scale - Analysis procedure: Bigger, better - Obtained punctuation: See radar graph below - Questions: See Table below *Operations strategy questionnaire* - Scale: 1-9 points - Analysis procedure: Smaller, better - Obtained punctuation: 1.86 (Consistently considerably better than our nearest competitor) - Question: What is the company's performance compared to the competitors?	*Comparative analysis*: *Strong Consistency* Quality performance criterion was the best evaluated obtaining an index of about 1.8 in performance scale (Consistently clearly better than competitors). So, performance in quality, according to this scale, is good. The specific questions confirmed this evaluation since the answers vary from somewhat better or much better than competitors, except for serviceability and features in recently launched products.

Quality performance compared to competitors	QUA_F1	Topic	Question	1	2	3	4	5
Quality performance compared to competitors	DIMENX08	Overall product quality	How does the quality of your plant's products compare to its competitors' products on Overall product quality perceived by customers?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors	DIMENX04	Conformance to established standards	How does the quality of your plant's products compare to its competitors' products on Conformance to established standards?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors	DIMENX01	Primary product performance characteristics	How does the quality of your plant's products compare to its competitors' products on Primary product performance characteristics?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors	DIMENX02	Secondary options or features	How does the quality of your plant's products compare to its competitors' products on Secondary options or features; characteristics that supplement the basic functioning of the product?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors	DIMENX06	Serviceability	How does the quality of your plant's products compare to its competitors' products on Serviceability; ease of repair?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors in recently launched products	QUA_F2	Topic	Question	1	2	3	4	5
Quality performance compared to competitors in recently launched products	NPDPFX05	Conformance quality	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Conformance quality?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors in recently launched products	NPDPFX01	Performance (functionality)	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Performance (functionality)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Quality performance compared to competitors in recently launched products	NPDPFX02	Features	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Features?	Much worse	Somewhat worse	About the same	Somewhat better	Much better

Reliability

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale

- Analysis procedure: Bigger, better

- Obtained punctuation: See radar graph below

- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points

- Analysis procedure: Smaller, better

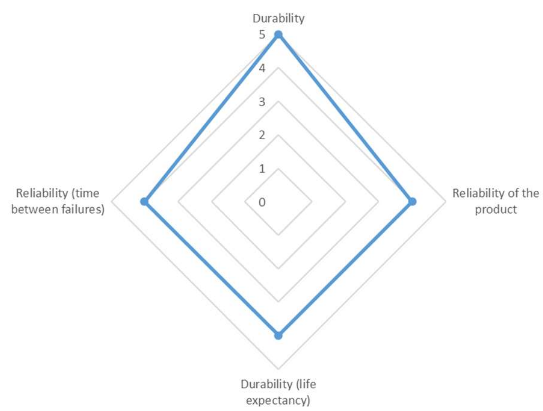
- Obtained punctuation: 2 (Consistently clearly better than competitors)

- Question: What is the company's performance compared to competitors?

Comparative analysis: Strong Consistency

The reliability performance criterion was evaluated with an index of about 2 in performance scale (Consistently clearly better than competitors). So, performance in reliability, according to this scale, is good.

The specific questions confirmed this evaluation since the answers vary from somewhat better or much better than competitors.



Reliability	RE_F1	Topic	Question	1	2	3	4	5
Reliability performance compared to competitors in recently launched products	DIMENX05	Durability	How does the quality of your plant's products compare to its competitors' products on Durability; amount of use before the product deteriorates or needs to be replaced?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Reliability performance compared to competitors in recently launched products	DIMENX03	Reliability of the product	How does the quality of your plant's products compare to its competitors' products on Reliability of the product; probability of failure in a specified time?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Reliability	RE_F2	Topic	Question	1	2	3	4	5
Reliability performance compared to competitors – quality management vision'	NPDPFX03	Durability (life expectancy)	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Durability (life expectancy)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better
Reliability performance compared to competitors – quality management vision'	NPDPFX04	Reliability (time between failures)	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Reliability (time between failures)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better

Speed

Competitive criteria performance questionnaire

- Scale: 5 points Likert scale

- Analysis procedure: Bigger, better

- Obtained punctuation: See radar graph below

- Questions: See Table below

Operations strategy questionnaire

- Scale: 1-9 points

- Analysis procedure: Smaller, better

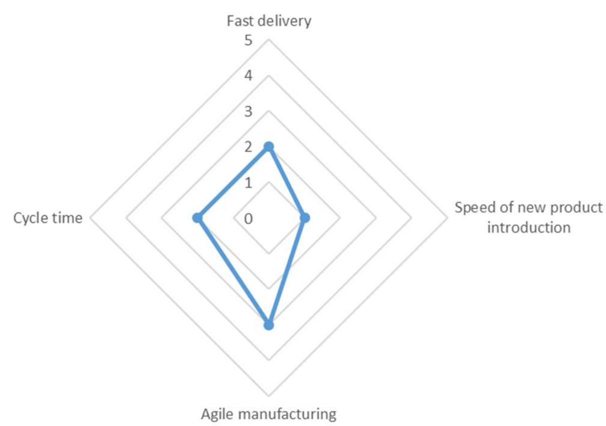
- Obtained punctuation: 4.83 (About the same than competitors)

- Question: What is the company's performance compared to competitors?

Comparative analysis: *Strong Consistency*

Speed performance criterion was evaluated around 5 in performance scale (About the same as competitors). So, performance in cost, according to this scale, can be improved.

The specific questions confirmed this evaluation since the answers varied from somewhat worse than competitors or about the same.



Speed performance	SPE_F1	Topic	Question	1	2	3	4	5
Speed performance	GLOBLX04	Fast delivery	How do your plant's products compare to its leading competitors, on Fast delivery?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Speed performance	GLOBLX09	Speed of new product introduction	How do your plant's products compare to its leading competitors, on Speed of new product introduction into the plant (development lead time)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Speed performance	DISTIX11	Agile manufacturing	How do your plant's products compare to its leading competitors, on Agile manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better
Speed performance	GLOBLX08	Cycle time	How do your plant's products compare to its leading competitors, on Cycle time (from raw materials to delivery)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better

The company respondents demonstrate a good and shared understanding of the operations strategy, and there was find the consistency among answers of *Competitive criteria performance questionnaire* and *Operations strategy questionnaire* to all variables.

The improvement recommendations are given based on the three best-positioned DMUs: 1304, 1924, and1909. This analysis seeks to recognize the performance drivers of the best-positioned DMUS and strategies to Company A to improve its position in the raking. Figure 46 shows the performance of Company A compared to the three best-positioned DMUs.

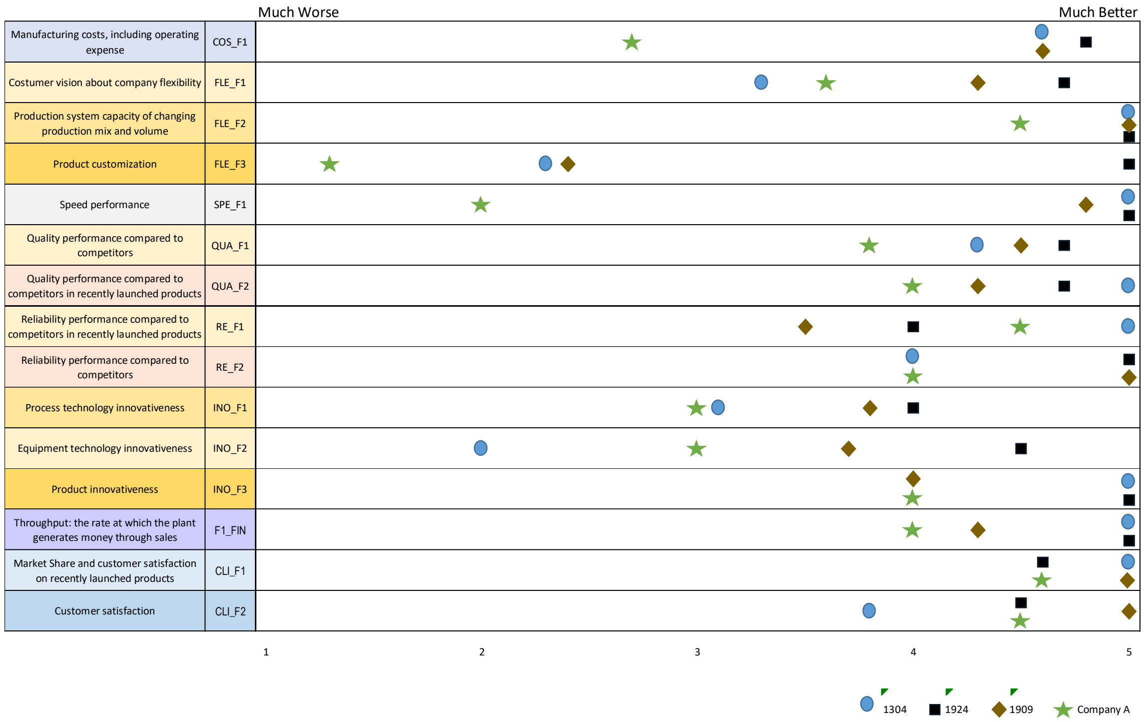


Figure 46 - Comparison of input variables performance (pilot case study)

As could be seen, there is no detached performance among top-ranked organizations. The advantage varies according to the variable. The same behavior occurs to output variables. There is a performance gap between Company A and the first positioned DMUs in some variables, which removes the studied company from the top positions in the ranking. To become the first position of the ranking, Company A must improve some input variables' performance, as well as to get a better result from the current performance of the output variables. Table 30 indicates the performance gap. To each of the input and output variables, the Company A current performance level is indicated, as well as the suggested performance level, which is based on the higher index of the three-best positioned DMU. Based on this, the gap (shortage) is then calculated. The shortage in % represents how many percent the performance of company A is lower than the suggested level. For example, FLE_F3 of company A is 72.9% smaller than the desired level. The % of needed improvement, in its turn, represents how much the current index of company A needs to be improved. For example, to achieve the suggested index in FLE_F3, company A needs to improve 269% its current performance level (1.28+1.28*269.22%=4.72).

Table 30 - Shortage of inputs and outputs (pilot case study)

	Company A Performance	Suggested Level	Shortage	% Shortage	% of needed improvement
Inputs					
FLE_F3	1.28	4.72	3.44	72.92%	269.22%
SPE_F1	2.02	5.00	2.98	59.68%	148.03%
COS_F1	2.66	4.79	2.13	44.52%	80.24%
INO_F2	3.00	4.50	1.50	33.33%	50.00%
INO_F1	3.00	4.00	1.00	25.00%	33.33%
FLE_F1	3.64	4.68	1.04	22.16%	28.47%
QUA_F2	3.95	5.00	1.05	21.00%	26.58%
RE_F2	4.00	5.00	1.00	20.00%	25.00%
INO_F3	4.00	5.00	1.00	20.00%	25.00%
QUA_F1	3.81	4.67	0.86	18.48%	22.67%
RE_F1	4.50	5.00	0.50	9.96%	11.06%
FLE_F2	4.51	5.00	0.49	9.89%	10.97%
Outputs					
F1_FIN	4.00	5.00	1.00	20.00%	25.00%
CLI_F2	4.48	5.00	0.52	7.23%	11.51%
CLI_F1	4.64	5.00	0.36	10.32%	7.80%

There are improvement opportunities in all the input and output variables. The biggest gap between Company A and suggested performance is for FLE_F3 (product customization), to this variable, Company A is 269% behind of DMU 1924 (the best performing DMU) and is behind of all the three references DMUs. The other flexibility variables also present call for improvement, but more smoothly. FLE_F1 (customer vision about company flexibility) is about one point behind DMU 1924 (28%), and FLE_F2 (production system capacity of changing production mix and volume) is only 0.5 points behind. To FLE_F1, Company A performs better than DMU 1304.

Speed represents the second-biggest gap, whereas Company A is 148% behind the suggested index. COS_F1 (manufacturing cost) also presented an important gap of 80% of the suggested level, which is coherent with the operations strategy questionnaire, where cost received the worse attribution. To both competitive priorities, Company A is worse than all the reference DMUs.

To innovativeness, Company A is not behind all the leading companies; however, all the innovativeness variables presented an important gap; INO_F2 (equipment technology innovativeness), INO_F1 (process technology innovativeness) and INO_F3 (product innovativeness), presented gaps of 50%, 33.3%, and 25%, respectively.

Looking at quality and reliability, despite these competitive priorities received the highest performance rating in the operations strategy questionnaire, two variables presented a gap equal to or bigger than 25%. QUA_F2 (quality performance in recently launched products) and RE_F2 (reliability performance compared to competitors) presented a gap of 26.58% and 25%, respectively. QUA_F1 (quality performance compared to competitors) and RE_F1 (reliability performance in recently launched products) presented a smaller gap of 22.7% and 11.1%, in this order.

On behalf of outputs, it is possible to identify a smaller difference between Company A and the best performing DMUs. The biggest gap is to F1_FIN (throughput), with a 25%- or 1-point difference.

4.3.6.5. Improvement recommendations

This topic summaries the call for improvement concerning the operations strategy and the performance efficiency frontier analysis. Recommendations are provided to deal with improvement opportunities.

Findings Summary

The summary of the main findings is presented in Table 31.

Table 31 - Summary of Findings (pilot case study)

Competitive Criteria	Findings	Description
Innovativeness	Lack of operations strategy consensus (performance scale)	The criterion of 'Innovativeness' has a low consensus among participants, presenting a standard deviation index of 1.72.
Cost	Lack of operations strategy consensus (importance scale)	The criterion of 'Cost' has a low consensus among participants, presenting a standard deviation index of 1.82.
Environmental Factors		The criterion of 'Environmental Factors' has a low consensus among participants, presenting a standard deviation index of 1.79.
Cost	Urgent Call for improvement in Cost	Cost is important to customers, but the company's performance is not consistent with this importance.
		COS_F1 presented an important gap of 80% of the suggested level, which is coherent with the operations strategy questionnaire, where cost received the worse attribution.
Speed	Urgent Call for improvement in Speed	Speed is important to customers, but the company's performance is not consistent with this importance.
		Company A is more than 1.5 points worse than the industry average, to 'SPE_F1: Speed performance.'
		Company A is 148% behind the suggested index and worse than all the reference DMUs.
Environmental Factors	'Excess' zone to Environmental Factors	Customer doesn't attribute so much importance to Environmental Factors, but the organization performance is exceeding expectations.
		To ENV_F1, Company A exceeds more than 1 point the industry average. However, the Environmental factor is not an order winning criterion for competition.
Flexibility	Urgent call for improvement in 'product customization.'	FLE_F3 (Product customization) has the biggest gap. Company A is behind the three-top positioner, with a performance of 269% smaller than the highest index.
		Company A is more than 1.5 points worse than the industry average, to 'FLE_F3: Product customization.'
	Call for improvement in Flexibility	The flexibility performance in behind the importance devoted by customers.
		FLE_F1 is one point behind DMU 1924 (28%).
Innovativeness	Call for improvement in innovativeness variables	Company A has all the innovativeness variables with an important gap, INO_F2 (Equipment technology innovativeness), INO_F1 (Process technology innovativeness), and INO_F3 (Product innovativeness), with gaps of 50%, 33.3%, and 25%, respectively.
Quality	Call for improvement in 'serviceability' and 'Features.'	Serviceability and Features in recently launched products had a poor performance perception in the Competitive criteria performance questionnaire.
	Not urgent call for improvement in Quality performance in recently launched products	Although this competitive priority received the highest performance rating in the operations strategy questionnaire, QUA_F2 presented a gap of 26.58%. QUA_F1 presented a smaller gap of 22.7%.
Reliability	Not urgent call for improvement in Reliability	Although this competitive priority received a high-performance rating in the operations strategy questionnaire, RE_F2 presented a gap of 25%. RE_F1 presented a smaller gap of 11.1%.
Output results	Good result	Company A is better positioned than the sector average to all of the output variables. An important advantage of 22%, is found in CLI_F1. CLI_F2 and FIN_F1 don't have a significant difference. Company A advantage is 12% and 10%, respectively.
Financial results (output)	Call for improvement in Financial results	The lowest output rate is to F1_FIN.

The call for improvement is delineated mainly to gaps bigger than 25%. This is because the supper-efficiency index is based on a perception scale, and the company positioning depends on the respondent's awareness of real performance. In doing so, there may be some variation between the response obtained and the actual performance.

Recommendations to enhance the competitive position

The improvement recommendations are addressed based on the findings; these were promoted with a discussion involving the respondents that participated in the data collection. The participants received the technical report with the results previously, to individual assessment. Then, a meeting was conducted to present the results formally and to discuss strategies to define the priorities as well as to detail the improvement recommendations, presented in Table 32. It is up to the managerial team to determine how to turn the improvement recommendations into detailed actions.

Table 32 - Improvement Recommendations

Improvement Recommendation	Competitive Criteria	Findings
Participant Consensus (shared understanding)		
Internal alignment of company initiatives	Innovativeness	Lack of operations' strategy consensus (performance scale)
Strengthen the sharing and discussion of customer's reports (e.g., market share and customer satisfaction)	Cost	Lack of operations' strategy consensus (importance scale)
	Environmental Factors	
Performance in key competitive criteria		
Determinate strategies to improve performance in the criteria that are considered important by clients	Cost	Urgent Call for improvement in Cost
	Speed	Urgent Call for improvement in Speed
Discuss the strategic positioning of being outperforming in environmental factors. If it represents a long-term strategy, it can be maintained.	Environmental Factors	'Excess' zone to Environmental Factors
Determinate strategies to improve performance in the criteria with low performance	Flexibility	Urgent call for improvement in 'product customization.'
		Call for improvement in Flexibility
	Innovativeness	Call for improvement in innovativeness variables
	Quality	Call for improvement in 'serviceability' and 'Features.'
		Not urgent call for improvement in Quality performance in recently launched products
	Reliability	Not urgent call for improvement in Reliability performance
Sustain the result in market share and customer satisfaction	Client results	Good result
Determinate strategies to convert good satisfaction into financial results	Financial results (output)	Call for improvement in financial results

The improvement recommendations are given to improve the shared managerial understanding of the operations' strategic positioning as well as to become better positioned in the frontier through the enhancement of the competitive priorities and business results. To Company A, the urgent call for improvement relies on cost, flexibility, and speed.

4.3.6.6. Findings into the framework development

The pilot case study revealed some improvement opportunities into both, the conceptual and the procedural framework. Some respondents Company A mentioned that serviceability should be stated as a variable. However, the HPM questionnaire does not support the study of serviceability as a single variable, as its constructs are not well defined. Therefore, the missing of serviceability can be considered as a limitation of the framework. Serviceability is inside the quality dimension. Reliability is also considered a quality dimension for some authors; however, Company A also indicated that this is an important variable. Seeking to turn the proposed framework into a generic format, both dimensions are included separately. This allows the studied company to include the variables or not, according to their operations strategy.

The managerial team of Company A demonstrates an interest in knowing their performance in the dependability criterion, so this criterion was included in the conceptual framework for the next studies.

The existence of a single financial output variable can be a limitation, as it can difficult the mapping of the financial performance. It was not possible to define more representative variables due to the lack of data. The HPM dataset contains variables as EBTIDA, income, and plant net sales, but the variables are measured in financial value and have a small number of responses.

Concerning the procedural framework, company A competes in more than one market segment, so the first required step was to define the segment to each the responses would be attributed. In the same way, Company A was a second-tier supplier, so the customer can be seen as the auto OEM (original equipment manufacturer) or the final customer, requiring a definition of which of the client will be considered in the analysis. Questions to identify these points were then included as a step on the operations strategy questionnaire to the next cases. These questions should be answered by the plant manager.

Another improvement opportunity befalls on the sequence of questions, some of them are similar, and in the first questionnaire version, were in sequence. Changing the order will enable the comparison of the responses of similar questions, to confirm the answer reliability.

Finally, it turned out that to perform the linear programming, it is necessary to invert the results of the input variables, using least squares formula, since the linear programming recognizes that the smaller the inputs, the best, and the scale considers that the bigger, the best. After performing the pilot case study results, this finding was noticed, and the results were re-calculated.

4.3.7. Multiple case studies

The proposed framework was applied to seven companies, after the pilot case study. All of the companies are located in the south of Brazil. The selection of the companies studied respects the HPM criterion of having more than 100 employees and being from the automotive sector. Additionally, prominent companies in their segments, with quality assurance, were prioritized. A final criterion is the availability of six representatives in the roles of the plant manager, supply chain management, process engineering, product development, quality management, and environmental affairs.

The comparative analysis enabled process validation as well as the understanding of the contribution framework. The first two framework steps are in connection with data collection and understanding of benchmarking data, both are required to perform steps 3, 4 and 5, which will be the focus of the demonstration of the results.

It is important to highlight that each case was run independently, that is, the data from one company is not used in establishing the comparative data for the other cases. Additionally, it is also important to highlight that the context analysis for each case is dependent on each company's business and operations strategy. The performance efficiency frontier is calculated considering only the order-winning criteria used by the company being studied, characterized as a context-driven framework.

4.3.7.1. Operations strategy Identification

Table 33 presents the comparative importance scale of attributes for the eight cases, including the pilot case study.

Table 33 - Importance scale comparison (multiple case studies)

Target DMU	Order Winning	Qualifying	Less Important	Consistency Issue*
Company A	C*, F, I, Q, R, S	E*	none	2
Company B	C*, D, F*, Q, R*	E, I*, S*	none	5
Company C	C, D*, F*, Q, R, S	E, I*	none	3
Company D	C, D, F*, I, Q, R	S	E*	2
Company E	C, D*, I, Q*, R*, S	E, F, S	none	3
Company F	C, D, Q, R, S*	E, F, I	none	1
Company G	C, D, Q, R	E*, F, I*, S*	none	3
Company H	C, D, I, Q, R, S	E*, F*	none	2

* Standard deviation higher than 1.5 (in a response scale of 9 points)

Dependability is a competitive criterion included as an improvement from case A to case B. The results of the importance scale show that most of the criteria are ‘Order Winning’ from the eight companies’ perspective, which means that companies must outperform their competitors to win customers, given that customers consider these criteria in making their buying decision.

From the comparison among the companies under study, some similarities were found, which might be representative of the Brazilian automotive sector’s behavior. All companies consider cost, dependability, quality, and reliability to be order-winning. On the other end of the spectrum, none of the companies consider environmental factors as order-winning. Environmental features were either qualifying or less important criteria, meaning that customers do not acknowledge this feature yet. Innovativeness and speed were both considered qualifying by three companies, and flexibility was considered qualifying by two companies.

Table 34 present a comparison of the performance scale. Most of the companies under study face some issues on cost Performance, as this criterion had a high incidence in ‘the same as competitors’ performance index, which reinforces the performance of the competitive sector. Looking at the descriptive statistics of the competitive environment, the two cost variables (COS_F1 and COS_F2) are among the criteria with the lowest evaluation.

Table 34 - Performance scale comparison (multiple case studies)

Target DMU	Better than competitors	The same as competitors	Worse than competitors	Consistency Issue*
Company A	E, I*, Q, R	C, F, S	none	1
Company B	D, E*, F, I*, Q, R, S*	C*	none	4
Company C	D, E*, I*, Q, R	C*, F, S*	none	4
Company D	C, D, E, F*, Q, R, S*	I	none	2
Company E	D*, E, I*, Q, R	C, F*, S	none	3
Company F	C, F, R	D, E, I, Q, S	none	0
Company G	C, D, E, F, Q, R, S	I	none	2
Company H	C, S	D, E*, F, I*, Q*, R*	none	4

* Standard deviation higher than 1.5 (in a response scale of 9 points)

Another point for attention is that, despite environmental factors being classified as a qualifying or less important criterion for all the companies under study, at the same time, the performance is better than competitors for most of them. From this, companies are performing above the customer expectation, as can be seen in Table 35, which presents the improvement priorities by identifying the importance-performance matrix zone. The table shows that the environmental criterion falls into the excess zone for several companies.

Table 35 - Importance x performance zone comparison

Target DMU	Excess	Appropriate – Maintain	Improve	Urgent Action
Company A	E,	F, I, Q, R	C, S	none
Company B	none	D, E, F, I, Q, R, S	C	none
Company C	none	D, E, F, I, Q, R, S	C	none
Company D	E	C, D, E, F, Q, R, S	I	none
Company E	E	D, E, Q, R, S	F	C
Company F	none	C, E, F, I, R, S	D, Q	none
Company G	none	C, D, E, F, I, Q, R, S	none	none
Company H	none	C, D, E, F, I, S	Q, R	none

Also, this table confirms that cost is an issue for most of the companies under study, falling in the improvement or urgent action zone. The other competitive criteria performance varies according to the company.

Comparing, specifically, managerial awareness with a ranking position in the operations strategy questionnaire displays another pattern of behavior. Companies with a high-ranking position have less awareness of their operations strategy. The scatter plot in Figure 47 relates the ranking position (axis y) with the total of the issues in answer consistency (axis x, which is the sum of problems in the importance and performance attribution). The answer consistency issues are mainly related to the criteria with issues in answer consistency (e.g. standard deviation higher than 1.5.).

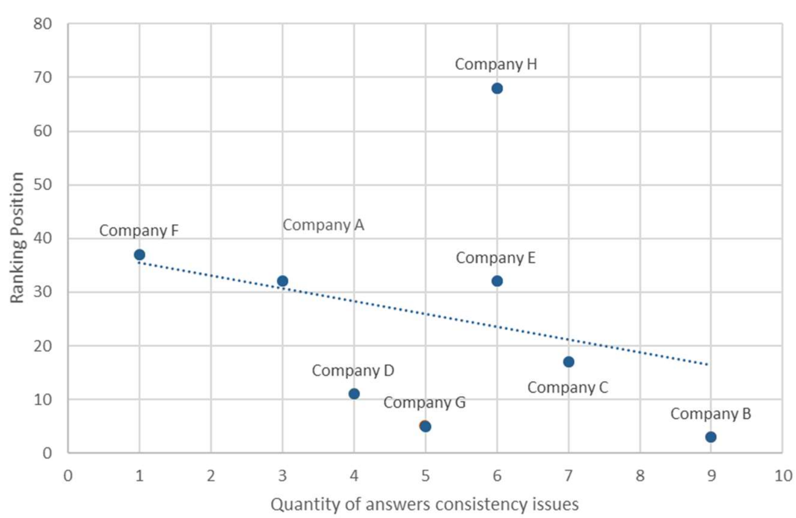


Figure 47 - Scatter plot, ranking position x answer consistency

The chart shows that company B which ranked third in a ranking with another 77 companies, does not display strategic consensus among the managerial team (a total of 9 issues in answer consistency). Company C, ranked seventeenth, displayed 7 incidences of lack of shared understanding. Company A and Company F placed only in the thirty-second and thirty-seventy positions respectively, have managerial teams with materially higher awareness of the company strategy. Company H positions differently, the company has issues in answer consistency, as some respondents attribute good indexes but most of them indicated low-performance indexes.

From this, the reliability of the results depends on the managerial awareness of their business and operations strategy as well as their awareness in providing answers to issues. Proximity with the customer and a deeper understanding of the competitive environment would be positive in strengthening business awareness and, thus, the quality of decision-making.

4.3.7.2. Performance efficiency frontier identification

The optimization model varies according to the company being studied since the respective input variables are different. Also, the inclusion of the company being studied in the data interferes with the results, since DEA envelops the data set with the frontier of the most efficient DMU, and the group of DMUs is used to generate the ranking (Liu et al., 2018). Table 36 provides the supper-efficiency index, the ranking position, and the five best-positioned DMUs for each of the case studies.

Table 36 - Summary of the super-efficiency analysis

Target DMU	Supper-efficiency Index	Ranking Position	Best positioned DMUs
Company A	0.96	32	1304, 1924, 1909, 502 and 922
Company B	2.00	3	1304 and 1924
Company C	1.16	17	1304, 922, 1924, 1909 and 502
Company D	1.48	11	1304, 922, 1924, 1909 and 502
Company E	0.88	32	1304, 922, 502, 1924 and 1724
Company F	0.73	37	1304, 922, 1924, 502 and 1909
Company G	1.70	5	1304, 922, 502 and 1924
Company H	0.54	68	1304, 922, 1924, 502 and 1909

Even with these variations of the optimization models for each company studied, the DMUs in the top position are recurrent, although their ranking positions vary.

4.3.7.3. Improvement Recommendation

The supper-efficiency score of the target DMU and its position in the ranking drives the definition of improvement recommendations. Improvement recommendations are developed considering the gap between the DMU studied and the best index among the five-best positioned DMU. Table 37 demonstrates the gap between the current and the target index for each company being studied. The ranking was generated considering the order-winning criteria for each DMU being studied, keeping the less important criteria from producing a bias in the results. The not available (N.A.) variables are not order-winning ones. Management attention should be drawn to gaps larger than 50%.

A performance gap may be perceived between the DMUs studied and those first positioned in the variables, which removes the company being studied from the top positions in the ranking. To become the first position of the ranking, companies must improve performance in some input variables, as well as get a better result from the current performance of the output variables. By eradicating the shortfall indicated, the companies under study can become market leaders, considering the benchmarking dataset.

Table 37 - % Of needed improvement into the best ranking position (multiple case studies)

Code	Variable	A	B	C	D	E	F	G	H
Inputs									
COS_F1	Manufacturing cost, including operations expense	80%	33%	61%	8%	72%	74%	47%	70%
COS_F2	Manufacturing cost - recently launched products	N.A.	13%	150%	11%	100%	43%	25%	53%
DEP_F1	Dependability performance	N.A.	8%	0%	23%	14%	49%	0%	35%
FLE_F1	Customer vision of company flexibility	28%	27%	0%	1%	N.A.	N.A.	N.A.	N.A.
FLE_F2	Production system capacity in changing production mix and volume	11%	0%	43%	0%	N.A.	N.A.	N.A.	N.A.
FLE_F3	Product customization	269%	30%	11%	52%	N.A.	N.A.	N.A.	N.A.
SPE_F1	Speed performance	148%	N.A.	67%	N.A.	N.A.	99%	N.A.	54%
QUA_F1	Quality performance compared to competitors	23%	12%	8%	40%	16%	16%	27%	46%
QUA_F2	Quality performance compared to competitors in recently launched products	27%	7%	35%	8%	37%	37%	7%	42%
RE_F1	Reliability performance compared to competitors in recently launched products	11%	25%	11%	0%	43%	43%	25%	24%
RE_F2	Reliability performance compared to competitors	25%	0%	43%	11%	43%	43%	25%	66%
ENV_F1	Capacity of environmental practices to positively influence other company's results	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
ENV_F2	Overall environmental performance	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
INO_F1	Process technology innovativeness	33%	N.A.	N.A.	17%	27%	N.A.	N.A.	33%
INO_F2	Equipment technology innovativeness	50%	N.A.	N.A.	50%	100%	N.A.	N.A.	20%
INO_F3	Product innovativeness	25%	N.A.	N.A.	67%	11%	N.A.	N.A.	33%
	Outputs								
F1_FIN	Throughput: the rate at which the plant generates money through sales	25%	25%	67%	0%	25%	67%	0%	150%
CLI_F1	Market Share and customer satisfaction for recently launched products	8%	0%	63%	37%	133%	8%	29%	81%
CLI_F2	Customer satisfaction	12%	0%	25%	45%	6%	11%	5%	42%

*COS_F2 is a variable included from case A to case B as an improvement of the conceptual framework.

Cost is a point of attention for all companies. Besides, both INO_F2 (Equipment technology innovativeness) and Speed presented issues in all the companies having these criteria as order-winning. Companies should evaluate whether they have large gaps in the order-winning criteria. These should become the managerial priority in establishing improvement actions.

4.4. GUIDELINES

Guidelines to implement the procedural framework (previously presented in Figure 40) are developed to enable the replication by other researchers and practitioners. A set of worksheets is proposed as a tool to apply the procedural framework. An excel file was developed to automate some aspects to the generation of the results in each of the process implementation.

4.4.1. Data collection

This step contemplates the gathering of data to recognize the operations strategic positioning of the studied company (S1-1), and data to recognize the performance in the competitive priorities (S1-2). The worksheets to collect these data are presented in Appendix D.

4.4.2. Depicting the benchmarking dataset

This stage has the objective of understanding the competitive environment used as the basis to benchmark the target company (S2-1) and to compare the studied company with the benchmarking dataset (S2-2).

In this research, the benchmarking data encompasses the 4th round of the HPM dataset. The performance of the target company is compared with the average performance of the sector. The comparison is promoted through the data collected in the competitive criteria questionnaire (S1-2). A worksheet is proposed to promote the comparison. Figure 48 demonstrates the worksheet fulfilled for Company D. The performance of the studied DMU in each of the input and output variables is compared with the sector average, then the size of the gap is calculated. Gaps bigger than 20% should be brought into managerial attention.

Step 2: Depicting the benchmarking dataset Descriptive Statistics										
			4th round of HPM data				Target DMU (Data from S1-2)			
Category	Variable	Factor or not observed variable	N	Sector Average	Median	Std Desviation	Target DMU	Gap	% Gap	Status
Costs	COS_F1	COS_F1: Manufacturing costs, including operating expense	77	3,29	3,23	0,78	4,44	1,15	26%	better than sector average
	COS_F2	COS_F2: Manufacturing costs - recently launched products	77	2,99	3,00	0,70	4,50	1,50	33%	better than sector average
Dependability	DEP_F1	DEP_F1: Dependability performance	77	4,06	4,05	0,65	4,06	0,00	0%	worse than sector average
Environmental factors	ENV_F1	ENV_F1: Capacity of environmental practices positively influence other company's results	77	3,41	3,39	0,79	3,85	0,44	11%	better than sector average
	ENV_F2	ENV_F2: Overall environmental performance	77	4,11	4,04	0,58	4,34	0,23	5%	better than sector average
Flexibility	FLE_F1	FLE_F1: Costumer vision about company flexibility	77	3,89	3,85	0,63	4,64	0,76	16%	better than sector average
	FLE_F2	FLE_F2: Production system capacity of changing production mix and volume	77	3,82	3,99	0,71	5,00	1,18	24%	better than sector average
	FLE_F3	FLE_F3: Product customization	77	3,47	3,55	0,78	3,11	-0,36	-12%	worse than sector average
Innovativeness	INO_F1	INO_F1: Process technology innovativeness	77	3,24	3,21	0,51	3,43	0,18	5%	better than sector average
	INO_F2	INO_F2: Equipment technology innovativeness	77	3,55	3,70	0,69	3,00	-0,55	-18%	worse than sector average
	INO_F3	INO_F3: Product innovativeness	77	3,86	3,80	0,66	3,00	-0,86	-29%	worse than sector average
Quality	QUA_F1	QUA_F1: Quality performance compared to competitors	77	3,76	3,79	0,51	3,34	-0,42	-12%	worse than sector average
	QUA_F2	QUA_F2: Quality performance compared to competitors in recently launched products	77	3,89	3,83	0,53	4,64	0,75	16%	better than sector average
Reliability	RE_F1	RE_F1: Reliability performance compared to competitors in recently launched products	77	3,80	3,75	0,61	5,00	1,20	24%	better than sector average
	RE_F2	RE_F2: Reliability performance compared to competitors – quality management vision'	77	3,83	3,82	0,66	4,50	0,67	15%	better than sector average
Speed	SPE_F1	SPE_F1: Speed performance	77	3,65	3,47	0,65	3,54	-0,11	-3%	worse than sector average
Client Output	CLI_F1	CLI_F1: Market Share and customer satisfaction on recently launched products	77	3,61	3,56	0,72	3,64	0,03	1%	better than sector average
	CLI_F2	CLI_F2: Customer satisfaction	77	3,94	3,92	0,63	3,45	-0,48	-14%	worse than sector average
Financial Output	FIN_F1	FIN_F1: Throughput: the rate at which the plant generates money through sales	77	3,60	3,55	0,86	5,00	1,40	28%	better than sector average

10	Input variables better than the sector average	2	Output variables better than the sector average
6	Input variables worse than the sector average	1	Output variables worse than the sector average

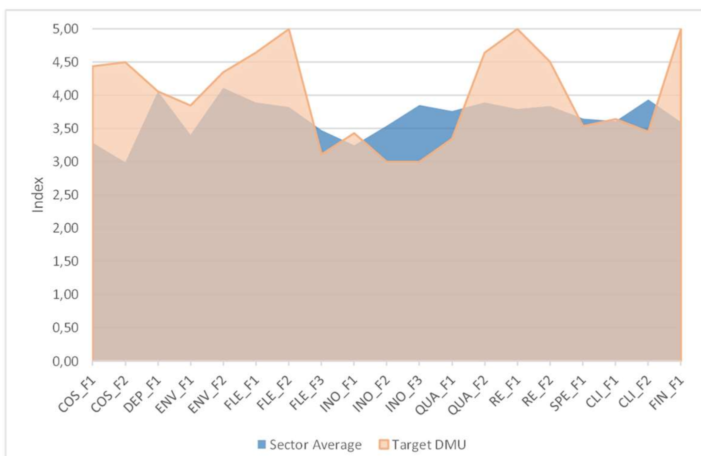


Figure 48 - Worksheet S2-2

4.4.3. Operations strategy identification

A detaching point of the proposed framework is being contextual driven, that is, the performance efficiency frontier analysis is developed to the variables that are important to the studied company. Therefore, each of the studied companies will have a particular frontier analysis method. The identification of the important variables is promoted through the recognition of the target company operations strategy (S3-1), by using the performance and importance matrix concept. Once the respondents have attributed the importance and performance index for each of the competitive priorities, the researcher should first evaluate the answers average and the standard deviation to each competitive criterion to both, importance and performance criteria. This is the first analysis made in S3-2. The guideline is that a standard deviation smaller than 1.5 represents a good answer standard. It is important to emphasize that the result is based on an opinion survey, and the answers can vary according to the participant's background. Even so, similar answers demonstrate the existence of a shared understanding of the company's strategic positioning.

The average classification of both, performance and importance, allow the chart a radar graph to easily recognize if business performance is consistent with customer expectations, the second analysis of S3-2. Then, the zone interpretation lets for the definition of priority to establish improvement actions. The results should be classified in the matrix, where the axis x is the importance assessment and the axis y the performance ones. The matrix allows the recognition of the relative importance of each of the manufacturing performance objectives according to the clients' priorities, which should be the manufacturing priorities. On the other hand, the matrix also promotes the assessment of the actual performance achieved by the production function by comparing the performance of the organization with that of the competitors. Therefore, it is possible to recognize the gaps between what is important to the operation (based on the client's perspective) and what performance is being achieved by classifying it into four zones. Identifying this gap provides the direction of choices and implementation of improvement plans.

The guideline indicates that an urgent action zone requires improvement in the performance since the criterion is at least qualifying for customers and the performance of the company is poor. The improvement action embraces the candidates for improvement since the performance is lower than the competitor in less relevant criteria or is the same as the competitor is relevant criteria. The appropriate zone, in turn, contains the satisfactory criteria. And the Excess zone includes criteria with high performance, but not particularly important. The company should analyze whether the resources devoted to achieving such a performance could be used elsewhere. Figure 49 demonstrates an example of a fulfilled worksheet.

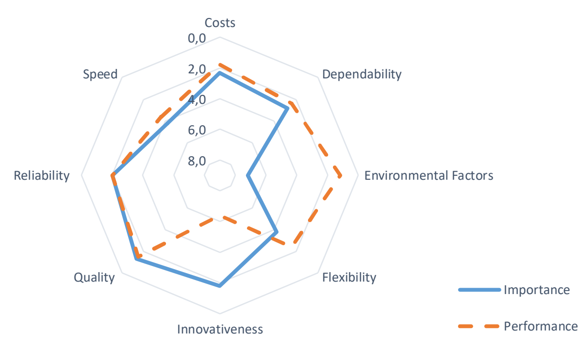
Step 3: Operations Strategy Identification

Importance Scale

	Quality	Process	Product Development	Plant Manager	Environmental Affairs	Supply Chain	Mean	Std Dv	Classification
1) Costs	2	2	2	4	1	3	2,33	1,03	Oder-winning
2) Dependability	3	4	2	2	0	3	2,33	1,37	Oder-winning
3) Environmental Factors	5	9	9	7	7	6	7,17	1,60	Less Important
4) Flexibility	2	2	6	5		4	3,80	1,79	Oder-winning
5) Innovativeness	1	2	3	1	2		1,80	0,84	Oder-winning
6) Quality	2	1	2	1	1	1	1,33	0,52	Oder-winning
7) Reliability	1	1	1	3	2	4	2,00	1,26	Oder-winning
8) Speed	5	5	4	4		3	4,20	0,84	Qualifying

Performance Scale 1,16

	Quality	Process	Product Development	Plant Manager	Environmental Affairs	Supply Chain	Mean	Std Dv	Classification
1) Costs	2	1	2	2		2	**1,80**	0,45	Better that competitors
2) Dependability	3	1	4	1		3	**2,40**	1,34	Better that competitors
3) Environmental Factors	1	1	1	1	2	1	**1,17**	0,41	Better that competitors
4) Flexibility	5	2	3	1		1	2,40	1,67	Better that competitors
5) Innovativeness	7	7	6	6		6	**6,40**	0,55	The same as competitors
6) Quality	3	1	1	1	2	1	**1,50**	0,84	Better that competitors
7) Reliability	2	1	3	1	1	4	**2,00**	1,26	Better that competitors
8) Speed	3	7	4	2		2	**3,60**	2,07	Better that competitors



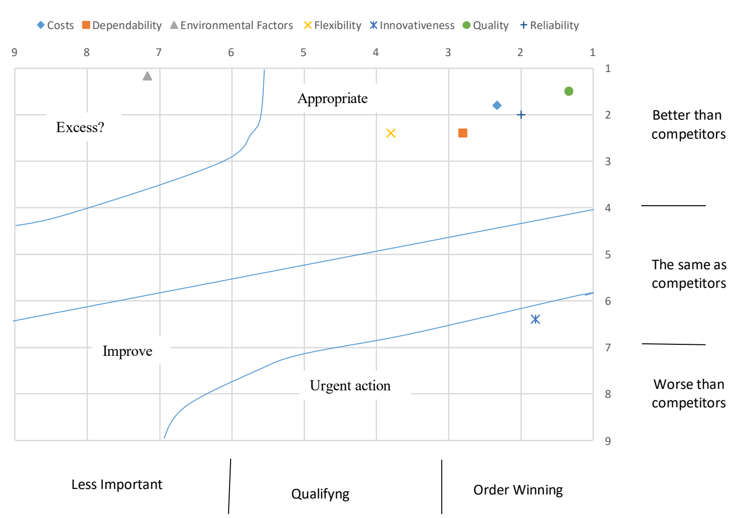


Figure 49 - Worksheet S3-2

4.4.4. Performance efficiency frontier identification

To perform the frontier identification, the frontier model must be prior specified (S4-1). At first, the DMUs under analysis should be defined. It is required homogeneity in terms of the period of analysis, type of business, and the number of employees. The definition of the input and output variables was promoted in the conceptual framework previously developed in this work, through an in-dept statistical process for defining representative variables. In the proposed framework, the input variables include the order winning criteria identified in the foregoing step, since the objective of the model is to provide a benchmarking relative to the aimed DMU operations strategy, being context-driven or context-dependent.

This step deals with the selection of the target set of DMUs, as well as defining the DMU characteristics to control sample heterogeneity (period of analysis, type of business, number of employees, region, etc.). The dataset is the 4th round of the HPM Project, as this is the dataset used to statistically define the conceptual model. The database in this stage count with 77 automotive companies for benchmarking. The DMUs with more than 30% of missing data in the interest variables were excluded from the basis.

Regarding the minimum required sample size to carry out the performance efficiency frontier analysis, there are plenty of approaches that define the minimum number of DMUs. The gold rule of Banker et al. (1989) is the adopted criterion since it is usually more demanding. The Golden Rule states that the number of DMUs should be at least three times the sum of the number of involved variables (inputs and outputs) or at least equal to the product of the number of input variables and the number of output variables, adopting the criterion associated to the greater number of required DMUs. The performance efficiency frontier is implemented through the super-efficiency DEA with a variable return to scale (VRS), the dual model with input orientation, calculates the efficiency. The preliminary frontier model definition worksheet is presented in Figure 50.

Step 4: Frontier Identification
Preliminary Definition Worksheet

DMU selection

Frontier analysis method choice

Data Envelopment Analysis with variable return to scale and output orientation

Definition of the input and outputs variables

Select the variables that you are interested in benchmarking. The order winning criterias should be selected.

Input Variables Selection			Input Variables Selection		
Quality			Flexibility		
	QUA_F1	Quality performance compared to competitors		FLE_F1	Costumer vision about company flexibility
	QUA_F2	Quality performance compared to competitors in recently launched products		FLE_F2	Production system capacity of changing production mix and volume in the vision of the plant manager
				FLE_F3	Product customization
Costs			Reliability		
	COS_F1	Manufacturing costs, including operating expense		RE_F1	Reliability performance compared to competitors in recently launched products
	COS_F2	Costumer vision about company costs		RE_F2	Reliability performance compared to competitors – quality management vision'
Dependability			Speed		
	DEP_F1	Dependability performance		SPE_F1	Speed performance
Innovativeness					
	INO_F1	Process technology innovativeness	Output Variables Selection		
	INO_F2	Equipment technology innovativeness	Financial perpective Results		
	INO_F3	Product innovativeness		F1_FIN	Throughput: the rate at which the plant generates money through sales
Environmental Factors			Client perspective Results		
	ENV_F1	Capacity of environmental practices positively influence other company's results'		CLI_F1	Market Share and customer satisfaction on recently launched products
	ENV_F2	Overall environmental performance		CLI_F2	Customer satisfaction

Definition of the miminum required sample size

Input the number of selected input and outout variables, to see the minimum requires sample size to allow the DEA.

	Number of inputs variables (ki)	ki*ko	0	According to Golany and Roll (1989)
	Number of outputs variables (ko)	(ki+ko)*3	0	According to Banker et. al (1989)

The recommended sample size is:
0 DMUs data

Figure 50 - Worksheet S4-1

Having the DEA model defined, linear programming can be performed. To do so, the super-efficiency DEA VRS dual model with input orientation is performed (S4-2). To perform the linear programming, it is necessary to invert the results of the input variables, since the linear programming recognizes that the smaller the inputs, the best, however, the scale of data collection considers that the bigger, the best (e.g.: An index of 4.7 should be turned into 1.3). The result generates a ranking of the supper-efficiency model.

The linear programming model is performed in Solver from Microsoft Excel. The critical analysis encompasses two evaluations. First, the answers given at the operations strategy step - concerning the performance of each competitive criteria - are compared with the ones given in the competitive criteria questionnaire, to identify the performance of each of the new variables, which are directly related to the competitive priority. The answers on behalf of each component (new variables) are plotted in a radar graphic to them be compared with the answer from the operations strategy performance scale. An example of such an analysis is given in the pilot case study report (Item 4.3.6.4 - Critical Analysis of the target DMU results).

As a second stage, the performance efficiency frontier itself is analyzed through the position of the target DMU in the supper-efficiency ranking. Then, the target company is compared with the 3 to 5 best-positioned companies in the ranking, to understand which of the input variables the improvement opportunities are. A graphic and a table that summarizes the size of the gap in each of the input and output variables are generated (see Figure 36 and Table 31). Gaps bigger than 20% should be brought into managerial attention.

4.4.5. Improvement recommendations

The development of multiple case studies enables the identification of an aimed behavior, which is formalized in interpretation guidelines. Standard deviation bigger than 1.5 can influence the average response, moving the result from one level to another. In the same way, a difference of 50% between the target DMU results and the aimed index, can expressively modify the ranking position. The objective when comparing the studied DMU to the average sector performance is to have at most 20% of the gap. The difference in performance should be smaller when comparing to the sector average, than when comparing to the best sector index. Table 38 demonstrates the use of these guidelines to develop improvement priorities for a studied company. The steps S5-1 and S5-2 interprets the results from previous steps and seek to define improvement opportunities based on the presented guideline.

Table 38 - Guideline to define improvement opportunities

Step	Evaluated Item	Aimed behavior
Depicting the benchmarking dataset – Step 2	- The difference between the target company and the sector average index	Gaps smaller than 20%
Operations strategy Identification – Step 3	- Gaps between importance and performance - Position in the matrix	Befalls in the appropriate zone
	- Answer consistency in the responses to evaluate the importance of the competitive criteria	Standard deviation smaller than 1.5
	- Answer consistency in the responses to evaluate the performance of the competitive criteria	Standard deviation smaller than 1.5
Performance efficiency frontier Identification – Step 4	- Supper-efficiency index	No aimed position, but the bigger, the best.
Improvement recommendations – Step 5	- The difference between the target company and the best index among the five best positioned (to input and output variables)	Gaps smaller than 50%

This set of guidelines is useful to identify the critical competitive priorities to prioritize the improvement opportunities. An example of the improvement opportunities for the pilot case study is given in Tables 31 and 32.

4.5. FINAL DISCUSSION

This research is developed in the context of performance efficiency frontier studies to measure, assess and improve operations strategy. The literature on performance efficiency frontier methods requires inputting and outputting variables, as observed in the classical papers of Farrel (1957), Charnes et al. (1978), Banker et al. (1984), and Parkan et al. (1997). However, it is not possible to find a consensus in defining what are the input and output variables that represent the decision areas, capabilities, competitive priorities or business results. Therefore, the establishment of inputs and outputs variables to allow the use of operations strategy as a lens for performance efficiency frontier analysis is still unclear, which justifies an in-depth study to reveal relationships among variables that define the content of operations strategy. Besides that, according to Smith (1997), the main weakness of DEA is that the choice of input and output variables depends on the judgment of the researcher, as there is no support to help the user determine wheatear or not the chosen model is appropriate. A conceptual framework was therefore proposed to formalize both, the relationship between operations strategy and performance efficiency frontier methodologies and the input and outputs variables to study the operations strategy efficiency frontier.

The definition of the inputs and outputs variables depends on the organizational perspective. From a strategic perspective, a more comprehensive approach is to use competitive priorities as input some organizational result measure as output. On the other hand, in a tactical approach, it is coherent to define the operations strategy competitive priorities as outputs, and the operations resources, in the decision areas, like the inputs. A range of authors uses financial and non-financial performance measures to represent the organizational results measures. Mainly the financial performance is measured by indicator as ROI, ROA, throughput, sales, and profitability, while the non-financial are related to customer satisfaction and market share. Such an approach is coherent with the balanced scorecard framework, which defines the financial and customer perspective as the results one, and the process and people/ learning as the process one. Bringing out again the causal relationship mentioned above.

The first level proposed framework discloses the causal relationship. As the aim of this research is to identify how the operations strategy contributes to the business results, the input is defined as the competitive priorities and the output, the business results. This conceptual framework gives a different picture to Schmenner and Swink (1998), who establish the competitive priorities are outputs to employ the performance efficiency frontier concept to operations strategy. A wider perspective is proposed bringing a different approach than the ones found in some empirical applications (Dutta et al., 2005; Abbasi and Kaviani, 2016; Hemmati et al., 2014).

Once the performance efficiency frontier model is delimitated (first level conceptual framework) the operations strategy constructs are proposed to represent the input and output variables. The PCA conducted the reduction of 97 variables in 19 variables of 8 input and 2 output categories, allowing for the DEA study. The second level conceptual framework is a result of this data analysis.

The conceptual framework delimitation is coherent with the market-based view approach. The performance efficiency frontier methodologies to study operations strategy performance are approached by some authors, but they focus mainly on a single line to operations strategies, exploring the capability resource-based concept (Ramanathan et al., 2016; Cai and Yang, 2014; Hemmati et al., 2016; Yu et al., 2014). However, scholars also have found a strong relationship between competitive priorities and business performance in the manufacturing and service industries (Avella and Vázquez-Bustelo, 2010). Although some researchers such as Abassi and Kaviani (2016) and Bulak et al. (2016) use competitive priorities to determine the operations strategy performance frontier, their assessments were not performed from a perspective of operations strategy, as they did not develop recommendations for the enhancement of competitive positions. This research develops its contribution to the gap of the market-based concept of competitive priorities to study operations strategy performance frontier. The importance of this proposal is supported by Hult et al. (2004) who state that translating market requirements into action is part of a strategic plan that supports the decision-making process to orient internal changes. Industrial firms with a market orientation are likely to devise and adapt products, services, and processes to continuously meet customer needs.

A second explored research opportunity is related to the lack of focus on a generic process perspective in studies related to operations strategy and performance efficiency frontier analysis. It is noticed that most of the papers are focused on the content analysis, seeking to identify which are the performance drivers or to estimate the frontier. There are also articles focused on the context, seeking to classify the target organization within an external context. The existing process-oriented papers generally propose frameworks for specific purposes (Seol et al., 2011; Achillas et al.; 2014; Samoilenko and Osei-Bryson, 2013)

This study gives insights into the strategic positioning of the operations function through the proposition of a benchmarking model. Such a model identifies the operations strategy of a target company, compares its performance with a competitive database, employing the competitive criteria, to finally determine the gap to the studied company to become leader, contributing then to the companies have their competitive positioning enhanced. Bulak and Turkyilmaz (2014) have a similar proposal, working with competitive priorities. They measure and assess the operations strategy performance efficiency using the DEA. However, the authors set the gaps concerning the minimization of the inputs, establishing the opposite point of view to delineate improvement recommendations. Also, their work doesn't detail the suggestions to become a leader, concentrating singularly on the gap definition.

From the procedural perspective, another point that enhances the contribution of this research is the fact of the implemented framework being context-driven which differs for each company being studied, this perspective was not approached by any of the few authors that focused on competitive priorities approach. Before calculating the ranking position, the operations strategy of each company has to be studied, seeking to identify the order winning criteria, which in turn, define the input variables of the DEA framework. The framework development its contribution to identifying in which of the order-winning criteria the organization should perform better, based on the behavior of the sector of competition. Such a proposal is grounded on the trade-off concept, which limits the organization's performance. In other words, improvement in one performance criterion can be achieved only by sacrificing the performance of another (Skinner, 1974). However, there are two recent visions of trade-offs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others. Most companies, at one time or another, will adopt both approaches (Amoako-Gyampah and Meredith, 2007; Slack and Lewis, 2018; Kathuria et al., 2018; Sarmiento, et al., 2018). This study contributes to understanding in what of the criteria the compensation can be affordable, and in what of those it is necessary to overcome the trade-offs barrier by being simultaneously efficient.

From the implementation perspective, the proposed conceptual and procedural framework was applied in 8 case studies and some patterns can be found based on the critical analysis of the findings of the case. The results of the importance scale show that most of the criteria are 'Order Winning'. In doing so, it is possible to confirm the literature findings of Soosay et al. (2016), Lotfi and Saghiri

(2018), Melnyk et al. (2014), among others, that indicate the exitance of a current highly competitive and dynamic environment. In such an environment, the bargaining power lies in with the customer, who may demand more from their suppliers, given they can choose among them. In this scenario, considering most of the criteria as being order-winning is reasonable, enhancing the complexity for companies to achieve a market standout position.

Four of the classic competitive criteria are considered order-winning by all of the companies under study - cost, dependability, quality, and reliability. Confirming that these criteria remain important over time. In recent literature environmental factors have been approached as an important coopetition criterion due to the current dynamic context (Wang, 2019; Díaz-Garrido et al., 2011; Vivares-Vergara et al., 2016). However, despite being considered important by literature, Environmental factors are only perceived by companies as qualifying criteria. Therefore, their understanding is that customers do not attribute so much importance to environmental factors. Even so, environmental factor performance is better than competitors for most of the companies under study. This means that they are generating a performance that exceeds customer expectations. According to literature, the natural course of events leads environmental factors to be increasingly valued in the long term so companies may be anticipating a standout position in this criterion, and this current excess can bring advantage in the future (Famiyeh et al. 2018; Wang, 2019).

In cost performance, despite being considered order-winning by customers, most of the companies under study face some issues, which are also encountered by other companies in the sector. This fact can alleviate the negative impact of this difficulty since it is a shared issue within the sector. On the other hand, a company that can excel in this criterion may have a competitive advantage, as there is consensus on the cost being considered as order winning. Narkhede (2017) reveals cost as the most important competitive criterion among the manufacturing industry's competitive criteria.

Innovativeness and speed were both considered qualifying by three companies, and flexibility was considered qualifying by two companies. Rubera and Kirca (2012) promoted a study that indicates that firm innovativeness affects its market and financial position. Cho and Pucik (2005) also prove that innovativeness interferes with market value through growth and profitability. However, for automotive companies in Brazil, innovativeness does not seem to be a decisive criterion from the customers' perspective, and, in the scenario studied, innovativeness may not contribute to enhancing financial position. Innovativeness may be a worldwide criterion, but it is not fully recognized in the Brazilian automotive competitive scenario. Speed, in its turn, may not be considered an order-winning criterion for being a parameter defined in the supplier contract, according to the comments made by the managers participating in the study.

Reliability is the single competitive criterion in the appropriate zone for all of the companies under study, which may be indicative that this is a criterion for current managerial attention. The serviceability advent may contribute to enhance the company's focus on reliability performance (Szász and Seer, 2018; Benedettini et al., 2015; Baines et al., 2013).

The patterns in answer consistency (evaluated through the standard deviation among the responses) demonstrated that the managerial awareness of company performance is higher than their awareness of the importance given to the customer, a reasonable result since most of the participants do not have direct interaction with end customers, particularly when the company does not play a first-tier position. From this behavior, proximity with the customer and a deeper understanding of the competitive environment would be positive in strengthening business awareness and, thus, the quality of decision-making.

The comparison among case studies also demonstrated that companies with a high-ranking position have less awareness of their operations strategy. From this, the high position of some of the studied companies is questionable, since the managerial team does not display a shared vision concerning the importance or performance of competitive criteria. There cannot be any certainty about the reliability of the answers. The usability of the framework proposed depends on the managerial awareness of their business and operations strategy as well as their awareness in providing answers to issues.

5. CONCLUSION

Literature has so far failed to provide a framework that explored how to identify the operations strategy drivers for competitiveness in the context of performance efficiency frontier methodologies. This research proposes a procedural framework to measure, assess and improve operations strategy using performance efficiency frontier methodologies, contributing to cover this gap. The proposed new framework offers companies under study improvement opportunities in their competitive priorities. Each company's efficiency score is calculated, and enhancements needed for becoming an efficient firm or sector in the analysis are reported. The results provide information about which firms have reached satisfactory levels in strategic competitive priorities for business performance and provide managers with an opportunity to manage the firms at the desired level. The framework implementation enhances the managerial awareness of each company's competitive position.

Four intermediate objectives were defined to leads such research. The intermediate research objective of examining the literature related to performance efficiency frontier and operations strategy was accomplished through an in-depth systematic literature review. The ProKnow-C methodology supported this step, and as a result, the research agenda was described, which testify that few papers approach operations strategy and performance efficiency frontier analysis, simultaneously. Results include 19 papers as part of the bibliographic portfolio. In this process, it was possible to figure out that published papers focus mainly on the content of identifying the performance efficiency frontier, but the process is still unclear. Additionally, looking at the papers that approached both concepts, many of them promote a relationship with the operations strategy through the concept of capabilities, based on the resource-based view theory. The concept of competitive criteria is little explored, at the same time, various authors defend that making an appropriate choice of competitive priorities leads to competitive advantage. Therefore, this research developed its contribution to the gap of the market-based view, proposing a process that leads to better-positioned operations strategies.

The second research objective of proposing a conceptual framework to translate the concept of operations strategy into the performance efficiency frontier methodology was also reached. The content analysis brings a theoretical contribution summarizing and reflecting on the current body of knowledge regarding performance efficiency frontier methodologies in the context of operations strategy. As a result, it was defined a first level framework to clarify how to represent input and output variables to study the operations strategy efficiency. Multivariate statistical analysis using HPM data was then conducted to define the operations strategy constructs to allow the performance efficiency frontier methodologies implementation, by the definition of the input and output variables, supported by the principal component analysis technique.

The third research objective is to propose a procedural framework to asses and improve the operations strategy performance, employing performance efficiency frontier methodology. Five steps procedural framework is proposed and tested in eight case studies. The first case revealed some improvement opportunities in the process, that is implemented in the following cases. The procedure implementation generates a ranking to position the studied DMU face to the competitive environment, as well as, calculates the gap in all the input and output variables. This quantitative analysis grounds the definition of improvement opportunities to the studied company become a leader in the market. The usability of the framework is higher with the fact of the procedural framework being context-driven, enhancing their value from a practical perspective, as a result, fit to a single studied company reality. This singularity is developed thought first identifying the important criteria from the studied company perspective. So, the ranking is generating with the order-winning criteria, only. This avoids the influence of less important criteria in the result.

The final specific objective concerns the development of guidelines to both, implement the process promptly and guide the interpretation of the results. The research concludes that specific processes contribute to continually adapting the operations strategy driven by the competition’s behavior.

The contributions are given in providing a deeper understanding of performance efficiency frontier estimation on the operations strategy context, which can also positively influence the firms to succeed in the current dynamic competitive environments. Due to the unpredictable and complex organizational environment, the set of representative variables might change more frequently which reinforces the need of updating operations strategy measures, bringing out the need for having a process to apprise variables seeking to continue accurately assessing the effectiveness of the operations strategy.

The proposed framework implementation affords important insights for managerial decision-making, providing a complete understanding of competitive performance priorities in the companies studied. The research concludes that specific processes contribute to continually adapting the operations strategy driven by the competition's behavior. When the process is properly fed in an accurate strategic performance framework, competitive priorities gaps can be qualified and quantified providing important insights for managerial decision-making. The implementation of the framework demonstrated feasibility since the only requirement is answering a questionnaire which takes about 30 minutes for each person in charge of the answers. This then enables the implementation of the framework in a dynamic manner promoting agility in decision-making for the company in alignment with internal and external demands.

5.1. OUTCOMES

This section organizes the main outcomes of the thesis according to the specific objectives.

RO 1 – To map the literature related to performance efficiency frontier analysis and operations strategy

- Concepts of operations strategy and performance efficiency frontier are simultaneously not so much explored by literature in a holistic and generic perspective, as most of the publications focus either on capabilities or in a context-driven model of implementation.

RO 2 - To propose a conceptual framework to translate the concept of operations strategy into the performance efficiency frontier methodology

- Definition of how operations strategy and performance efficiency frontier concepts are related to each other. The definition of the inputs and outputs variables depends on the organizational perspective. From a strategic perspective, a more comprehensive approach is to use competitive priorities as input some organizational result measure as output. On the other hand, if you look at a tactical approach, it is coherent to define the operations strategy competitive priorities as outputs, and the operations resources, in the decision areas, like the inputs.

- Definition of the operations strategy constructs, establishing input and output measures for performance efficiency frontier analysis studies.

RO 3 - To propose a procedural framework to asses and improve the operations strategy performance, employing performance efficiency frontier methodology.

- The proposition of a benchmarking model identifies the operations strategy performance of a target company.
- Delimitation of improvement recommendations based on the improvement of the inputs and outputs results.
- The proposition of a context-driven framework, enhancing the value of the results from the managerial perspective.
- Identification of which of the order-winning criteria the studied organization should perform better, based on the behavior of the sector of competition.

RO 4 - To develop guidelines contemplating the steps for the application of the procedural framework.

- Guidelines to implement the proposed five steps procedural framework.
- Guidelines to interpret the results of the procedural framework implementation.
- From the case studies developed in this research, the patterns of behavior confirm that:
    - Most of the competitive criteria are order-winning, enhancing the complexity for companies to achieve a market standout position.
    - Four of the classic competitive criteria are considered order-winning by all of the companies under study - cost, dependability, quality, and reliability. Confirming that these criteria remain important over time.

- Environmental factors are yet not understood are important in the studied sector, but the companies have the environmental focus as a way of anticipating future requirements.
- Despite cost performance being considered order-winning by customers, most of the companies under study face some issues, which are also encountered by other companies in the sector.
- Innovativeness may be a worldwide criterion, but it is not fully recognized in the Brazilian automotive competitive scenario.

5.2. LIMITATION

A limitation includes the fact of the performance efficiency frontier being estimated base on a perceptive Likert scale for the responses collected. Therefore, the reliability of the data depends on the participants' awareness of the business being analyzed. The establishment of the improvement opportunities also depends on the managerial disposal to assess and discuss the framework results, since there is no defined process to define the recommendations. The existence of a single financial output variable also represents a limitation of the conceptual framework. It was not possible to define more representative variables due to the lack of data. The HPM dataset contains variables as EBITDA, income and plant net sales, but the variables are measured in financial value and have a small number of responses.

In this dissertation, the improvement recommendations are addressed considering the critical analysis of the procedural framework implementation results, establishing the recommendations from a generic perspective, not meeting the level of manufacturing practices. The managerial team of the studied companies was involved in the defining of the improvement recommendations, but the procedural framework lack of a protocol to gather their inputs. The managerial team availability was a constraint to the procedural framework implementation.

Besides that, the consumed database includes information of automotive companies with more than 100 employees from 13 countries, which can be positive in defining high-performance levels as a target. However, on the other hand, it brings unanticipated heterogeneity in the model, as well as, some regional behavior might not be captured by this data. Additionally, the research has identified the main variables using the data of the 4th round of the HPM databases and then, it is possible to declare that the results are representative of this set of data. The availability of reliable data is an important assumption for this research, as the framework requires an updated database to represent the competitive environment. When the 4th round of the HPM data becomes outdated, other data must be considered.

5.3. FUTURE RESEARCH

Base on this dissertation's results and limitations, future research can be recommended. As a first opportunity, one can state the implementation of the proposed framework with quantitative data, based on the evidenced collection. This proposition would require a joint effort to capture benchmarking data from a representative set of DMUs. This suggestion overcomes the limitation presented by this work in assessing manufacturing performance through operations strategy lenses with data based on the managerial perception.

The development of a quantitative approach to defining improvement recommendations is also a research opportunity. This can be accomplished by the promotion of quantitative analysis to identify causal relationships between practices and results in competitive priorities. This recommendation can also be developed considering the HPM dataset since this wide database focus not only on the performance but also on the manufacturing practices.

From this, there is also a future research opportunity concerning the procedure to define the recommendations. The proposition of a methodology to integrate the quantitative analysis with the experience and knowledge of the studied company managerial team can also be valuable from a practical perspective. This proposition has to take into account the availability of the involved managerial team, in this sense, the development of automated software to capture the information could be useful. An automated process to gather the data and identify the performance efficiency frontier can also be positive to allow the framework implementation more frequently. An automated process, as well as open data sources, can contribute therefore to multiply the quantity of data, generating more data to identify the sector behavior through big data and data mining techniques. The big data can contribute to the definition of the benchmarking targets, using more robust statistical measures.

A future work opportunity also includes the replication and of the process of selecting representative inputs and outputs variables with other databases that cover competitive priorities and business results.

The inclusion of sustainability constructs in the input/ output variables can be another opportunity, as the growing magnitude attributed by the literature may predict the importance that will be attributed by customers shortly. Innovativeness is not presented as a reflexive construct in this research work, which can represent either a lack of respondent understanding about the concept or a characteristic of the variable. Due to this behavior, innovativeness constructs were defined with semantic analysis in a qualitative approach. Future studies are recommended to clarify this question and to define innovativeness constructs with quantitative methodology.

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Appendix A - Research Papers

This appendix contains the main research papers developed as a result of this research work.

Appendix	Title	Publication	Research Objective
Appendix A - 1	Efficiency frontier identification based on operations strategy - A retrospective analysis of leading authors.	ICPR 2019/ Procedia Manufacturing	RO1
Appendix A - 2	A Content Analysis on Efficiency Frontier Identification and Operations Strategy.	ICPR 2019/ Procedia Manufacturing	RO1
Appendix A - 3	Efficiency Frontier Identification on the Context of Operations Strategy – A Study on Representative Constructs and Variables.	ICPR 2019/ Procedia Manufacturing	RO2
Appendix A - 4	Defining variables to assess operations strategy efficiency	International Journal of Productivity and Performance Management	RO2
Appendix A - 5	Assessing manufacturing performance through operations strategy lenses	International Journal of Production Economics	RO3
Appendix A - 6	Implementing a procedure to asses and improve Operations Strategy	Journal of Operations Management	RO4
Appendix A - 7	A Procedure for assessing and improving operations strategy	Production Planning and Control	RO4

Appendix A– 1 Research Paper 1

Title: Efficiency Frontier Identification Based on Operations Strategy - A Retrospective Analysis of Leading Authors.

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Efficiency Frontier Identification Based on Operations Strategy - A Retrospective Analysis of Leading Authors

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Abstract

Increasingly, organizations must be able to compete in the context of global standards. The operations function has an important role in this scenario as the operational efficiency can contribute to the competitive advantage development. The operations strategy, in its turn, has an important role in making feasible operational efficiency. This paper seeks to investigate the literature about Efficiency Frontier Identification in the context of Operations Strategy. This is accomplished through a comprehensive systematic literature review supported by bibliometric analysis techniques. The search was realized at web of science and Scopus databases, screening papers between 1997 and 2017, all in English language and published in refereed journals. The systematic literature review is based on the Proknow-C process framework and resulted in 19 papers fully related to Operations Strategy and Efficiency Frontier identification. Such a set of papers is reviewed bringing out the research standard. A bibliometric analysis is also presented, including keywords, main authors and journals in a timeframe perspective. The paper brings insights into future work opportunities, revealing that the main publication's focus is on the resource-based view approach and the concept of capabilities. Therefore, there is a clear need for extending the research with a focus on the market-based view approach.

Keywords: Systematic literature review; bibliometric analysis; Operations Strategy; Efficiency Frontier; Proknow-C

1. Introduction

Increasingly, organizations must be able to compete in the context of global standards. At the same time, many authors argue that the operations have an important influence on the competitive advantages' development as the level of competitiveness increases [1, 2]. Therefore, operational efficiency is needed for successful businesses [3]. The operations strategy, in its turn, has an important role in making feasible operational efficiency [4].

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Operations strategy can be defined as the development of competitiveness, based on the production function, to help achieve the long-term competitive objectives [5]. The operations strategy must consider how market needs and manufacturing capabilities might be combined by competitive strategy in a dynamic and unpredictable marketplace to sustain competitive performance [6]. The operations strategy supports the achievement of business objectives, and consequently the competitive advantage, by means of structural items (buildings, plant, equipment, etc.) and infrastructural ones (control policies, structure organizational, etc.) [7] add decision area of human aspects. The action in the decision areas generates results at competitive dimensions, like quality, speed, flexibility, dependability, innovativeness, and costs [8, 9].

However, it is well known that, according to the concept of the trade-off, it is not possible to be excellent in all its performance criteria. The essence of strategy is to choose between what to do and what not to do, trade-offs, therefore, limit organizational performance [10]. The advent of technology helps in breaking the barrier of tradeoffs, however, as the resources of an organization are finite investments [11], making choices between what to do and what not to do is still needed. In this context, identifying the elements that lead the organization to reach the maximum performance in the order winning criteria, may represent a differential in the search for a prominent position in the market, and the concept of performance frontier identification may contribute to this aim.

In the performance frontier identification scenario, the performance is measured in terms of the efficiency level of the use of inputs, production effectiveness of outputs and efficiency in the conversion of inputs into outputs [12]. The firm production frontier concept specifies the maximum performance that can be achieved using a set of inputs. The distance between the production frontier and current production performance is called technical inefficiency. In this way, technical efficiency is the organization's ability to obtain the maximum result from a set of inputs [13].

The production frontier identification is a concept already known in the literature, however, it is realized that it can be used to boost the results in the operations function, as the excellence organizational performance is not reached unless it achieves optimal operations performance which is provided by the operations strategy effectiveness. The proposal is that the production frontier identification on the context of operations strategy can increase the assertiveness in the design of the manufacturing strategy and the exploitation of the key inputs. The extent to which a company must emphasize a competitive priority depends on its asset and operating frontier [14]. Measuring operational performance promotes managers' awareness of the efficiencies of their operations strategies, enabling accurate strategic and operational decisions to increase performance [3].

Based on the potential of applying the performance frontier concept within the operations strategy context, this paper aims to promote an in-depth systematic literature review to figure out the papers related to the theme of operations strategy and performance frontier analysis, simultaneously. The proposal is to identify leading authors bringing out the research standard. A bibliometric analysis is also presented, including keywords, main authors and journals in a timeframe perspective. This SLR is part of the research seeking to propose a process for the production frontier identification within the context of operations strategy.

A theoretical background on operations strategy and performance frontier is provided first. Then, the research design with the SLR steps is presented. Such steps are applied in the results section. A discussion of the results as well as a conclusion is then provided.

1.1. Operations Strategy

The operations strategy defines how manufacturing will support the achievement of business objectives by providing structural items (buildings, plant, equipment, etc.) and infrastructural ones (control policies, organizational structure, etc.) to ensure effective [7]. The traditional model of manufacturing strategy distinguishes between content and process. The process refers to the implementation, development, and use of the manufacturing strategy. The content covers the decision areas of the competitive dimensions [15].

Identifying the decision areas allows the organization to relate its daily decisions to the position of its competitive strategy. In addition, it provides a tool for diagnosing the historical pattern in decisions related to the organization's competitive performance and provides a level of detail that can be used as a guide for future decisions [16]. For competitive priorities, there are several approaches to defining the most important competitive dimensions. The definition used in this work is quality, reliability, flexibility, speed, and cost [8].

Analyze the competitive position for each competitive criterion is primary important since there are commonly tradeoffs between performance objectives. In other words, improvement in one performance criterion can be achieved only by sacrificing the performance of another. However, there are two visions of trade-offs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others. Most companies, at one time or another, will adopt both approaches. This is best illustrated by the concept of "efficient frontier" in production performance. Companies located at the efficiency frontier that aim to improve the effectiveness of their operations should seek to overcome the trade-off that is implicit in the efficiency frontier curve [4].

1.2. Performance Frontier

The firm production frontier discussion was first placed by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society. The efficiency frontier is a function that indicates the maximum level of the attainable result by a given set of inputs [13]. The frontier is estimated based on the observation population of company's inputs and outputs (or a representative sample). While the efficiency of the organization is expressed by a proportion of its relative results to the ideal or fully efficient result [18]. It is a ratio between outputs and inputs. Results smaller than 1 represent inefficient firms [19].

$$Efficiency = \frac{Value\ of\ outputs}{value\ of\ inputs} \quad (1)$$

Some of the approaches are parametric and some are non-parametric and both approaches can be deterministic or stochastic. Farrel (1957) proposed the non-parametric deterministic frontier methodology [13]. In 1978, Charnes, Cooper, and Rhodes proposed the DEA (data envelopment analysis) CCR model, with constant returns to scale [20]. In 1984, Banker, Charnes, and Copper proposed the DEA BCC model suitable to variable returns to scale [21].

The Data Envelopment Analysis DEA is a non-parametric method in which the production frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to evaluate the performance of organizations based on multiple metrics [19]. That is, the DEA is a way of calculating productivity or efficiency [22]. It can be considered a technique to aims to compare the operational performance of production units (DMU – decision make units). It is a measure of relative efficiency, as it considers the presented data, therefore, it is not possible to determine an absolute efficiency, outside the group of analysis [20].

DEA models are further divided into two groups, input-oriented and output-oriented. An input-oriented DEA model shows proportional relation of inputs while consuming the current level of outputs for an inefficient organization to become efficient. So, an input-oriented model is concerned with the minimization of the use of inputs for achieving a given level of outputs. On the other hand, an output-oriented DEA model determines how efficient a firm consuming its current level inputs to convert into output to become efficient. Output oriented approach seeks the maximization of the level of outputs per given set of inputs [20].

Unlikely the DEA, the SFA (Stochastic Frontier Analysis) is a parametric approach, in which the form of the production function assumes to be known or is estimated statistically [23]. The SFA is motivated by the idea that organizations can be inefficient for a variety of reasons and some of them may not be the organization's responsibility. Deviations that are not common to all organizations are called the stochastic term [18,24].

2. Research Design

This paper aims to present the results of an in-depth systematic literature review (SLR) proposing a research mapping that organizes the main research topics related to operations strategy and performance frontier. First, the systematic literature review method is selected to map the body of knowledge of this field of study. Next, bibliometric analysis is promoted to describe current research themes and extract information that could be used as an opportunity for future research.

The proposed SLR uses an adaptation of the Knowledge Development Process - Constructivist (ProKnow-C) instrument developed by the Multicriteria Decision Support Laboratory - LabMCDA - the Federal University of Santa Catarina, Brazil [25].

The ProKnow-C process helps in accumulating knowledge of the intended research area. The process identifies a bibliographic portfolio aligned with the subject of study, weight the most relevant articles, authors, and journals in the bibliographic portfolio, evaluate the portfolio's articles according to the researcher's preferences; and highlight the strengths of those articles and the ways in which they can be improved [26]. The process to define the bibliographic portfolio follows various filter steps, including different procedures to papers with and without scientific recognition. The process is summarized in Fig. 1.

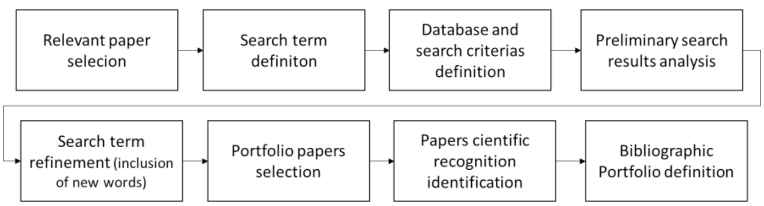

Fig. 1 – Systematic literature review main steps

Once the bibliographic portfolio was defined, the bibliometric analysis was developed on two fronts: a bibliometric analysis of the bibliographic portfolio and bibliometric analysis of bibliographic portfolio references. The aim at this stage is to identify a research pattern, including the main research area authors, key-words and journals.

3. Results

This section presents in detail the results of the systematic literature review phase as well as the bibliometric analysis.

3.1. Systematic Literature Review

As described in Fig. 1, the first SLR step is to select relevant papers in the field of study, to help on defining keywords and search terms. Therefore, some papers related to operations strategy and frontier identification are randomly selected to identify keywords and to build search terms, they are denominated ‘control group’. Them, two study axes were defined as described in Table 1, to helping on a further definition of keywords and search terms.

The reading of the selected works of the control group allowed the identification of keywords and search terms for each axis. The defined search term was therefore tested at selected databases to check whether they return the control group papers or not. The defined databases are Scopus and Web of Science. The search criteria assigned in the web of science and Scopus include a period less than 20 years (between the years of 1997 and 2017) and all paper in the English language. The first proposition of the search term was tested and the results of both, Web of Science and Scopus missed bringing some of the control group papers. Because of that, the search term was refined, by the inclusion of new keywords, and retested. In order to validate the proposed new search term, the same test was conducted again to identified whether the articles previously selected, called 'control group', were pointed out in the search result. Now all items in the control group were presented in the search term result. The final group of keywords is also presented in Table 1. They bring the result of 1385 works at Scopus and 126 works at Web of Science.

Table 1. Key Words.

Axes	Key Words
Axes 01: Technical axes that cover the methodology that will be used to carry out the study, which focuses on the identification and analysis of performance frontier	Frontier analysis, Frontier approach, Efficiency evaluation, Technical efficiency, Data envelopment analysis, stochastic frontier analysis, Operational Competitiveness Rating Analysis, Coob-Douglas, Estimation of frontiers, Frontier production function.
Axes 02: Context: Context axis related to the operations strategy, concept used as the structuring basis of the work	Operation(s) strategy (ies), Manufacturing strategy (ies).
	competitive priority (ies), competitive dimension(s), performance criteria(s), competitive criteria(s), performance dimension(s).
	Decision area(s)
	Capabilities, Resource-Based View.

At this point, some exclusion action was taken to eliminate works that do not matter to the research. First, works in duplicity were eliminated. EndNote X8 supported this action. At this stage, a result of 1.511 (Scopus and Web of Science) dropped down to 1.403. Next, works that are not papers were eliminated as the Proknow-C methodology advocates the selection of only scientific articles. In this way, works of other nature, as books and book chapters, have been eliminated, generating then 1.211 papers. Next, the title was read and papers with misaligned titles were also eliminated, remaining 426 papers.

The following step in selecting the key references for understanding the state of the art in the aimed theme is the filtering of articles according to their scientific recognition. To do so, a spreadsheet in Excel was organized with the list of articles and information of author, date, article title, journal, as well as the information related to the JCR impact factor from 2016 and the number of citations of each of the articles. The information was extracted from the Scopus database and was included. The papers were organized in descending order of the number of citations. At this stage, an adaptation of the Proknow-C methodology is promoted, since this process indicates the use of academic google as a source of the number of citations. The result of the Pareto analysis of the number of citations reflects that 1.41% of articles (6 articles) are responsible for 25.41% of the total number of citations. 156 articles, representing 36.62% of the articles, contributed 90.09% of the total number of citations.

Based on the analysis, it was defined that the articles of the first two groups, 156 articles, are part of those with confirmed scientific recognition. While the remaining 270 articles are those with unconfirmed scientific recognition. The screening process, developed so far, is detailed in Fig. 2.

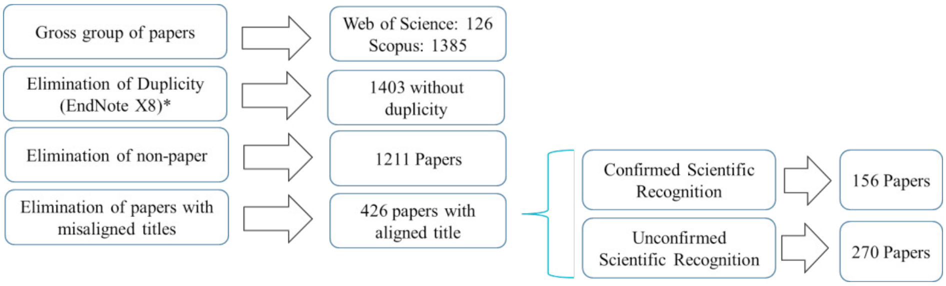

Fig. 2. SLR Screening Process.

The next step is the evaluation of the papers abstract, to verify their adherence to the research theme. To make this phase feasible, there was a selection of the articles that would be submitted to the abstract evaluation. Different procedures were adopted for articles with confirmed scientific recognition and for those with unconfirmed scientific recognition.

The abstracts of the 156 papers (confirmed scientific recognition) were analyzed and it was identified that only 24 papers had the abstract aligned. These authors composed the repository A. Of the 24 papers, 20 were available at the databases, and the authors of these papers composed what was called 'Basis of Authors (BA)'.

The papers classified as without scientific recognition (270 papers) were analyzed considering the year of its publication. Recently published articles - with less than 2 years of publication (from 2015 through 2017) – also had their abstracts analyzed to check adherence to the research topic. This procedure was taken since the recent articles might have a lack of scientific recognition due to the short period in which they are exposed to the academic community. The papers with more than two years of publication were evaluated in relation to their authors. Those articles developed by the authors that are included in the Basis of Authors (BA) were selected for the abstract reading, while the works developed by other authors were eliminated from the database. From this process, 127 articles proceeded to the abstract evaluation stage, that is, they were read. As a result, 17 papers with aligned abstracts were identified and all of them were available, composing the repository B.

The 20 papers from repository A and the 17 from repository B had been submitted to a full analysis of the whole paper content. And the result identified 19 papers aligned to the research theme, which compose the bibliographic portfolio of the research. The whole screening process is presented in Fig. 3.

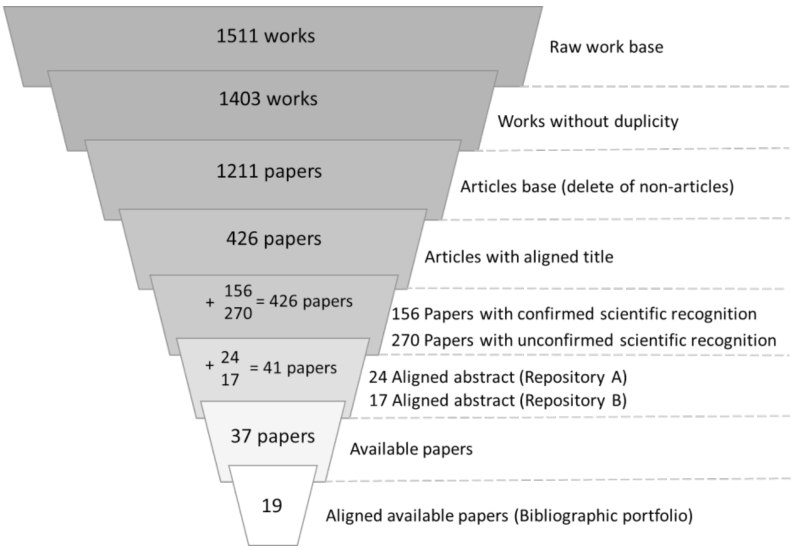

Fig. 3. Screening Process

The references in the bibliographic portfolio are presented in Appendix A. The bibliometric analysis, following presented, studied this set of papers in relation to its keywords, authors, year and journal, seeking to promote an understanding of the research standard.

3.2. Bibliometric Analysis

The bibliometric analysis was developed on two fronts: a bibliometric analysis of the bibliographic portfolio and bibliometric analysis of bibliographic portfolio references. In this stage, the information on the 19 bibliographic portfolio papers was collected. To do this, a spreadsheet in Excel was organized. First, an identification of the keywords was done and from this, a diagram of affinities aiming to identify the subjects most approached by the authors (see Table 2).

Table 2. Bibliographic portfolio key words.

Topic name	Kew Word (as indicated by the author)	Incidence
Capabilities	Operations capability / Operations capability/ Operations capability / capability / Operational capability / Capabilities / Marketing capability / Marketing capability / Marketing capability / Marketing capability / Marketing capability / IT Capability	12
Methods for technical efficiency calculation	Data envelopment analysis / Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis/ Data envelopment analysis / Stochastic frontier analysis / Stochastic frontier analysis / Operational Competitiveness Ratings Analysis (OCRA)	10
Performance Management	Performance management / performance / Performance measurement / Performance / Performance measurement (quality) / Financial performance / corporate social performance / financial performance	8
Environments Specification	Economic downturns / Dynamic environments / emerging economy / New business areas / Uncertainty/ Transaction cost economics / Additive manufacturing / buyer-supplier ties	8
Sector specification	Electrical machinery industry / Retail / 3D printing / Dealership network / high-technology markets / Logistics / Processed food industry / IT consultants	8
Resources	Resource-based-view / Resource-based-view / Resource-based-view / Resource-based-view / resources	5
Competitive Advantage	Competitive advantage / Competitive advantage / Competitive advantage / Competitive advantage / Competitive priority	5
Methods	Fuzzy logic / Multicriteria analysis / Data mining / Clustering / Text mining	5
Efficiency	Efficiency / Efficiency / Efficiency / productivity	4
Operations Strategy	Operations strategy / operations strategy / manufacturing strategy / content analysis	4
Frontier Analysis	stochastic frontier estimation / Operating frontier / Asset frontier	3
Decision Making	Decision making / Decision Support System	2
Region	Turkish SMEs / UK	2
Others	Innovation / innovation and R&D / Patent information / Model-based approach of competitive analysis / financial risk / financial market reaction / Diversification / Management / Strategic agility / Technological strength / Functional importance / Benchmarking / network / Institutional theory / Resilience / business group	16

The next step was the identification of the involved authors. Two researchers participated in the authorship of more than one study, they are Ramanathan, R. and Nath, P., the others had only one incidence. To check the involved authors, see Appendix A. Following, the analysis of the journals most used for the publication was promoted, the evolution of journal incidence over time is presented in Fig. 4. One can note that Industrial Marketing Management and the International Journal of Production Economics were the most used, with three incidences, followed by the Strategic Management Journal with two occurrences.

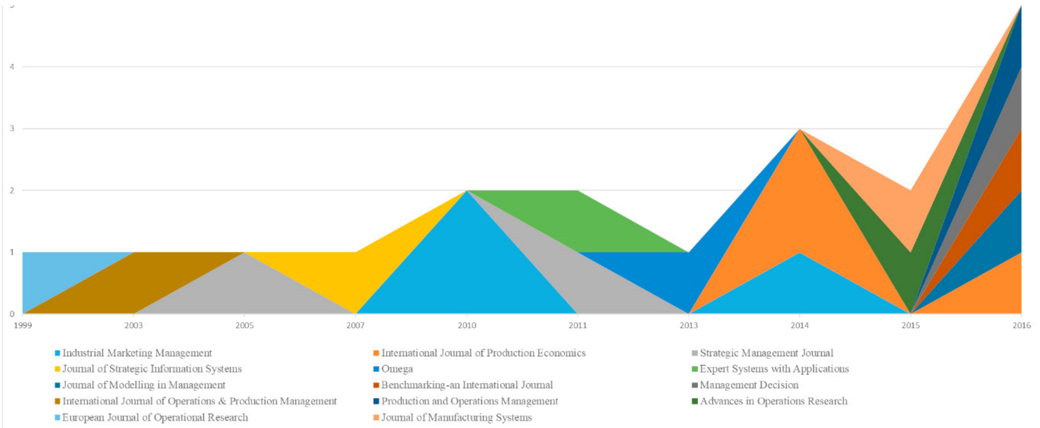

Fig. 4. Journals of the bibliographic portfolio.

The next step was the bibliometric analysis of the references used in the 19 papers of the bibliographic portfolio. To do so, another Excel spreadsheet was organized. Firstly, an analysis of the authors was promoted. The graphic in Fig. 5 presents the main incident authors. Only authors with 7 citations or more were included. The graphic also distinguishes if they are the main author (author 1), the second author (author 2) and so on.

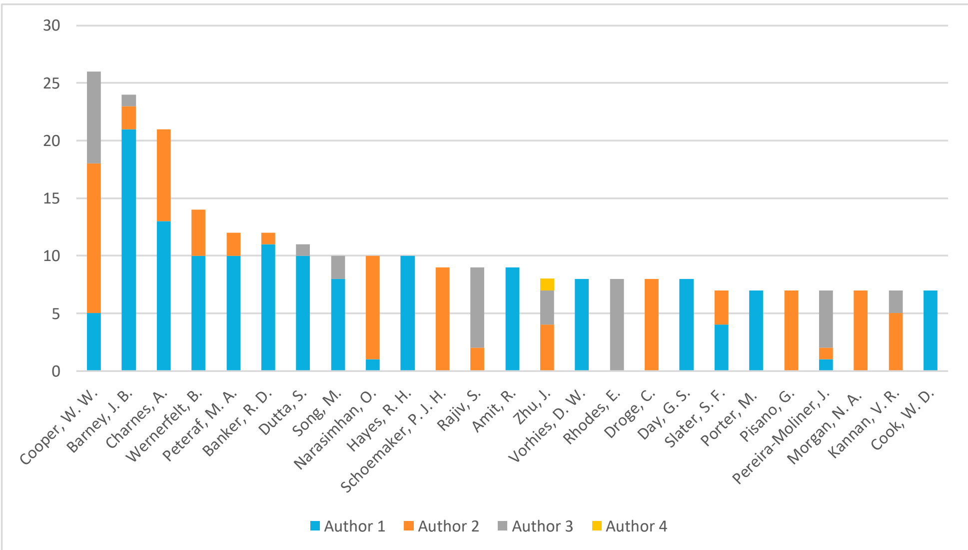

Fig. 5. Involved authors in the references of the bibliographic portfolio.

The most used journals were also evaluated, the 'Strategic Management Journal' was used in 135 works, followed by 'Management Science' with 53 references and the 'Journal of Operations Management' with 48. Fig. 6 shows the standard of the journal incidence over time, only for the 20 journals with higher participation.

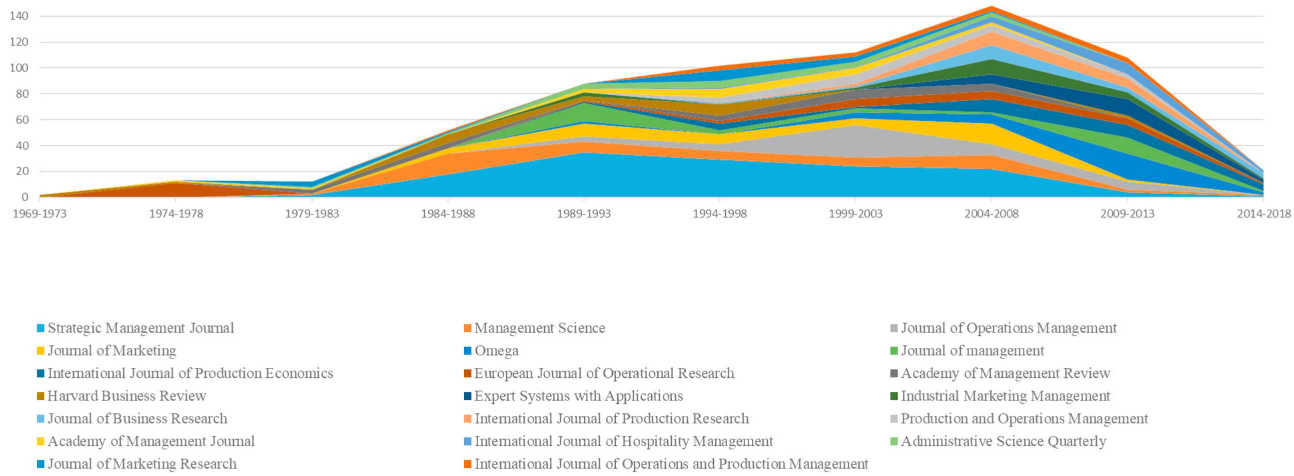

Fig. 6. Involved journal in the references of the bibliographic portfolio.

All the presented results from SLR and bibliometric analysis are the following discussed and main conclusion is delineated.

4. Discussion

Looking at the data from the 19 papers of the bibliographic portfolio, an important research pattern is recognized in the key-word incidence analysis. Words similar to capabilities are found as the most incident ones, and words related to resource-based view theory also presented a prominent position. This can reveal that a focus on resource-based operations strategy approach is given by literature to promote performance frontier analysis studies. This finding is proven when we look at the main references of these 20 papers (See Fig. 5), they are concentrated in the seminal authors that approach both performance frontier and resource-based view theory. Cooper, W., Charnes, A., and Banker, R. D. are all the authors that proposed the Data Envelopment Analysis (DEA) performance frontier methodology to variable return to scale, in 1984. This work is an extension of Charnes, Cooper, and Rhodes (1978), that presents the original DEA constant return to scale (CRS) model. Likewise, Barney, J. B.; Wernerfelt, B., Peteraf, M.A. are all authors recognized for the development of the resource-based view theory [27, 28]. Birger Wernerfelt proposed the resource-based view concept [28] and Jay Barney is one of the main authors of this area, and in 1991 published a seminal work 'Firm Resources and Sustained Competitive Advantage' in the Journal of Management, which states the attributes that firm's resources must have to become a source of sustained competitive advantage [27]. From this perspective, resources must have value, rareness, imperfect imitability and imperfect substitutability. The market-based view (MBV), mainly approached by Porter [29, 30, 31], was less explored, but also appeared in the references. This is because of some research stream focus on identifying the influence of the operation on developing capabilities, focusing on RBV approach, while few papers explore the role of operations strategy in attending market requirements, focusing on MBV approach. The words 'competitive priorities' and 'decision areas' or similar, that regards to the recognized definition of operations strategy [15] are not also highlighted by keywords.

Another important detection is that publications of performance frontier and operations strategy, simultaneously, is most recent, showing a growth in 2016, revealing to be a topical topic in current research. When we look at the standard of the journal incidence over the time, regarding the bibliographic portfolio references (Fig. 6) we see older papers, but they are the seminal research used as a foundation for the recent ones.

Lastly, there was identified that there are no authors that stand out in the 19 papers of the bibliographic portfolio. Only two researchers participated in the authorship of more than one study, with two incidences, indicating that the topic could be more explored by in deep research to increase the authors' potential for prominence.

Therefore, based on the presented systematic literature review is possible to identify two main research opportunities. The exploration of the topic of performance frontier and operations strategy, that is still being a topical topic in current research. And the use of the market-based view (MBV) approach of operations strategy in the literature about performance frontier.

5. Conclusion

The paper proposal is to present the result of the systematic literature review focusing in identify the research stream that explores the concept of operations strategy and performance frontier, simultaneously. After an in-depth systematic literature review, using the Proknow-C process framework, it was found 19 papers fully related to both topics. The main findings can be summarized as follows:

- The market-based view focus is less explored, therefore, frequently, the connection within the competitive strategy is missing;
- There is a focus on resource-based view theory when applying performance frontier methodologies;
- There is a gap in exploring the grounded definition of operations strategy of 'decision areas' and 'competitive priorities';
- Publications of performance frontier and operations strategy, simultaneously, is mostly recent, with a growth in the number of publications from 2016;
- There are no authors that stand out in the theme of performance frontier identification within the operations strategy context.

A preliminary research standard could be acknowledged, and the bibliographic portfolio identification gives an opportunity to the continuation of this study. Therefore, a future work opportunity is the development of a content analysis continuing the systematic literature review, seeking to confirm the findings and clarify the research gaps.

Appendix A. Bibliographic portfolio

References of the bibliographic portifolio
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Appendix A–2 Research Paper 2

Title: A Content Analysis on Efficiency Frontier Identification and Operations Strategy.

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A Content Analysis on Efficiency Frontier Identification and Operations Strategy

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Abstract

Operations strategy and efficiency frontier are two topics widely covered in Operations Management literature in its own development path. However, when we survey both topics in an integrative way it is not possible to identify a wide range of papers. Considering this research gap, an important contribution to operations management research area is given, approaching the two concepts in a complementary manner. Through a comprehensive systematic literature review, we find out 19 papers fully related to operations strategy and efficiency frontier identification, which composes the portfolio of analysis. This paper focuses on promoting a content analysis of this portfolio seeking to identify research gaps in this stream of study and therefore making it possible to strengthen it. As a result, a mapping of the research stream as well as future work opportunities is presented in the perspective of operations strategy approach, context, completeness analysis, and research proposal. Based on the content of the portfolio papers set, the relation between operations strategy and efficiency frontier concept are clarified and represented.

Keywords: Content analysis, operations strategy, performance efficiency frontier

1. Introduction

The literature widely recognizes that the operations have an important influence on the competitive advantages' development as the level of competitiveness increases [1, 2, 3, 4]. Therefore, a request for operational efficiency is made for successful businesses [5]. However, the potential of operations is not properly exploited, going against the achievement of a better competitive position [6].

The concept of production frontier identification can be used to boost the results in the operations function and help to explore the whole potential of the production function. The firm production frontier concept specifies the maximum performance that can be achieved using a set of inputs [7]. The proposal is that the frontier methodology can contribute to increasing assertiveness in the design of the operations strategy and the exploitation of the key inputs.

Based on the potential of applying the performance frontier concept within the operations strategy context, a in depth systematic literature review (SLR) was promoted to figure out the papers related within the theme of operations strategy and performance frontier

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analysis, simultaneously. The results evidenced that operations strategy and efficiency frontier are two topics widely covered in Operations Management literature in its own development path. However, when we survey both topics in an integrative way it is not possible to identify a wide range of papers. After all the exclusion criteria of the SLR method, the results revealed 19 papers fully aligned with both themes, efficiency frontier, and operations strategy.

The proposal is now, deepen in the content of these set of papers seeking to clarify the relation between operations strategy and efficiency frontier concept, as well as to confirm the potential findings and to detect new ones. To do so, a conceptual mapping and a conceptual framework are proposed. Additionally, the research agenda is proposed by presenting a mapping of the research stream in the perspective of operations strategy approach, context, completeness analysis, and research proposal. Future work opportunities are also delimited. This content analysis is part of the research seeking to propose a process for the production frontier identification within the context of operations strategy.

First, a theoretical background is provided, then, the research design presents the steps of the content analysis, which are in its turn performed at results section, culminating in the proposition of the Conceptual Framework of operations strategy and performance frontier. By the end, conclusions are addressed.

1.1. Theoretical Background

The operations strategy defines how manufacturing will support the achievement of business objectives by providing structural items (control policies, organizational structure, etc.) and infrastructural ones (buildings, plant, equipment, etc.) to ensure effective organizational results [8]. The traditional model of manufacturing strategy distinguishes between content and process. The process refers to the implementation, development, and use of the manufacturing strategy. The content covers the decision areas of the competitive dimensions [9].

Identifying the decision areas allows the organization to relate its daily decisions to the position of its competitive strategy. In addition, it provides a tool for diagnosing the historical pattern in decisions related to the organization's competitive performance and provides a level of detail that can be used as a guide for future decisions [10]. For competitive priorities, there are several approaches to defining the most important competitive dimensions. This research considers quality, reliability, flexibility, speed, and cost [6, 11].

On the other side, the firm production frontier discussion was first placed by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society. The efficiency frontier is a function that indicates the maximum level of the attainable result by a given set of inputs [7]. The frontier is estimated based on the observation population of company's inputs and outputs (or a representative sample). While the efficiency of the organization is expressed by a proportion of its relative results to the ideal or fully efficient result [12]. It is a ratio between outputs and inputs. Results smaller than 1 represent inefficient firms [13].

Some methods for calculating technical efficiency are proposed in the literature. The best known are SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis). The DEA is a widespread approach since 1978 when Charnes, Cooper, and Rhodes proposed the original DEA constant return to scale (CRS) model [14, 15]. Fig. 1 illustrates the DEA frontier by considering a simple case with an input and an output of seven companies (company a to g).

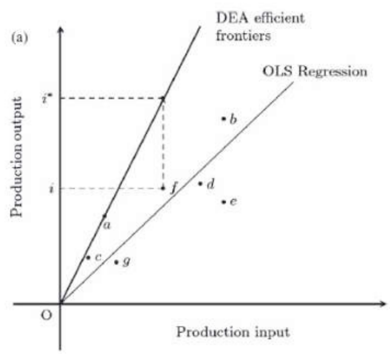

Fig. 1 – DEA Frontier [14]

The DEA frontier is the line that starts at the origin and follows the performance relationship of the company 'a', which corresponds to a higher proportion of outputs by the inputs. The area below this line represents inefficient input-output relationships. The figure also contains an OLS (ordinary least squares) regression line. Inefficiency is measured by the distance of each organization from the frontier. The companies are the DMUs – decision make units - any group of entities that receive the same inputs and produce the same outputs [16], and those that achieved 100 percent efficiency are considered efficient, while DMUs with efficiency scores below 100 percent are inefficient [12].

The objectives for applying DEA can vary, including the identification of the sources of relative inefficiency in the input-output dimensions; Raking the DMU by their efficiency outcomes; Evaluating the effectiveness of program that are out of company control, as well as differentiating between program inefficiency and managerial ones; Creating a quantitative basis for allocating resources [16]. The COOPER-framework provides guidance for non-parametric analysis, encompassing a systematic checklist with the required phases to assess performance [17].

2. Research Design

This paper aims to present the content analysis of an in-depth systematic literature review (SLR) that organizes the main research topics related to operations strategy and performance frontier. The SLR uses an adaptation of the Knowledge Development Process - Constructivist (ProKnow-C) instrument developed by the Multicriteria Decision Support Laboratory - LabMCDA - Federal University of Santa Catarina, Brazil [18]. The SLR steps have included the selection of relevant papers through the definition of keywords and search term (raw work base), exclusion of duplicated works, exclusion of non-articles, exclusion of papers with non-aligned title, exclusion of papers with non-aligned abstracted and finally, exclusion of non-aligned papers. A different procedure has been adopted for papers with and without scientific recognition. The step by step procedure details can be found in Veiga et al. (2019) [19]. The main results of all steps of the method are presented in Fig. 2.

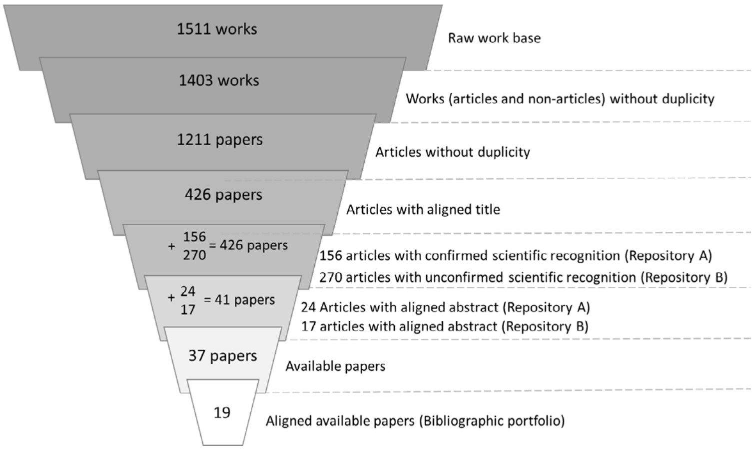

Fig. 2 – SLR results step by step

This paper aims to explore the content of these set of literature in the bibliographic portfolio, promoting an in-depth understanding and using causal mapping to organize the main contribution of them. The content analysis is developed in three steps (see Fig. 3.)

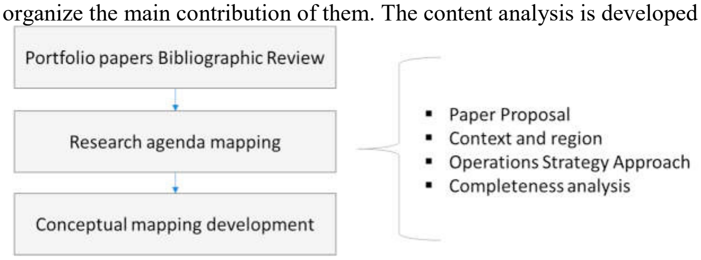

Fig. 3- Content Analysis main steps

Portfolio papers bibliographic review section is going to approach main concepts and proposals covered by papers included in the portfolio. The second section presents a research agenda mapping to identify literature gaps. Finally, a conceptual map is developed to clarify mainly the interaction of both concepts, performance frontier analysis, and operations strategy.

This content analysis is promoted to the 19 papers of the bibliographic portfolio, which represent the articles fully related to both themes, of operations strategy and performance frontier. They are presented in table 1.

Table 1. Bibliographic Portfolio.

Author	Title	Year	Journal	Proposal
Abassi and Kaviani (2016) [5]	Operational efficiency-based ranking framework using uncertain DEA methods an application to the cement industry in Iran	2016	Management Decision	To propose a framework for evaluating and ranking the organizations based on the effectiveness of their operations strategies.
Achillas et al. (2015) [20]	A methodological framework for the inclusion of modern additive manufacturing into the production portfolio of a focused factory	2015	Journal of Manufacturing Systems	To propose a model that use multi-criteria decision aid and DEA for determining the optimum operations strategy.
Ahmed et al. (2014) [21]	Impact of operational and marketing capabilities on firm performance: Evidence from economic growth and downturns	2014	International Journal of Production Economics	To examine how the importance given to operations and marketing functions impacts their capabilities and firm performance.
Akdeniz et al. (2010) [22]	An integrated marketing capability benchmarking approach to dealer performance through parametric and nonparametric analyses	2010	Industrial Marketing Management	To discuss marketing capabilities as a source of sustainable advantage through the DEA and SFA application.
Bulak et al. (2016) [13]	Measuring the performance efficiency of Turkish electrical machinery manufacturing SMEs with frontier method	2016	Benchmarking-an International Journal	To measure and evaluate the efficiency of electrical machinery manufacturing to determinate whether competitive priorities maximizes firm performance.
Cai and Yang (2014) [23]	On the relationship between business environment and competitive priorities: The role of performance frontiers	2014	International Journal of Production Economics	To explore the link between business environment and competitive priorities in the Chinese firms' environment.
Chang et al. (2015) [24]	An Empirical Study of Strategic Positioning and Production Efficiency	2015	Advances in Operations Research	To propose a framework using DEA model to identify how strategic positioning have affected firm performance.
Dutta et al. (2005) [25]	Conceptualizing and measuring capabilities: Methodology and empirical application	2005	Strategic Management Journal	To exemplify the measurement of R&D capabilities in the semiconductor and computer equipment industries.
Hemmati et al. (2016) [26]	Development of fuzzy two-stage DEA model for competitive advantage based on RBV and strategic agility as a dynamic capability	2016	Journal of Modelling in Management	To develop a framework based on RBV and dynamic capabilities theory.
Jacobs et al. (2016) [27]	Operational Productivity, Corporate Social Performance, Financial Performance, and Risk in Manufacturing Firms	2016	Production and Operations Management	To examine the relationship between Operational Productivity, Corporate social performance, financial performance and risk.
Jayanthi et. al (1999) [28]	Competitive analysis of manufacturing plants: an application to the US processed food industry	1999	European Journal of Operational Research	To propose a framework to identify and classify the competitiveness drivers in structural and infrastructural terms.
Mahmood et al. (2011) [29]	Where can capabilities come from? network ties and capability acquisition in business groups	2011	Strategic Management Journal	To use SFA to study how the type of ties between businesses can affect the development of capabilities.
Miller and Ross (2017) [30]	An exploratory analysis of resource utilization across organizational units - Understanding the resource-based view	2003	International Journal of Operations & Production Management	To explore the RBV concept investigating why resource utilization differ within a firm.
Nath et al. (2010) [31]	The impact of marketing capability, operations capability and diversification strategy on performance: A resource-based view	2010	Industrial Marketing Management	To identify the impact of functional marketing and operations capabilities, and diversification strategies on the financial results.
Nevo et al. (2007) [32]	An examination of the trade-off between internal and external IT capabilities	2007	Journal of Strategic Information Systems	To compare the impact of internal and external IT capabilities on productivity.
Ramanathan et al. (2016) [33]	Linking operations, marketing and environmental capabilities and diversification to hotel performance: A data envelopment analysis approach	2016	International Journal of Production Economics	To analyze the impact of marketing capability, operational and environmental capability, and diversification strategy on financial performance.
Samoilenko and Osei-Bryson (2013) [34]	Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system	2013	Omega-International Journal of Management Science	To propose and test a DEA Centric Decision Support System that seeks to asses and manage the relative performance of organizations based on internal (RBV) and external organization environment.
Seol et al. (2013) [35]	Identifying new business areas using patent information: A DEA and text mining approach	2011	Expert Systems with Applications	To use DEA to identify new business opportunities.
Yu et al. (2014) [36]	The impacts of marketing and operations capabilities on financial performance in the UK retail sector: A resource-based perspective	2014	Industrial Marketing Management	To investigate the relationship among marketing capabilities, operational capabilities and financial performance.

3. Results

The first topic summarizes the empirical work from the 19 papers of the bibliographic portfolio. The analysis of these papers content sustains the development of the conceptual mappings as well as the conceptual framework.

3.1. Portfolio Papers Bibliographic Review

From the 19 papers of the portfolio, few papers directly relate performance frontier analysis with and operations strategy [5, 13, 28]. There are some papers that establish competitive priorities as outputs, providing a narrow picture of operations strategy performance [23]. Several authors use resource-based view (RBV) as background for performance frontier study, since its theory link superior performance to firm resources and capabilities [21, 22, 25, 26, 30, 34, 36]. Capabilities are the ability of a company to transform a set of inputs (resources) into certain outputs (objectives) for sustainable advantage [21, 22, 25]. The RBV designates how an individual firm's resources (e.g. tangible and intangible assets and organizational capabilities) affect its financial performance [37, 38]. There are papers that focus on marketing and operations capabilities [21, 22, 26, 29, 31, 33, 36], R&D capabilities [25, 29] and environmental capability [33]. There are also some authors that approach the concept of operations strategy and analysis of the performance frontier in more specific contexts [20, 32]. By the end, some papers indirectly approach the operations strategy concept [27].

3.2. Research agenda mapping

The second stage of the content analysis was developed through the analysis of the works that compose the bibliographic portfolio, the analysis considered: work proposal, context, and region of the empirical application, if it exists; operations strategy approach and completeness analysis [39]. Based on the papers content analysis, the generated mappings for each element is following presented. There were identified three main work proposals objectives: Examine the relationship of some element with productivity, to measure productivity or to propose a framework for supporting decision making. In the first stream of study, the evaluation shows that many of the authors work in the context of Capabilities [21, 22, 25, 26, 29, 31, 32, 33, 36]. Some of them relate the impact of one or more capabilities on business performance while others explore how some element influence capabilities building. Most authors specify the context of the business and the region where the studies are promoted. There are also some authors with a similar objective, but they do not work with the concept of capabilities, instead, they seek to raise the drivers of organizational performance, not restricting to capabilities. In this case, organizational performance is measured by financial measures or not [23, 24, 27, 28, 30].

The second line of work is those that specifically aim to measure organizational performance or estimate the performance frontier [5, 13]. In the end, a third line, include the authors who work with the proposition of frameworks to support decision making. Some authors provide subsidies for the decision on the production model [20, 34], others support decisions regarding new business opportunities [35]. The paper's proposals are indicated in table 1.

In general, the authors select a context and a region for the estimation of the performance frontier. The most explored context is manufacturing companies, while the region is the United States. It is noticed that Brazil did not focus on any of the studies. The context of applications is presented in Fig. 4.

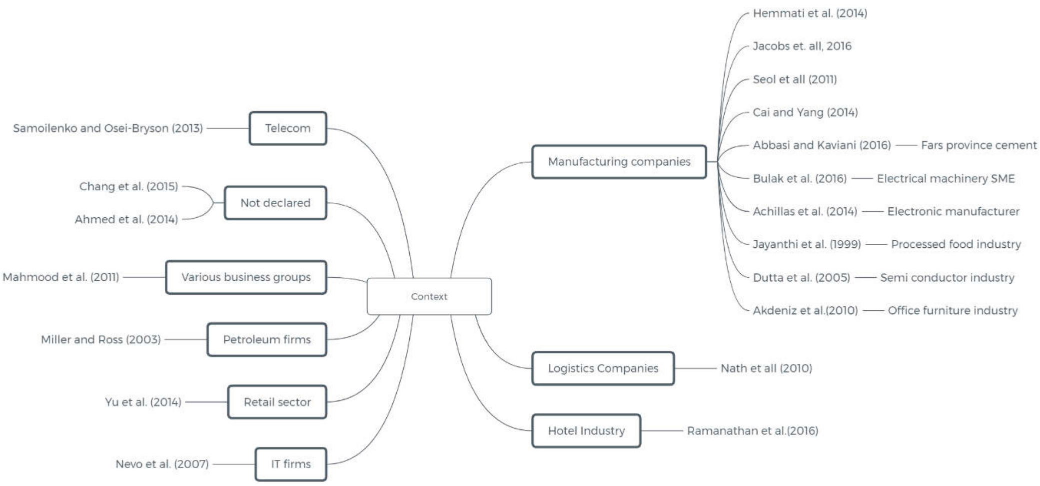

Fig. 4 - Summary of bibliographic portfolio papers context

As the requirement of bibliographic portfolio work content, they should have addressed the topic of performance frontier analysis and operations strategy, simultaneously. Therefore, the operations strategy approach was also analyzed. It is noticed that the operations strategy focus of most of the works is in the resource-based view (RBV) approach, working with the concept capabilities. Some of the papers promote only an indirect relation within the operations strategy concept.

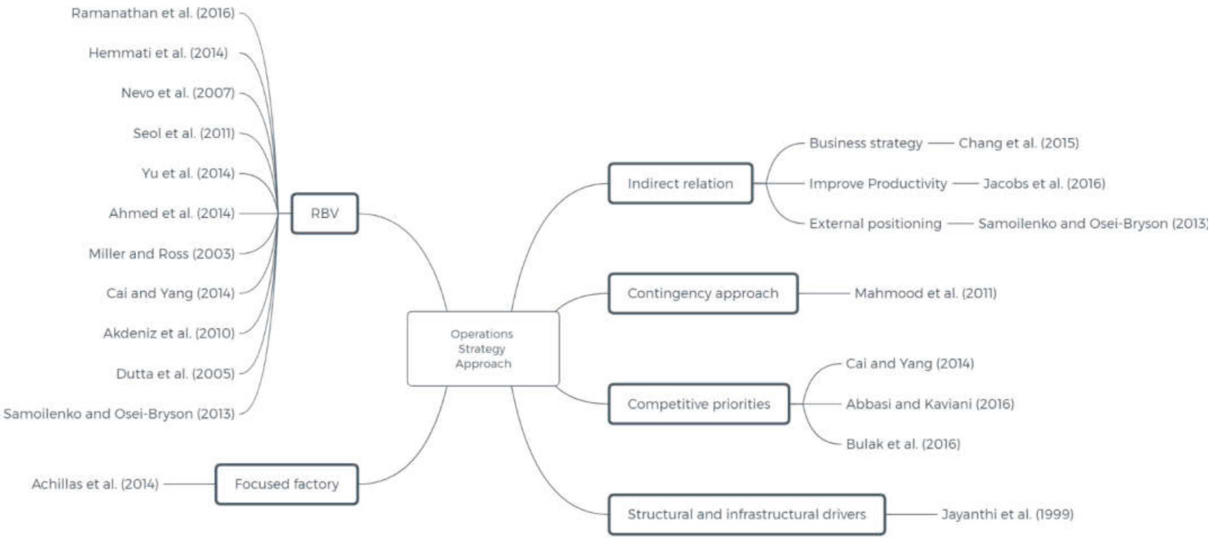

Fig. 5 - Summary of the operations strategy approach of the bibliographic portfolio papers

Finally, the completeness analysis seeks to identify the paper focus, which may be focused primarily on context, content or process analysis [39]. The context can be internal or external, the internal is related to structure, organizational culture, politics, among others; while the external context is linked to the economic, political and competitive environment in which the organization operates. The content is related to the organizational objectives and the organizational area in transformation, such as technology, hierarchical structure, products, geographic positioning, culture, among others. Finally, the process analysis contemplates the actions, reactions, and interactions of the various stakeholders that are part of the changing process from the current state to a future state. Fig. 6 shows that most of the papers focus on content perspective.

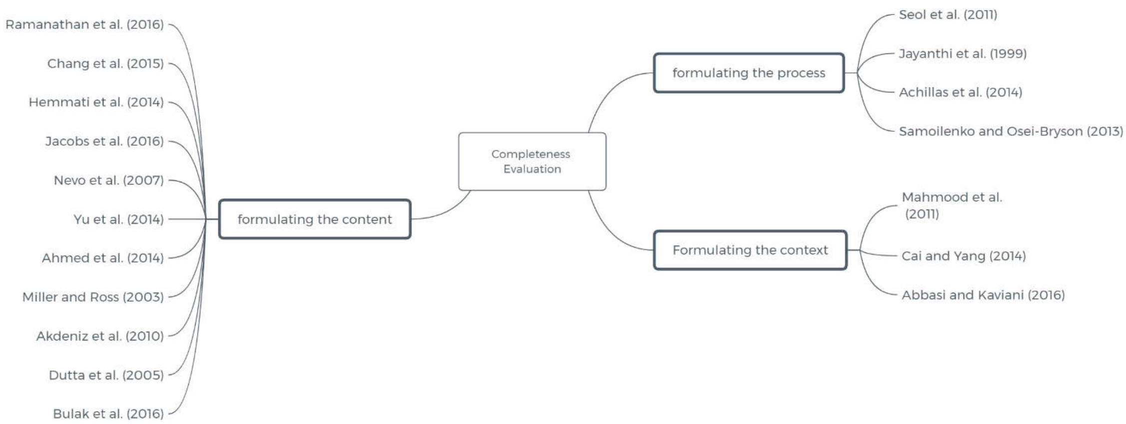

Fig.6 - summary of the completeness evaluation of the bibliographic portfolio papers

These mappings provide the research agenda of works that relate both, efficiency frontier methodologies and operations strategy. The research remaining opportunities in literature are further discussed in this paper.

3.3. Conceptual mapping development

The literature review of the bibliographic portfolio provided an in-dept understanding of the performance frontier and operations strategy concept. This understanding has enabled the making of a conceptual connection between both themes, which is now presented in the conceptual map (See Fig. 7).

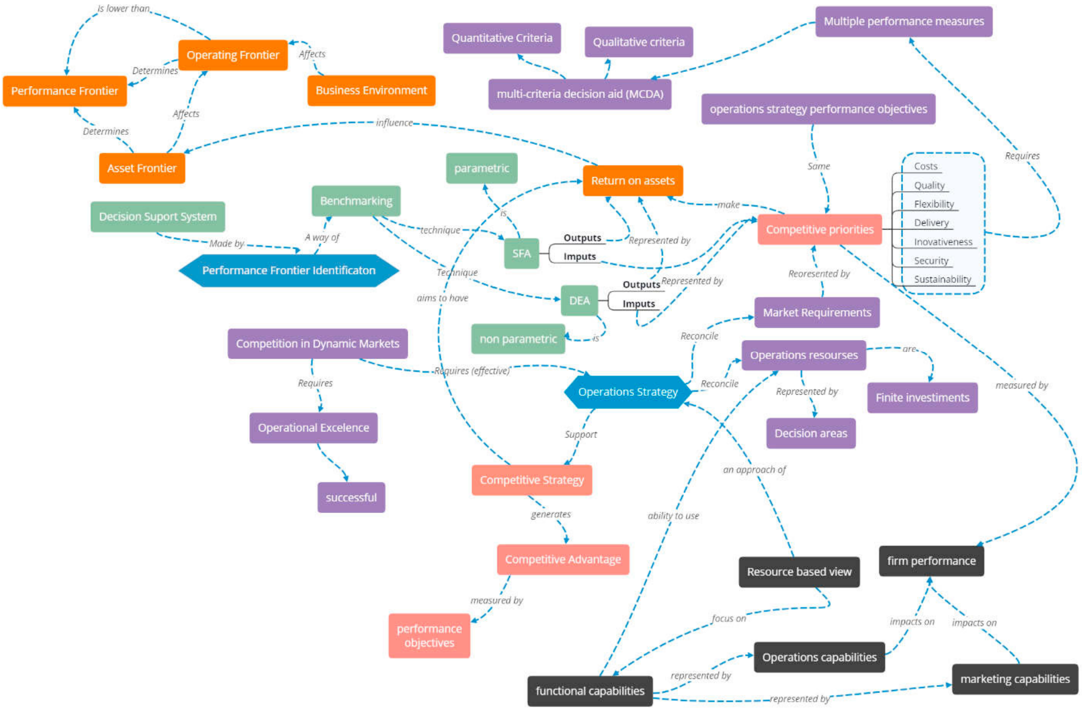

Fig. 7 – Conceptual mapping of the relation between operations strategy and performance frontier analysis

The conceptual mapping makes clear that the performance frontier identification is a decision support system, by means of a benchmarking, and there are some methodologies already proposed in the literature to perform it. The methodologies can be parametric or non-parametric and the most known are stochastic frontier analysis (SFA) and data envelopment analysis (DEA). Both are based on the measurement of inputs and outputs (See green boxes).

On the other hand, operations strategy reconciles market requirements as well as operations resources, which are finite investments and therefore, limit the potential of its organizational function. The operations resources are represented by the decision areas while the market requirements can be translated to operations function by means of the competitive priorities (costs, quality, speed, dependability, innovativeness, sustainability, and so on). The competitive priorities, in a recent competitive scenario, requires multiple performance measures, enhancing the complexity of the decision making. These competitive priorities are operations strategy performance objectives. The operations strategy is even more important when competing in dynamic and competitive markets, in this scenario, operational excellence is a need (See purple boxes). A very recognized approach of operations strategy is the resource-based view which works with the concept of capabilities to enhance operations strategy results (See black boxes).

Operations strategy supports the competitive strategy that, in its turn, seek the achievement of competitive advantage, measured by performance objectives. Therefore, it is possible to establish a relation between the competitive priorities and the competitive strategy, in other words, competitive priorities reveal the operations strategy results, which, in its turn support the achievement of competitive strategy (See red boxes).

When we look at performance frontier identification, seeking to enhance competitive advantage by means of operations strategy, the competitive priorities should be analyzed as an input, to evaluate its capacity of enhancing the outputs, represented by some metric related to the return on assets, a way of identifying competitive strategy effectiveness. The return on assets, influence the assent frontier, which, in its turn, determines the performance frontier, and affect operating frontier, which is also affected by the business environment (See orange boxes).

In the face of the conceptual mapping presented at Fig. 7 and in the previous explanation, one notices that the concept of operations strategy and performance frontier are closely related. Fig. 8 summarizes the relationship between the concepts of operations strategy and efficiency frontier, providing a general view of the concepts depicted in the previous conceptual mapping.

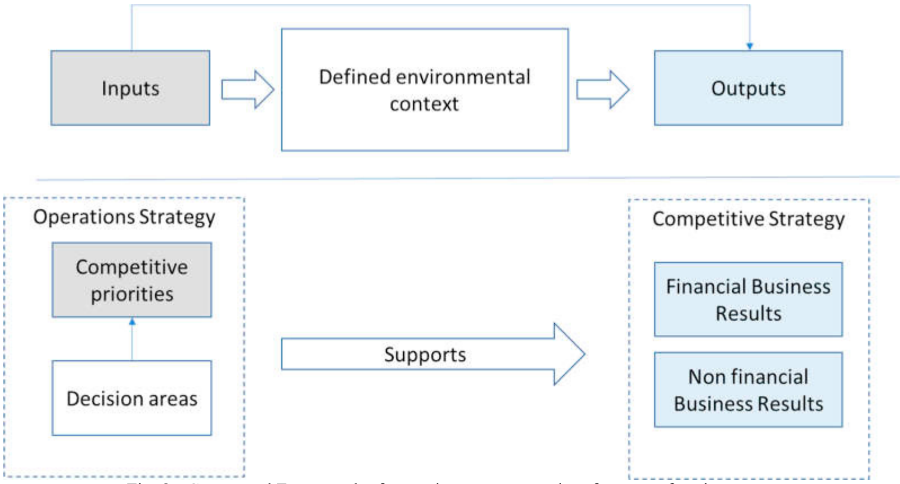

Fig. 8 - Conceptual Framework of operations strategy and performance frontier

The operations strategy is deployment from the corporate strategy and aims to achieve excellent performance in the key competitive priorities, this is achieved through acting in the so-called decision areas. While the concept of efficiency frontier is a function that indicates the maximum level of result attainable for a corresponding quantity of inputs. The frontier is estimated based on the observation of inputs and outputs of a population of companies (or a representative sample). Outputs are understood as the desired result of the business, in financial and non-financial terms, which are defined through corporate strategy. These results are achieved through action in operations, represented by functional strategies. The operations function has its strategy composed of the competitive priorities, supported by the action in the decision areas. In this way, inputs are defined by competitive priorities.

4. Discussion

Examining the content analysis presented in this research paper, it is possible to delimitate two main research gaps. The first gap is related to the lack of focus on operation strategy concept of competitive priorities. None of the papers fully addresses the concept of operations strategy, focusing on the competitive dimensions and decision areas and promoting the integration of them within the organizational performance. When integrating the concept of operations strategy and performance frontier methodologies, the main stream of literature focus on capabilities and RBV as an approach for operations strategy, in this kind of work, inputs and outputs depends on the aimed capability [21, 22, 25, 29, 31, 32, 33, 36]. For authors who works on the operations strategy concept of decision areas and competitive priorities, Cai and Yang (2014) explored the connection between business environment and firms' competitive priorities, however competitive priorities are considered output for their model, giving, therefore, a narrow picture of operations strategy as the relation with the organizational competitiveness is not made [23]. Jayanthi et al. (1999) use the structural and infrastructural drives of plant competitiveness, or decision areas [40], such drivers are considered the inputs and revenue as the output, the model does not focus on competitive priorities issue [28]. There are also authors who indirectly approach the operations strategy concept in their papers [24, 27, 34]. However, a more shared approach is to use competitive priorities as input, and financial and non-financial performance measures as outputs [5, 13].

The second gap is related to the lack of focus on a generic process perspective in studies related to operations strategy and performance frontier analysis. It is noticed that most of the papers are focused on the content analysis, seeking to identify the performance drivers or to estimate the frontier. There are also articles focused on the context, seeking to classify the target organization within an external context. The existing process-oriented papers generally propose frameworks for specific purposes. For instance, Seol et al. (2011) aim to identify potential new business areas, based on each company's technology strengths [35]. Jayanthi et al. (1999) seek to identify the drivers of competitiveness based on the decisions regarding the infrastructure and structure of the organization [4]. Achillas et al. (2014) work in the specific context of additive manufacturing [20]. Samoilenko and Osei-Bryson (2013) propose a model for decision-making. Therefore, a generic process to implement performance frontier in a given scenario has still the opportunity to be explored [34].

Beyond the contribution of providing the research agenda, this paper contributes to clarifying the relation between organization strategy and performance frontier analysis. The former literature on frontier analysis methods requires inputting and outputting variables [7, 14, 41, 42] and we identified that is not possible to find a consensus in what inputting and outputting variables on the context of operations strategy is. A more comprehensive approach is to use competitive priorities as input and to use financial and non-financial performance measures as outputs, as proposed in the conceptual framework. A shared consensus is that the measurement of the competitive priorities with multiple-related variables is increasingly common since the competitiveness is growing.

5. Conclusion

This research work contributes to providing a complete picture of the relationship between organization strategy and performance frontier analysis. It was promoted a content analysis based on the results of an in deep SLR. It was noticed that in spite of the concepts of operations strategy and performance frontier analysis being simultaneously little explored by literature, some papers promote this kind of work. However, most of the literature explored the relationship between these concepts in an indirect way. The proposed model in Fig. 17 aimed to formalize such a relation in a comprehensive way.

The paper also contributed to establish the research agenda, which made possible the identification of some research gaps, promoting an important contribution to theory. The gaps consist mainly in the lack of using a more comprehensive concept of operations strategy when seeking to its performance frontier; and the lack of generic process that help on promoting the frontier study.

From the research gaps, we state the future work opportunities of approaching the operations strategy concept of decision areas and competitive priorities to develop the performance frontier analysis, as stated in the proposed framework. As well as to explore the process of promoting such a study.

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Appendix A-3– Research Paper 3

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Efficiency Frontier Identification on the Context of Operations Strategy – A Study on Representative Constructs and Variables

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Abstract

The efficiency frontier is a function that indicates the maximum level of attainable performance result by a given set of inputs. The frontier is estimated based on the observation population of companies' inputs and outputs, considering a representative sample. On the operations strategy context, inputs can be understood as the competitive priorities, with should be managed to lead through a superior organizational performance. Some methods for calculating technical efficiency are proposed in literature and all of them requires inputting and output variables. This paper presents a process for defining variables based on statically analysis of the round 4 of High-Performance Manufacturing (HPM) data. The HPM project seeks to identify the practices adopted by high performance organizations and applies a survey with companies in 18 countries. The survey includes 1597 questions in 12 categories, culminating in a huge set of variables. Multivariate Data Analysis techniques are performed to establish a representative set of variables. As a result, we present the constructs to evaluate each input and output performance. This is an important contribution for the development of a Decision Support Systems for Manufacturing based on the frontier estimation techniques, which could be seen as a representative innovation to operations management and production research.

Keywords: Multivariate Data Analysis, Operations Strategy, Frontier Analysis, Performance Measurement.

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1. Introduction

The concept of performance frontier is a linear programming function that indicates the maximum level of attainable result by a given set of inputs [1]. Efficiency frontier methodologies allow the examination of performance in operational processes and helps organizations to test their assumptions about performance, productivity, and efficiency in operation decisions [2].

Such a concept is applied in a wide range of studies, in different areas. And the proposal is that it can be applied at operations strategy level, to enhance organizational competitiveness. Which would be very useful as the presence of a dynamic external environment is a factor that contributes to increasing the density of the organizational context. Nowadays, there are multiple factors that compose the operations strategy, growing the complexity of its design. The support of mathematical methods to choose the key factors, can contribute to the strategic planning assertiveness.

Additionally, given the economic limitations present in the markets, obtaining assertiveness in the improvement initiatives and in the operations strategy design, is of paramount importance. Specially in conditions where resources for improvement and innovation are limited and, once invested, must bring returns. In this sense, the proposed model, can bring an important direction for the success of the improvements initiatives and hence for the enhancement of operations results. In the context of economic planning, it is important to know to what extent an industry can expect to increase its output solely by increasing its efficiency without absorbing other sources of resources [1].

In this way, companies that knows the maximum production performance frontier can stand in a better competitive position as they can have a reasoned decision making based on strategic information about market. Applying the frontier estimation in the context of operations strategy can provide to managers important information for a more accurate and agile decision making to the development of emerging strategies.

The frontier is estimated based on the observation population of company's inputs and outputs (or a representative sample). While the efficiency of the organization is expressed by a proportion of its relative results to the ideal or fully efficient result [3]. It is a ratio between outputs and inputs. Results smaller than 1 represent inefficient firms [4]. However, defining a representative set of performance measures is not a straightforward task as the growing of the competitiveness and complexity of the organization requires multiples performance measures. Identifying companies that have competitive advantage is an easy exercise if performance can be captured by a single performance indicator, however, in the context of multiple metrics, this is no longer a trivial matter [3].

This paper presents a process for defining inputting and outputting variables to allow performance frontier identification within the context of operations strategy. To do so, this study deals with multiple performance measures and therefore is based on multivariate statistical analysis to ground decisions over the proposed framework. Multivariate data analysis refers to techniques that simultaneously evaluate multiple measures regarding objects under investigation. For being classified as multivariate the variables must be random and interrelated in such a way that their effects cannot be significantly interpreted separately [5]. The multivariate techniques encompass a range of research aims. There are techniques already established in literature as well as emergent ones. This study is grappling with following concepts and techniques: (i) descriptive statistics, (ii) Cronbach's alpha and (iii) factor analysis.

First, a theoretical background of performance frontier analysis, operations strategy and factor analysis is provided. Then, the research design presents the generic frontier model as well as the steps for the variable's definition. Next, each step of variables definition is presented, culminating with the conceptual framework proposition and the research paper conclusion.

1.1. Performance Frontier Analysis

The firm production frontier discussion was first placed by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society. The efficiency frontier is a function that indicates the maximum level of attainable result by a given set of inputs [1].

Some of the approaches are parametric and some are non-parametric. The parametric models undertake a particular a priori specification on the production process (i.e., how the inputs are converted into outputs). A benefit of this model is its well-established statistical inference making easy to include environmental characteristics. The non-parametric ones let the data speak for themselves, bringing more flexibility. For this reason, non-parametric models are very attractive. Both approaches can be deterministic or stochastic. In the deterministic data, all observations belong to the production set; while the stochastic data allow for noise in the data and capture the noise by an error term, even if it is difficult to distinguish the noise from inefficiency [6].

A well-known parametric model is the Stochastic frontier analysis (SFA) and a non-parametric is the Data Envelopment Analysis (DEA). The Data Envelopment Analysis DEA is a non-parametric method proposed by Charnes, Cooper, and Rhodes (1978) which the original DEA constant return to scale (CRS) model [7], later extended by Banker, Charnes, and Copper (1984) to variable return to scale (VRS) [8]. At DEA the production frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to evaluate the performance of organizations based on multiple metrics [4]. It can be considered a technique to aims to compare the operational performance of production units. It is a measure of relative efficiency, as it considers the presented data, therefore, it is not possible to determine an absolute efficiency, outside the group of analysis [9, 10].

The DEA methods aim to measure the efficiency of a decision-making unit (DMU). Any group of entities that receive the same inputs and produce the same outputs can be designated as DMU (eg. a firm). The group of analysis must include a homogeneous set of DMUs, where comparison makes sense. A homogeneous group is one where: the units under consideration perform the same tasks and have similar objectives; all the units are under the same set of 'market conditions' and the inputs and outputs are the same [10].

The comparison generates a ranking of a given DMU in terms of its relative efficiency, where the DMU with the highest-ranking are considered relatively efficient. DEA envelops the data set with frontier of the most efficient DMU. In DEA, a group of DMUs is used to assess each other with each DMU having some degree of managerial autonomy in decision-making [2].\

Unlikely the DEA, the SFA (Stochastic Frontier Analysis) is a parametric approach, in which the form of the production function assumes to be known or is estimated statistically [11]. The SFA is motivated by the idea that organizations can be inefficient for a variety of reasons and some of them may not be the organization's responsibility. Deviations that are not common to all organizations are called the stochastic term [3, 12].

1.2. Operations strategy

The operations strategy defines how manufacturing will support the achievement of business objectives by providing structural items (buildings, plant, equipment, etc.) and infrastructural ones (control policies, organizational structure, etc.) to ensure effective [13]. The traditional model of manufacturing strategy distinguishes between content and process. The process refers to the implementation, development, and use of the manufacturing strategy. The content covers the decision areas of the competitive dimensions [14]. This research paper deals with the concept of competitive priorities to represent the inputs of the conceptual model. The selected competitive priorities in our research work include Quality, costs, flexibility, dependability, speed, and environmental affairs. They are presented in Table 1.

Table 1. Competitive Priorities.

Competitive Priority	Definition
Quality	Offer products according to project specifications [15]
Flexibility	Have the capacity to adapt the operation whenever necessary and with sufficient speed, either by changes in demand or by needs of the production process [15]
Costs	Production and distribution of the product at a low cost [14, 15]
Speed	React quickly to customer orders [14, 15]
Dependability	Fulfill the deadline promises [14, 15]
Sustainability	Ability to achieve simultaneous performance in environmental, social and economic dimensions in the present time, without compromising the ability to maintain this performance in future [15, 16]

Quality, costs, flexibility, and delivery are considered by most authors [4, 17, 18] and the interest in these dimensions seems to grow constantly. Delivery encompasses speed and dependability. The environment is also pointed out by some authors. Environmental is a new dimension that starts to appear in 2008 and its presence is growing [19]. The input variables approach major competitive priorities and all of priorities are measured with multiple related variables, bringing out the necessity to deal with multivariate statistical analysis.

2. Research Design

The concept of efficiency frontier is a function that indicates the maximum level of result attainable for a corresponding quantity of inputs. The frontier is estimated based on the observation of inputs and outputs of a population of companies (or a representative sample). In the proposed model, outputs are understood as the desired result of the business, in financial and non-financial terms, which are defined through corporate strategy. These results are achieved through action in operations, represented by functional strategies. The operations function has its strategy composed of the competitive priorities, supported by the action in the decision areas. In this way inputs are defined by competitive priorities. Fig. 1 demonstrate the generic frontier analysis model.

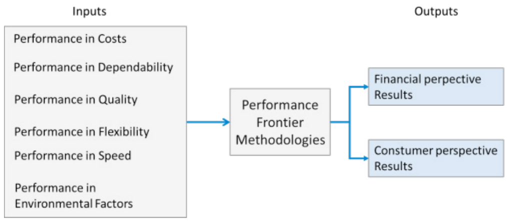

Fig. 1. Frontier analysis model.

Once the relationship between the concepts of operations strategy and frontier analysis is defined, the following step was to determinate the variables that represent each element. To do so, the variables on behalf of inputs (competitive priorities) and outputs (organizational results) were selected.

The selection of variables was based on 'High-Performance Manufacturing data (HPM)', round 4. The availability of reliable data is an important assumption for this research, as the processual model will further require benchmarking data. The HPM project seeks to identify the practices adopted by high-performance organizations and applies a survey with companies in 18 countries. The survey includes 1597 questions in 12 categories: Accounting, Downstream Supply Chain Management, Environmental Affairs, Human Resources Management, Information System Management, Plant Management, Process Engineering, Product Development, Production Control, Quality Management, Supervision, and Upstream Supply Chain Management. They are answered by different people inside organization. Round 4 was realized between 2012 and 2013. The HPM includes machinery manufacturers, vehicle component manufacturers and electronics manufacturers companies with at least 100 employees [20].

However, this study deals with multiple performance measures and therefore is based on multivariate statistical analysis to ground decisions over the proposed framework. Multivariate data analysis refers to techniques that simultaneously evaluate multiple measures regarding objects under investigation. For being classified as multivariate the variables must be random and interrelated in such a way that their effects cannot be significantly interpreted separately [5]. There are techniques already established in literature as well as emergent ones. This study is grappling with the following concepts and techniques: (i) descriptive statistics, (ii) Cronbach's alpha and (iii) factor analysis. Cronbach's alpha is a reliability measure for data [5]. While the Factor analysis can be used to analyze the interrelation within a huge number of variables and explain such variables in terms of their inherent common dimensions, or factors. Therefore, factorial analysis allows the original variables to be expressed as linear combinations of the factors and is useful when the objective is to reduce the number of variables [5, 21].

The objective of the factor analysis techniques is to summarize several original variables in a smaller group of new dimensions composed of statistical variables, called factors, with a minimum loss of information [5]. The design of a factor analysis includes three steps: (1) verify the adequacy of the database, (2) determine the extraction method and the number of factors to be extracted and (3) decide the method of factor rotation [22].

The factor analysis is usually performed with metric variables and it is difficult to carry out an analysis with less than 50 observations [5]. Preferably, the sample size should include more than 100 observations. In general, the stronger the data, the smaller the sample required for an accurate analysis. In factor analysis, strong data means high communalities without cross-loadings and several variables with strong loads on each factor [23, 24]. The communality of a variable is the estimation of its shared variance between the variables as presented by the obtained factors [5]. Usually the minimum acceptable value is 0.50. Therefore, if the researcher finds any communality below this threshold, the variable must be excluded, and the factor analysis must be performed again [22, 25].

It is also necessary to guarantee that the variables are sufficiently intercorrelated to produce representative factors. The correlations need to be higher than 0.30. Another method for determining the appropriateness of factor is by means of the entire correlation matrix, the Bartlett test of sphericity. It provides the statistical significance that the correlation matrix has significant correlations among at least some of the variables [5]. The null hypothesis of the Bartlett sphericity test states that there is no correlation between the initial variables. Therefore, values greater than 0.1 indicate that the null hypothesis cannot be rejected and that the data are not suitable for treatment. In this sense, a p-value of less than 0.1 is desired, which rejects the null hypothesis [22]. A third measure to quantify the degree of intercorrelation among variables is the measure of sampling adequacy (MSA), index that varies from 0 to 1, reaching 1 when each variable is perfectly predicted without error by the other variables. This test is promoted by means of Kaiser-Meyer-Olkin (KMO) at SPSS software. Results bigger than 0.80 is meritorious, 0.70 or above is middling, 0.60 or above, mediocre, 0.50 or above, miserable and bellow 0.50 is unacceptable [5].

The next step is to determinate the factor extraction method and the number of factors to be extracted. Principal Component Analysis (PCA) is preferred when the objective is to reduce data, while EFA is recommended when the research aims to detect the data structure [23, 25]. The number of factors to be extracted should also be determined, since some of the factors may explain a substantial of the total variance across all variables. This is an important step since both over-extraction and under extraction of factors retained for rotation can have harmful effects on the results [23]. There are several criteria cited in the literature to conduct such an analysis [5], and no consensus among authors is found [22]. Determining the number of factors be included in the model requires the researcher to balance the need for parsimony (a model with relative few factors) against the need for plausibility (a model with enough number of common factors to adequately account for the correlations among measured variables) [25].

The Kaiser Criterion and the scree test, which considers the eigenvalues are the default procedure in most statistical software, however, this is among the least accurate method for selecting the number of factors [23, 26, 27]. Frequently, there is over-extraction when using Kaiser criterion [26, 28]. Alternate tests for factor retention include parallel analysis. The Parallel analysis is based on the generation of random variables for estimating the component that needs to be subtracted. The proposition is that the number of common factors should not be determined using the eigenvalues bigger than one. The parallel analysis determines the number of common factors by selecting the number of the eigenvalues of a correlation matrix that were greater than or equal to those provided by data computer-simulated with known characteristics [29, 30]. Another criterion is the percentage of the total variance. No absolute threshold has been adopted for all applications [5, 21, 27], 60% is considered satisfactory in social sciences studies [5], some recommend 80% [21].

Factor rotation simplifies the structure of factorial loads and often makes the factors more clearly distinguishable and easy to interpret. In this way, step 3 consists of deciding the type of rotation of the factors, which can be orthogonal or oblique. Unrotated factor loads are often difficult to interpret. The simplest case of rotation is orthogonal. The type of rotation most commonly used is varimax, which has been very successful as an analytical approach to obtain an orthogonal rotation of factors [5]. A factor with fewer than three items is generally weak and unstable; 5 or more strongly loading items (.50 or better) are desirable and indicate a solid factor [23]. The process in Fig. 2 is proposed seeking to establish a representative set of inputting and outputting variables.

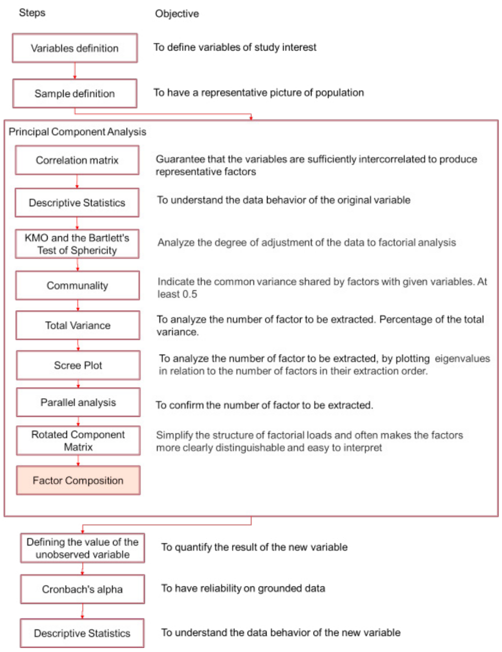

Fig. 2. Proposed Process to define the variables.

3. Results

The development of each step demonstrated in Fig. 2 are now described.

Variables definition

The first step of variables definition was the questionnaire understanding seeking to choose those questions (variables) that evaluate competitive priorities as well as organizational results (financial and client's perspective). At this step, only questions (variables) with less than 30% of missing data were included. That's because it is possible to remediate missing data until 30% [5]. There were selected a set of questions (variables) that represents the competitive priorities of costs, dependability, quality, environmental issues, and speed; as well as variables that represent the outputs, or organizational results of financial and client results.

Sample definition

The questionnaire has 304 respondents' companies. However, only companies that answered all the questions were maintained in the database, that's why the sample size varies from one competitive criterion to another. The exception was the quality criterion. If only the companies with no missing data were maintained, the criterion of having an average of 10 samples per variable would be endangered. In this case, companies with less than 30% of missing data were included and the missing data were replaced by the mean, as a corrective action (see Table 2).

Table 2: Sample characteristic

Category	Number of variables	Sample Size	Ratio Sampling Size/ Variable	Missing data replaced?
Costs	11	116	10.5	No
Dependability	6	240	40.0	No
Flexibility	19	211	11.1	No
Quality	23	262	9.1	Yes
Speed	5	237	47.4	No
Environmental factors	3	256	85.3	No
Outputs (Financial Results)	3	248	82.7	No
Outputs (Clients Results)	10	241	24.1	No

Factor Analysis

As it remains a huge quantity of questions, the researcher needs alternatives to manage them, grouping highly correlated variables. Factor analysis allows the identification of correlations in many variables and defines strongly interrelated groups, which define the factors. The objective is to summarize several original variables in a smaller group of new dimensions composed of statistical variables, called factors, with a minimum loss of information.

The analysis considered PCA as the method to extract the factor and the varimax as the rotation method, as the main objective is the dimensionality reduction, according to the definitions previously provided. Factorial analysis was performed for each set of variables representing the inputs as well as the outputs (see Fig. 1). The output category of financial issues does not require the factorial analysis as they have only three variables and therefore are not necessary to reduce the number of variables. The financial results outputs variables are (1) Overall profitability, (2) Return on investment and (3) Throughput: the rate at which the plant generates money through sales.

The first step of the factor analysis was to analyses the correlation matrix, variables that presented a low correlation value within the other ones were excluded from the study since the correlation is a requisite to guarantee that the variables are sufficiently intercorrelated to produce representative factors [5]. Next, the descriptive statistics were performed to a better understanding of data. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy as well as the significance level of Bartlett's Test of Sphericity, to each category was performed. Then, the communality was analyzed. The communality of a variable is the estimation of its shared variance between the variables as presented by the obtained factors, the minimum acceptable value was 0.50 [5], variables with values below than the stipulated were excluded.

As a criterion to define the number of factors to be extracted, total variance, scree plot and parallel analysis were performed. The parallel analysis was the main decision criteria as proposed by a wide range of literature [23, 26, 27]. The rotated component matrix then allowed to easily see the factor composition, as well as to weigh each variable to compose the factor.

The results of the factor analysis are next summarized, considering only the remaining variables in the final composition. Relevant ponderations are made at the appropriate time. All the variables were measured through a five-point Likert scale. KMO results ranged from mediocre to meritorious, but all categories have enough indication of sampling adequacy for the factorial analysis method. Table 3 present the results summary.

Table 3: KMO and Bartlett's Test of Sphericity

Category	KMO	Bartlett's Test of Sphericity (Sig)
Quality	0.876 (meritorious)	0.000
Costs	0.810 (meritorious)	0.000
Dependability	0.761 (middling)	0.000
Flexibility	0.755 (middling)	0.000
Speed	0.799 (middling)	0.000
Environmental factors	0.852 (meritorious)	0.000
Clients results	0.775 (middling)	0.000

Related to the number of factors to be extracted, for some variables, the total variance and the scree plot recommended a bigger quantity that the parallel analysis. The parallel analysis was promoted using the syntax (parallel.sps) by Brian O'Connor [31] and this criterion prevailed in most situations. Based on the parallel analysis results, factor analysis was performed again with the fixed number of factors recommended by parallel analysis. For cost variables, the total variance recommended 3 factors to be extracted while the parallel analysis indicated only two. For quality variables the Kaiser criterion recommended 4 factors and the parallel analysis only three. For some variables, the parallel analysis confirmed the results given by Kaiser criterion. The environmental factors variables had two factors extracted as well as the client results variables, the flexibility ones, three factors. The exception was the dependability and speed variables, the total variance recommended 2 factors to be extracted white the parallel analysis only one. However, if the factor composition recommended by Kaiser criterion is analyzed, the factor formation appears to be very coherent, segregating company perception of those from costumers. For this reason, two factors were retained, according to eigenvalues criteria.

At the Rotated component matrix, the Varimax rotation method was used, which simplifies the interpretation of the factors. This analysis presents the factorial loads of each variable in relation to the extracted components. The same variable cannot contribute to the formation of different factors, therefore, a few cases where conformance was not presented, the unsuited variable was excluded, and the factorial analysis was promoted again without such a variable. The final number of rotation interactions, number of original variables and number of factors (new variables) are presented in Table 4.

Table 4: Number of iterations at the rotated component matrix

Category	Number of iterations to converged rotation	Number of original variables	Number of factors or new variables
Quality	4	15	3
Costs	3	8	2
Dependability	3	6	2
Flexibility	4	9	3
Speed	3	5	2
Environmental factors	3	9	2
Financial results	Not applicable	Not applicable	Not applicable
Clients results	3	7	2

Source: Author

Defining the value of the unobserved variable

Based on the Rotated Component Matrix the composition of factors was formed. This matrix was also used to establish the weight of each variable to compose the result of the factor, which is proportional to the given component factorial load. Factors for input cost variables are shown in Table 5, as an example.

Table 5: Cost variables composition of factor based on the rotated component matrix

#	Factor	Original variable		Weight
Costs 1	Manufacturing costs	POSTNX01	Product selling price	17,4%
		GLOBLX01	Unit cost of manufacturing	19,8%
		GLOBLX23 and DISTIX12	Labor cost	41,5%
		GLOBLX27	Operating expense	21,1%
Costs 2	Costumer vision about company costs	COSTCN01	Low cost is the most important criterion used by our customers in selecting us as a supplier	30,4%
		COSTCN03	Our customers can rely on us for low-cost products	32,7%
		COSTCN04	We are selected by our customers because of our reputation for low cost	36,7%

Cronbach's alpha

Once the related question was identified, questionnaire comprehension can be tested. To do so, Alpha de Cronbach calculus was realized. Cronbach's Alpha is a reliability measure that varies between 0 and 1. Values from 0.6 to 0.7 are considered the inferior limit of acceptance [5]. The Cronbach alpha (CA) examines the relationships among variables, therefore, it is important to find internal reliability within the factor variables. Table 6 presents the results for each of the factors generated or new variables. Financial outputs are represented by single variables; therefore, no factors are formed, and CA are no longer required to demonstrate relation between variables.

Table 6: Reliability Statistics Cronbach's Alpha for factor or new variables

Category	Factor or not observed variable	CA
Costs	F1: Manufacturing costs	0.893
	F2: Costumer vision about company costs	0.797
Quality	F1: Quality performance compared to competitors – quality management vision	0.915
	F2: Quality performance compared to competitors in recently launched products	0.855
	F3: Costumer vision about company quality	0.740
Environmental factors	F1: Capacity of environmental practices positively influence other company's results	0.899
	F2: Overall environmental performance	0.722
Flexibility	F1: Costumer vision about company flexibility	0.844
	F2: Production system capacity of changing production mix and volume (plant manager vision)	0.773
	F3: Product customization	0.730
Speed	F1: Speed performance compared to competitors	0.839
	F2: Customer vision about company speed	0.727
Dependability	F1: Company perception about its on-time delivery	0.661
	F2: Costumer vision about company on time delivery	0.635
Client Output	F1: Market Share and customer satisfaction on recently launched products	0.751
	F2: Customer satisfaction	0.882

New Variables Descriptive Statistics

A better understanding of the variable's behavior is provided by the descriptive statistics as presented in Table 7.

Table 7: Descriptive statistics or new variables

Category	Factor or not observed variable	N	Mean	Median	Std Deviation	Skewness	Kurtosis
Costs	F1: Manufacturing costs	258	3.55	3.62	0.71	-0.22	0.03
	F2: Costumer vision about company costs	258	3.89	4.00	0.65	-0.37	0.22
Quality	F1: Quality performance compared to competitors – quality management vision	230	3.81	3.82	0.60	0.22	-0.86
	F2: Quality performance compared to competitors in recently launched products	230	3.78	3.81	0.59	-0.09	-0.14
	F3: Costumer vision about company quality	230	4.28	4.34	0.60	-1.02	1.44
Environmental factors	F1: Capacity of environmental practices positively influence other company's results	249	3.51	3.64	0.78	-0.52	-0.17
	F2: Overall environmental performance	249	4.07	4.04	0.58	-0.40	-0.35
Flexibility	F1: Costumer vision about company flexibility	246	3.84	3.86	0.68	-0.48	0.36
	F2: Production system capacity of changing production mix and volume in the vision of the plant manager	246	3.82	3.99	0.75	-0.34	0.16
	F3: Product customization	246	3.47	3.52	0.74	-0.44	0.14
Speed	F1: Speed performance compared to competitors	189	3.72	3.74	0.73	-0.06	-0.27
	F2: Customer vision about company speed	189	3.47	3.50	0.81	-0.31	-0.11
Dependability	F1: Company perception about its on-time delivery	253	3.82	3.82	0.66	-0.16	0.09
	F2: Costumer vision about company on time delivery	253	3.97	4.00	0.64	-0.41	-0.45
Client Output	F1: Market Share and customer satisfaction on recently launched products	258	3.55	3.62	0.71	-0.22	0.03
	F2: Customer satisfaction	258	3.89	4.00	0.65	-0.37	0.22

4. Conceptual model

Since the aim of this study is to analyze operations performance regarding competitive priorities and their effects on business performance, proper performance measures (as input and output variables) must be operationalized. The model is based on an efficiency perspective of using manufacturing resources for high-performance results.

Shown in Fig. 3, the left-sided variables are the inputs of the performance measurement while the right-sided components are the consequences. However, in a real case, there may exist some more relative variables for efficiency evaluation, the most significant components are considered in the model. The selection was promoted by the multivariate data procedure previous presents in this paper. Instead of measuring performance efficiency under one priority, we used multiple variables for some priorities.

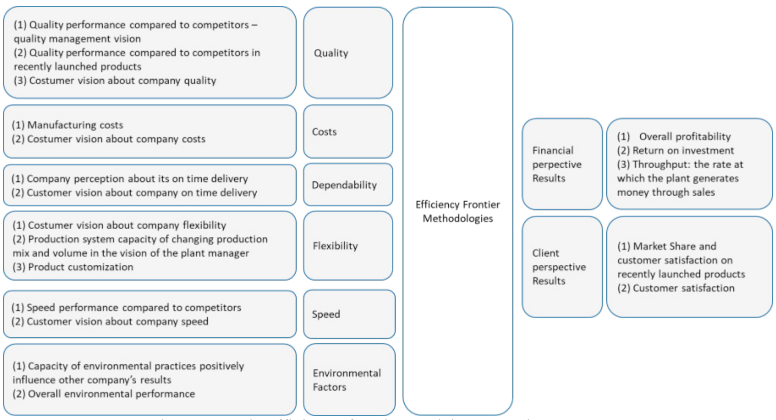

Fig. 3. Generic efficiency frontier model to operations strategy.

The proposed conceptual framework is based on performance elements that act as output/input variables and delimit the scope of the frontier analysis to be conducted. The inputs variables are determined to competitive criteria, quality, costs, dependability, flexibility, speed, and environmental components. The output variables are established to organizational results represented by financial and non-financial perspectives.

5. Conclusion

Methods for production performance frontier estimation is already known in the literature, however, there is a small number of papers in the literature that explore such a concept in the context of operations strategy. The few pieces of literature that explore both concepts together, do not clarify the process of defining model variables.

Besides that, it is known that the operations strategy has to consider how market needs and manufacturing capabilities can be combined by competitive strategy in a dynamic and unpredictable marketplace to sustain competitive performance [32]. Therefore, due to the unpredictable and complex organizational environment, the set of representative variables might change more frequently, which reinforces the need of updating operations strategy measures, bringing out the need for having a process to update variables seeking to continue accurately evaluating the effectiveness of the operations strategy.

This research paper proposes a conceptual framework of constructs for measuring operations strategy effectiveness. The process of defining these constructs are also fully explored. As a result, the presented constructs can significantly represent the input and output performance measures for operations strategy.

A limitation of the proposed procedure is that it depends on the adequacy of the variables. The lack of correlation of a set of variables makes the procedure implementation unfeasible. Additionally, the research has identified the main variables using the data of the fourth round of the HPM databases and then, it is possible to declare that the results are representative of this set of data.

As future work opportunities, ones can address the improvement of the proposed conceptual model thought the inclusion of innovativeness competitive criteria, as it appeared as real current topic only in 2006 [19]. Additionally, it is recommended to test the conceptual model through the promotion of the performance frontier analysis methodology.

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Appendix A-4– Research Paper 4

Title: Defining variables to assess operations strategy efficiency.

Journal: International Journal of Productivity and Performance Management.

International Journal of Productivity and Performance Management

Definition variables to assess operations strategy efficiency

Journal:	*International Journal of Productivity and Performance Management*
Manuscript ID	Draft
Manuscript Type:	Standard Paper
Keywords:	Multivariate Data Analysis, Operations Strategy, Performance Frontier Analysis, Performance measures

Definition variables to assess operations strategy efficiency

Purpose – To investigate the relationship between performance frontier and operations strategy. A two-level conceptual framework is proposed based on performance elements that act as output/input variables and delimit the scope of the frontier analysis.

Design/methodology/approach – The framework proposition is based on the 4th round of High-Performance Manufacturing survey data. Multivariate Data Analysis techniques establish a representative set of variables for assessing performance based on operations strategy constructs. The main used method is the Principal Component Analysis.

Findings – The first level model that formalizes the relationships between performance frontier analysis techniques and operations strategy, delimiting the scope and the structural definitions. As a second level framework, a causal representation based on operations strategy constructs is developed, defining input and output elements for frontier analysis studies.

Originality/value – The paper contribution is developed in the gap of market-based view approach to study operations strategy performance frontier, since most related literature focuses on capabilities development, representing a narrow focus at the RBV approach. A generic model based on the competitive priorities is therefore proposed to represent the Operations Strategy in the view of the Frontier techniques. The value befalls on defining performance measures which are not a straightforward task as the growth of organization competitiveness and complexity require multiple performance measures. A deeper understanding of frontier estimation on the operations strategy context can also positively influence the firms to succeed in the current dynamic competitive environments.

Keywords: Multivariate Data Analysis, Operations Strategy, Performance Frontier Analysis, Performance measures.

Article Type: Research paper

1 Introduction

Increasingly, organizations must be able to compete in the context of global standards. As commented by Cagliano et al. (2005) and Thun (2008), many authors argue that the operations have an important influence on the development of the competitive advantages as the level of competitiveness increases. In this scenario, Abassi and Kaviani (2016) reinforce that operational efficiency is a need for successful businesses; the superiority organizational performance is not achieved unless it achieves excellence levels of operations performance which is provided by the operations strategy effectiveness.

Slack and Brandon-Jones (2018) observe that operations strategy could be understood in terms of competitiveness development based on the production function, which contributes to the achievement of long-term competitive objectives. However, as observed by Slack (2005), the full potential of operations is not properly exploited, which in turn does not contribute to the achievement of a better competitive position. Anand and Grady (2017) indicate that the identification of elements that lead the organization to reach a position of relative maximum performance is still present in operations strategy research, which may represent a differential in the search for a prominent position in the market. This can be accomplished by the concept of performance frontier analysis, originally defined by Farrel (1957). The frontier methods imply the performance through an efficiency score, which is calculated as the distance from the organization to the best practice frontier, through the observation of inputs and outputs of each organization (Chen et al., 2015). In the operations strategy context, this approach is being explored by Liu et al. (2018), Kathuria et al. (2018) and Demeester et al. (2014). To them, inputs can be understood as competitive priorities, which should be managed to lead through superior organizational performance, defining the outputs.

However, the connection between operations strategy and firm performance frontier is not exhaustively explored in literature, as a comprehensive approach. There are some papers that integrated both concepts as Abassi and Kaviani (2016), Bulak et al. (2016), Ramanathan et al. (2016), Cai and Yang (2014), Hemmati et al. (2016); Yu et al. (2014), Ahmed et al. (2014), Akdeniz et al. (2010), Nath et al. (2010), Nevo et al. (2007), Dutta et al.(2005). However, many of these works are based on capabilities concept from resource-based view (RBV) theory, as could be seen in the works of Miller and Ross (2003), Maslen (1997), Prahalad and Hamel (1990), Barney (1991), and Wernerfelt (1984).

It is unquestionable that the capabilities approach can help in leading through operations effectiveness. However, it encompasses one research stream of the operations strategy, the RBV, only. The present paper develops its contribution to the gap of the market-based view approach to study the operations strategy in the leans of frontier analysis methodologies, to do so, explores the concept of the competitive priorities.

The lack of the exploitation of the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. The appropriate choice of competitive priorities reflects on the future direction of a firm and has fundamental importance to the achievement of its competitive advantage which may lead to business performance improvement (Okoshi et al., 2019; Phusavat and Kanchana, 2008).

The research paper proposition importance can be enhanced when it is observed that most of the published works address specific variables of the business in which the application is made, therefore, the literature fails in providing generic models (Abassi and Kaviani, 2016; Bulak et al., 2016, Cai and Yang, 2014). Additionally, the frontier methodologies, such as Data Envelopment Analysis (DEA), do not provide guidance for the specification of the input and output variables. Frequently, variables are defined using the criterion of availability of information in the intended application context, failing to search for variables that provide a holistic view of the operations function and the business performance. According to Smith (1997), the main weakness of DEA is that the choice of input and output variables depends on the judgment of the researcher, as there is no support to help the user determinate wheatear or not the chosen model is appropriate.

This paper develops a conceptual framework that identifies representatives' inputs and output variables, defining a model to allow the performance frontier identification on the context of operations strategy. A first-level framework formalizes the relationship between frontier analysis techniques and operations strategy, and a second level one presents the constructs that expressively represent the input and output measures for operations strategy. This proposition is accomplished through a statically analysis of the 4th round of High-Performance Manufacturing (HPM) survey data with companies in 14 countries.

This proposal has significative importance due to most of the frontier methods approached by authors requires inputting and output variables. However, defining a representative set of performance measures is not a straightforward task as the growth of the competitiveness and complexity of the organization requires multiples performance measures. Chen et al. (2015) state that identifying companies that have a competitive advantage is an easy exercise if performance can be captured by a single performance indicator, but, in the context of multiple metrics, this is no longer a trivial matter. This approach is reinforced by Slack and Lewis (2018) that argue that performance is not a simple concept, since the current complexity of the environment requires multi-faceted metrics, as a single measure could never fully communicate such a complexity.

First, the performance frontier analysis concept is introduced. A first-level conceptual model is then presented, covering the relationships between performance frontier analysis techniques and operations strategy, delimiting the scope and the structural definitions. Next, the research methodology is depicted. Such a methodology conducts to the results by the use of Multivariate Data Analysis techniques to ground the second level conceptual framework. A discussion is made to analyze the strengths and weaknesses of the conceptual framework.

1 Firm Performance Frontier

Organizations need to respond to competitors with their own increased performance. This occurs because modern companies typically operate in dynamic and competitive environments, generating the need to position themselves in advance of their competitors, that is, increasing levels of efficiency and effectiveness in the market where they operate (Abbasi and Kaviani, 2016; Singh et al. 2016). In this way, companies that know the maximum production performance frontier could be in a better competitive position, as they have a reasoned decision making based on strategic information about competition.

According to the original concept proposed by Farrel (1957), the efficiency frontier is a function that indicates the maximum level of the attainable result by a given set of inputs. The frontier is estimated based on the observation population of the company's inputs and outputs or a representative sample. While, as reinforced by Chen et al. (2015), the efficiency of the organization is expressed by a proportion of its relative results to the ideal or fully efficient result, represented by a ratio between outputs and inputs. Bulak et al. (2016) state that results smaller than 1 represents inefficient firms.

The Data Envelopment Analysis (DEA) is one of the methods for calculating firm performance frontier. The DEA was proposed by Charnes, Cooper, and Rhodes (1978) and the production frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to assess the performance of organizations based on multiple metrics. The traditional DEA methods, CCR (Charnes, Copper, and Rhodes) and BCC (Banker, Charnes, and Copper) use clear and certain data for inputs and outputs. The aim is to measure the efficiency of a decision-make unit (DMU). Any group of entities that receive the same inputs and produce the same outputs can be designated as DMU. The comparison generates a ranking of a given DMU in terms of its relative efficiency, where the DMU with the highest ranking is considered relatively efficient. DEA envelops the data set with the frontier of the most efficient DMU.

According to Bulak et al. (2016), DEA models are non-parametric techniques further divided into two groups, input-oriented and output-oriented. An input-oriented DEA model identifies technical inefficiency as a proportional reduction in input usage, with output levels held fixed. The output-oriented DEA model measures the technical inefficiency as a proportional increase in output production, with input levels being constant (Coelli et al., 2005).

2 Efficiency Frontier to Operations Strategy

The analysis of the competitive position formed by competitive criterion is of primary importance since there are commonly tradeoffs between performance objectives. In other words, improvement in one performance criterion can be achieved only by sacrificing the performance of another. However, there are two visions of tradeoffs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others. Most companies, at one time or another, will adopt both approaches. This is best illustrated by the concept of "efficient frontier" in production performance (Slack et al., 2018).

When comparing the concepts of operations strategy and performance frontier, one notices that both concepts are closely related. To operations strategy is deployment from the competitive strategy and aims to achieve excellent performance in the key competitive priorities; this is achieved through acting in the so-called decision areas (Slack and Lewis, 2018; Hill and Hill, 2018). While the concept of efficiency frontier is a function that indicates the maximum level of result attainable for a corresponding quantity of inputs. The frontier is estimated based on the observation of inputs and outputs of a population of companies or a representative sample, as stated by Coelli et al. (2015). Fig. 1 shows the relationship between the concepts of operations strategy and the efficiency frontier.

Fig. 1–First level framework

To all the frontier analysis methods, it is observed that a clear consensus is the existence of a causal relationship between the inputs and outputs. The proposed first level framework represents this relationship from the operations strategy frontier analysis perspective. If the analysis regards operations function results, the inputs are taken as the cause, defined by the decision areas, and the outputs, as the effect, represented by the competitive priorities (eg. Cai and Yang, 2014). Taken an upper management level regarding a business results analysis, the competitive priorities or capabilities are the cause or input, and the business results the effect or output (eg. Ramanathan et al, 2016; Bulak et al, 2016).

This study aims to identify the operations strategy's influence on business results. the operations strategy constructs are defined as the inputs and the business results, as the outputs. To Slack and Lewis (2018) the business objectives are typically set in the form of financial and non-financial targets. Therefore, the proposed first level framework takes the outputs as the desired result of the business, in financial and non-financial terms which are defined through competitive strategy. These results are achieved through action in operations, represented by functional strategies. In this way, inputs are defined by the operations strategy competitive priorities.

There are some papers that already approached the relationship between operations strategy and performance frontier analysis. From them, mostly the approach is to face Operations Strategy in the view of its capabilities, characterizing a resource-based view perspective (eg. Akdeniz et al., 2010; Ahmed et al., 2014; Hemmati et al., 2016; Yu et al., 2014; Samoilenko, 2013). A less shared perspective is taking the operations strategy in the view of competitive criteria, considering then a market-based view perspective (eg. Abbasi and Kaviani, 2016; Ramanathan et al., 2016; Bulak et al., 2016).

The proposed framework not only explores the gap into the market-based view perspective but also specifies the input and output variables. Addressing then a DEA weakness of not indicating a way of selecting the required input and output variables (Smith, 1997).

3 Research Design

Once the relationship between the concepts of operations strategy and frontier analysis is defined in the first level framework, the development of a generic frontier model to study the operations strategy results is grounded by defining the input and output categories.

According to Slack and Lewis (2018) by grouping competitive factors into clusters under the heading of generic performance objectives, market requirements are translated into a form useful for the development of the operation. The patter of decisions in these set of performance objectives shape long term capabilities and contribute to the overall strategy through the ongoing reconciliation of market requirements and operation resources. This concept grounds the conceptual model proposed in this research work, which establishes the performance objectives as the input variables (costs, dependability, environmental factors, flexibility, innovativeness, quality, speed, and reliability) and the organizational results as output variables (clients and financial results). The subsequent analysis seeks to define variables that represent each element of inputs and output constructs. The research methodology steps are presented in Fig. 2.

Fig. 2–Research Steps

Given the generic frontier operations strategy model, the variables on behalf of inputs (competitive priorities) and outputs (organizational results) must be selected. The selection of variables is based on 'High-Performance Manufacturing data (HPM)' of the 4th round. The HPM project seeks to identify the practices adopted by high-performance organizations and applies a survey with companies in 13 countries. The survey includes 1597 questions answered by different people inside the organization. Round 4 was realized between 2012 and 2018. The HPM includes machinery manufacturers, vehicle component manufacturers and electronics manufacturers companies with at least 100 employees .

As this study is performed with multiple performance measures, multivariate statistical analysis is required. Multivariate data analysis refers to techniques that simultaneously evaluate multiple measures regarding objects under investigation (Hair et al, 2009). The research is grappled with the following techniques for sampling selection, principal component analysis, and, Cronbach's alpha investigation.

3.1. Sampling definition

Regarding the techniques for sampling selection, most of the recommendations involve determining the sample size based on the number of measured variables included in the analysis, the more the number of variables the bigger the sample size. However, as observed by Fabrigar et al. (1999), the recommendations given by existing literature vary dramatically. According to Hair et al. (2009), it is difficult to carry out an analysis with less than 50 observations; preferably, the sample size should include more than 100 observations. Beyond that the number of observations must be at least 5 times greater than the number of variables; considered a best practice a ratio of 10 observations per variable, as also pointed by Nunnally and Bernstein (1994). The adopted criterion, therefore, is at least 100 samples and, simultaneously, a minimum of 10 observations per variable. Another important discussion on this behalf is whether to replace missing data or not. To Hair et al. (2009), it is possible to remediate missing data until 30%.

3.2. Principal Component Analysis

As more variables are added more correlation (or overlapping) occurs between them. Therefore, the researcher needs alternatives to manage variables, grouping highly correlated ones. (Hair et al, 2009; Velicler and Jackson, 1990). The principal component analysis (PCA) is a strongly recommended technique for data reduction when the aim is to later perform a DEA model (Nataraja and Johnson, 2011; Ueda and Hoshiai, 1997; Alder and Golany, 2001). PCA is useful for summarizing or describing the variance in a set of variables into fewer dimensions (Denis, 2019). According to Alder and Golany (2001) and Alder and Yazhemsky (2010), an excessive number of input/output variables in a DEA model results in many efficient DMU, not allowing to differ the superior performed companies.

Filho and Junior (2010) propose a three steps design to run the PCA technique (1) verify the adequacy of the database, (2) determine the extraction method and the number of factors to be extracted e (3) decide the method of factor rotation. Regarding the database adequacy, Denis (2019) argues that it is recommended to guarantee that the variables are at least some intercorrelated to produce representative factors. Hair et. al. (2009) include another method for determining the appropriateness of factor is by means of the entire correlation matrix, the Bartlett test of sphericity. It provides the statistical significance that the correlation matrix has significant correlations among at least some of the variables. Another measure to quantify the degree of intercorrelation among variables, approached by Hair et. al (2009), is the measure of sampling adequacy, promoted by means of Kaiser-Meyer-Olkin (KMO) test. Results bigger than 0.80 is meritorious, 0.70 or above is middling, 0.60 or above, mediocre, 0.50 or above, miserable and bellow 0.50 is unacceptable.

To define the factor extraction method is important to understand the difference between common factors and PCA. Both techniques aim to generate a linear combination of the variables that capture the maximum variance of observed variables. However, PCA considers the total of variance and derive factors that contain a small proportion of unique variance and, in some cases, error variances. PCA does not discriminate between shared and unique variance, as indicated by Hair et al. (2009), and Costello and Osborne (2005). Meanwhile, Hair et al. (2009) indicate that the common factors analysis reflects only the shared variance, assuming that both are unique and error variance is not of interest in defining the structure of the variables. PCA is preferred when the objective is to reduce data (Denis, 2019; Costello and Osborne, 2005; Fabrigar et. al, 1999).

Another critical decision is the number of factors to be retained. This is an important step since both over-extraction and under extraction of factors retained for rotation can have harmful effects on the results. There are several criteria cited to conduct such an analysis, and no consensus among authors is found (Filho and Júnior, 2010; Hair et al. 2009). To Fabrigar at. Al (1999) determining the number of factors to be included in the model requires the researcher to balance the need for parsimony (a model with relative few factors) against the need for plausibility (a model with enough number of common factors to adequately account for the correlations among measured variables).

Rencher and Christensen (2012) and Hair (2009) indicate the Kaiser Criterion, which considers that only components with eigenvalues greater than 1 are considered significant, the others should be discarded. However, a number of authors advocate that this is among the least accurate method for selecting the number of factors, even being a default procedure in most statistical software (Rencher and Christensen, 2012; Laros, 2012, Costello and Osborne, 2005; Nunnally and Bernstein, 1994). Laros (2012) and Velicler and Jackson (1990) denote that frequently, there is over-extraction when using Kaiser Criterion. Alternate tests for factor retention include the scree test and parallel analysis.

To Rencher and Christensen (2012) The scree test is used to identify the optimum number of factors that can be extracted before the amount of unique variance being to dominate the common variance structure. The scree test is determined by plotting eigenvalues in relation to the number of factors in their extraction order. The Parallel analysis proposed by Horn (1965) is based on the generation of random variables for estimating the component that needs to be subtracted. The proposition is that the number of common factors should not be determined using the eigenvalues bigger than one. The parallel analysis determines the number of common factors by selecting the number of the eigenvalues of a correlation matrix that was greater than or equal to those provided by data computer-simulated with known characteristics. The idea is to generate random data of similar size and calculate the latent roots and vectors of these random data to provide a criterion tailored to the data set being analyzed. Only factors that correspond to empirical eigenvalues, which exceed the mean values of the eigenvalues obtained randomly, would be extracted (Laros, 2012). An advantage of the parallel tests model, indicated by DeVellis (2003) is that its assumptions make it easy to grasp useful conclusions about how individual items relate to the factors or latent variables, based on our observations of how the items relate to one another.

A third criterion is the percentage of the total variance. To this, Hair et al. (2009) consider that 60% is satisfactory in social sciences studies, Rencher and Christensen (2012) recommend 80%. But this value depends heavily upon average correlation, consequently, this rule is basically inapplicable as advice to determinate the number of factors (Nunnally and Bernstein, 1994).

In relation to the factor rotation method, it has the aim of simplifying the structure of factorial loads and often makes the factors more clearly distinguishable and easy to interpret. It can be orthogonal or oblique. The simplest case of rotation is orthogonal. The type of rotation most commonly used is varimax, which has been very successful as an analytical approach to obtain an orthogonal rotation of factors (Hair et al., 2009).

3.3. Cronbach's alpha

To Hair et al. (2009) Cronbach's alpha is a reliability measure for data that varies between 0 and 1. Values from 0.6 to 0.7 are considered the inferior limit of acceptance.

4 Results

This section details the results of the main steps presented in the research design. After the first level framework definition, the subsequent step is the HPM questionnaire comprehension, in order to understand and map variables for assessing operations strategy as inputs and outputs constructs. All the HPM questions are examined and those with relation either with outputs or inputs are selected. Only variables with less than 30% of missing data were considered for this study, respecting the Hair et. al (2009) proposition. Even so, a huge quantity of variables was still remaining after this stage; therefore, a PCA analysis is next conducted, to consistently reduce the number of variables.

4.1. Sampling definition

To promote the PCA, it was first necessary to consider whether to replace missing data or not. A corrective action, through the replacement by the mean, was promoted only for the quality category, ensuring that would have at least 10 respondents per variable, respecting the proposition of Nunnally and Bernstein (1994). Table 1 shows the number of variables, sample size (SS), as well as the indication of the need for replacing missing data.

Table 1: Sample characteristic

The descriptive statistics of all variables data are presented in the supplemental material. Having treated the variables to be used in the study, the process of reducing them through PCA is performed.

4.2. Principal Component Analysis

The PCA is promoted to each category. The exceptions are the output category of financial issues and input innovativeness category. The financial one does not require the PCA as it has only one variable, throughput. To the innovativeness category, the correlation matrix exposed a low correlation between many of the variables. Denis (2019) argues that does not make sense to perform PCA if the analyzed variables are not at least to some degree correlated.

Therefore, considering the low correlation level of Innovativeness, it is more coherent to classify the variables of this category as formative constructs as there is a set of exogenous variables. According to Hair et al. (2009) in this situation, the indicator causes the construct, whereas, in more conventional latent variables (or reflexive constructs) the indicator is caused by the latent variable. The compression of the innovativeness variables was then promoted through semantic analysis, applying an affinity diagram. In this procedure, three groups of variables were defined; they are related to equipment technologies, process technologies, and product innovativeness.

PCA was performed with a varimax rotation method. The KMO as well as the significance level of Bartlett's Test of Sphericity, to each category are presented in Table 2.

Table 2: KMO and Bartlett's Test of Sphericity

KMO results ranged from mediocre to meritorious, but all categories have enough indication of sampling adequacy for the PCA method. The Sphericity test has also determinate conformance. The significance of Pearson correlation values tests was also analyzed, and a few cases where conformance was not presented, the unsuited variable was excluded.

Related to the number of factors to be extracted, for some variables, the total variance and the scree plot recommended a bigger quantity that the parallel analysis. The parallel analysis was promoted using syntax by Brian O'Connor (O'Connor, 2018) and this criterion prevailed. For flexibility variables, the Kaiser criterion recommended six factors and the parallel analysis only three. For quality variables, the Kaiser criterion recommended five factors and the parallel analysis only two. For Speed variables, the total variance recommended two factors to be extracted while the parallel analysis indicated only one. Based on the parallel analysis results, PCA has performed again with the fixed number of factors recommended by parallel analysis. For some variables, the parallel analysis confirmed the results given by Kaiser Criterion. The costs, environmental factors, and reliability variables had two factors extracted as well as the client results variables. Dependability variables had one factor extracted.

The Rotated component matrix was performed to identify the factorial loads of each variable in relation to the extracted components. Based on these results the weight of each variable to compose the component was established, which are proportional to the given component load. Components (or new variables) are shown in Table 3, which also shows the previous variable and its weight, the initial eigenvalues (EV), as well as the cumulative percentage of the total variance that the component can explain (TV) through the 'Rotation Sums of Squared Loadings'.

Table 3: Component composition

Once the framework components, or new variables, have been defined, it is expected that the variables inside the same component have a conceptual consistency between them. The Cronbach's alpha (CA) is therefore performed to confirm such an assumption.

4.3. Cronbach's alpha

The CA is performed to evaluate whether the component has a response standard demonstrating conceptual correlation and therefore, representing formative constructs. The CA is performed for each component generated in the PCA analysis and they presented an acceptable CA, as expected, confirming the consistency among variables inside the same component. The exception is the innovativeness category that has two components with CA inferior of 0.70. Endorsing therefore that they are not reflexive construct (latent variables).

5 Conceptual Framework

The conceptual framework developed based on the PCA results is presented in Fig. 3 After all the exclusion process inherent of the PCA procedure, the framework identifies the input and output variables that can be used for the frontier analysis purpose, depicting the generic model presented in Fig. 2.

Fig. 3 – Second Level Conceptual Framework

The framework encompasses a representative set of inputting and outputting variables for measuring the effectiveness of operations strategy.

6 Discussion

The former literature on frontier analysis methods requires inputting and outputting variables. However, it is not possible to find a consensus in defining what are the input and output variables that represent the decision areas, capabilities, competitive priorities or business results. Therefore, the establishment of inputs and outputs variables to allow the use of operations strategy as a lens for performance frontier analysis is still unclear, which justifies an in-depth study to reveal relationships among variables that define the content of operations strategy. This research work deals with the concept of competitive priorities, as the input variables, and business results as the output ones, as it focuses on the market-based approach.

The choice of focusing on the market-based approach is because most of the existing papers in this area deal with the capabilities concept, characterizing the RBV approach. In this kind of work, inputs and outputs depend on the aimed capability. For example, there are some papers that focus on marketing and operations capabilities (eg. Ahmed et al, 2014; Yu et al, 2014), Dutta et al. (2005) work with R&D capabilities and Ramanathan et al. (2016) include environmental capability and diversification strategy to the study.

Even though there is some author that already explored a market based oriented approach, there is no clear consensus about defining what the inputting and outputting variables are, since the existing papers focus in a specific context. For example, Bulak et al. (2016) measure and evaluates the efficiency of Turkey's electrical small and medium machinery manufacturing. The output variables are defined for the aimed sector and the input variables approach major competitive priorities (cost, delivery, quality, and flexibility). Abassi and Kaviani (2016) seek to propose a performance evaluation framework for evaluating and ranking the organizations based on the effectiveness of their operations strategies in the context of the cement factory industry of Iran. Input variables are the competitive priorities (quality, costs, speed, flexibility, and dependability) while the output variables include financial indicators (ROA and ROI) and non-financial measures (market share).

The present paper contributes to providing a generic approach based on a representative set of variables, which are next discussed facing existing literature to evaluate whether the variables are a good representation of each category or not. The selected competitive priorities include quality, costs, flexibility, dependability, speed, reliability, innovativeness and environmental affairs. The first five are considered by most of the authors (eg. Bulak et al., 2016; Abbasi and Kaviani, 2016; Cai and Yang, 2014; Hallgren et al., 2011) and the interest in these dimensions seems to grow constantly. For Slack and Lewis (2018) these five competitive priorities have meaning for any type of operation.

Speed and dependability are approached by some authors are delivery (Sansone et al., 2017). The proposed framework suggests including speed and dependability as a separated competitive criterion, as we understand that, in a short time, there will be a tendency to increase the importance attributed to dependability, due to the advent of online businesses and it should be evaluated complementary to speed. This research deals with the meaning provided by Slack and Lewis (2018) which consider dependability as the fulfillment of delivery promises and speed as the lead time to delivery.

Innovation, service, and environment are also pointed out by some authors. According to Sansone et al. (2017) both innovation and service appeared as real interest only in 2001 and for innovation, the confirmation that it is really a current topic occurred only in 2006. Environmental is a new dimension that starts to appear in 2008 and its presence is now growing.

From the discussion above, it is accepted that service is an important competitive priority and it is included in the proposed conceptual model on the component 'overall quality performance' of quality criteria, with the 'serviceability' original variable. The framework results, that includes service inside the quality affairs, is supported by Sansone et al. (2017), that argues that although service can be already being pointed at a single competitive priority it is still being behind others according. Support of this framework result is also given by Bulak et al. (2016) that likewise have included service - defined as the quality level of service that a company provides before and after the sale - as a criterion of the quality variable. Slack and Lewis (2018) argue that quality is a multidimensional issue.

To Slack and Lewis (2018) quality is about offering products according to project specifications and to Sansone et al. (2017) the competitive criterion includes performance, conformance, and durability. In the proposed conceptual framework, this definition of quality is taken in place, but there is a separate assessment of current products and recently launched ones. The overall quality performance includes aspects of conformance to established standards, primary product performance characteristics, secondary options or features, aesthetics, and serviceability. Bulak et al. (2016) also included certification in quality evaluation. The proposed framework does not include it, as we understand that certification is a cause of quality results and therefore could not be selected in the HPM questionnaire, as it is in a different level of causal relationships.

Flexibility is understood as having the capacity to adapt the operation whenever necessary and with sufficient speed, either by changes in demand or by needs of the production process (Slack and Brandon-Jones, 2018). It can be volume, production mix, customization or broad product line flexibility (Sansone et al., 2017). The proposed framework approached volume and production mix in the same component and product customization in a distinctly one. Additionally, the customer vision about company flexibility was included.

To Slack and Lewis (2018) costs represent offering competitive costs. To Sansone et al. (2017) it can be the total cost and the ability to optimize the utilization of manufacturing resources (Sansone et al, 2017). The proposed framework is coherent with both definitions. However, the costs are distinguished from current and recently launched products.

Environmental factor is an important aspect of sustainability discussion that is an updated theme recently, Wang (2019) for example, reinforces the impact of green culture on the performance advantage. To Slack and Lewis (2018) sustainability is the ability to create an acceptable profit, minimizing the damage to the environment and enhancing the existence of the people with whom it has contact. The Slack and Lewis (2018) three levels of operations performance framework show the sustainability as an integrative criterion that encompasses the five main competitive priorities (quality, speed, dependability, flexibility, and costs). In this sense, sustainability could be classified as an output variable. We considered that the environmental impact is the perspective that can be faced as an input variable. Sansone et al. (2017) divide this category into environmentally friendly products and processes. The conceptual framework proposes different segregation including aspects of the ability of environmental practices positively influence other company's results and an overall view of environmental performance.

Yet, innovativeness is a topic of current interest, and the variables are then included, even revealing a different behavior that does not allow them to be classified as a latent variable. The innovativeness components are generated through affinity diagram segregating in three new variables: Process technology innovativeness, Equipment technology innovativeness, and Product innovativeness.

Regarding independent variables, the performance is usually assessed by using financial and non-financial performance measures (e.g. Bulak et al. 2016; Abbasi and Kaviani, 2016), being consistent with Kaplan and Norton (2000) Balanced Scorecard proposal, that defines the financial and clients as the results perspectives. Additionally, the organization may have other strategic objectives, but the costumer and financial are the survival goals to most organizations. We proposed the Throughput as the financial measure and market share and customer satisfaction as the non-financial ones.

According to the above discussion, lessons learned can be summarized as follows.

- Concepts of operations strategy and performance frontier are simultaneously not so much explored by literature in a holistic and generic perspective, as most of the publications focus either on capabilities or in a context-driven model of implementation.
- The definition of the inputs and outputs variables depends on the organizational perspective. From a strategic perspective, a more comprehensive approach is to use competitive priorities as input some organizational result measure as output. On the other hand, looking at a tactical approach, it is coherent to define the operations strategy competitive priorities as outputs, and the operations resources, in the decision areas, like the inputs. The first level proposed framework discloses the causal relationship.
- A range of authors uses financial and non-financial performance measures to represent the organizational results measures. Mainly the financial performance is measured by indicator as ROI, ROA, throughput, sales, and profitability, while the non-financial are related to customer satisfaction and market share. Such an approach is coherent with the balanced scorecard framework, which defines the financial and customer perspective as the results one, and the process and learning as the process one. Bringing out again the causal relationship mentioned above.
- The measurement of the competitive priorities with multiple-related variables is increasingly common since the competitiveness is growing. The conceptual framework has generated 16 grouped variables to eight competitive dimensions as a representative construct of operations strategy performance.
- Sustainability can vary from input and output variables. The triple bottom line concept encompasses the economic, environmental and social dimensions. The economic dimension is mainly an output variable, related to the

organization's financial health. Environmental and social variables can be input or output depending on the intended scope.

Finally, we state that traditionally, the concept of tradeoff has been imposed among competitive priorities. However, as indicated by Slack et al. (2018), in the face of current competitiveness, it is necessary to break the tradeoff barrier to being excellent in seemingly contradictory performance criteria, and therefore acquire efficiency in the desired output. The tradeoffs broken have become possible by constantly technology evolution. In this scenario, the maximum performance frontier evaluation model grows into importance, as it can enable the company to identify whether it is still possible to increase its efficiency at the same level of investment. Whereas the concept of tradeoffs is settled, the company can wrongly think that it is on the maximum attainable results, when in fact it can still progress, and more than, need to progress, since some competitor already reached a superior outcome.

7 Conclusion

By means of the proposed framework, this research work contributes then in providing a complete picture of the relationship between operations strategy and performance frontier analysis. Which is an important contribution, since the concepts of operations strategy and performance frontier analysis simultaneously are not exhaustively explored by the literature. Besides that, the literature does not clarify the process of defining model variables.

It is known that the operations strategy has to consider how market needs and manufacturing capabilities can be combined by competitive strategy in a dynamic and volatile marketplace to sustain competitive performance. Therefore, due to the unpredictable and complex organizational environment, the set of representative variables might change more frequently which reinforces the need of updating operations strategy measures, bringing out the need for having a process to update variables seeking to continue accurately assessing the effectiveness of the operations strategy. The process of defining operations strategy constructs are fully explored. As a result, the presented constructs are able to significantly represent the input and output performance measures for operations strategy, composing the conceptual framework for performance frontier analysis in this context. Moreover, this study brings more recent perspectives to the main competitive priorities. In this model, those priorities are measured with related multiple variables. The conceptual framework has generated 16 grouped variables to eight competitive dimensions as a representative construct of operations strategy performance.

The proposed conceptual framework has its importance grounded in the complexity characteristic of the competitive environment that requires multifaceted measures. In this context broken the barrier of tradeoffs can represent competitive advantage and the application of the performance frontier concept can help of focusing the right effort of doing so.

A limitation of this study is that the variables were defined using the data of the HPM database and then, the results are representative of this set of data. In doing so, the future work opportunity can be addressed to replicate and the improvement of this process of selecting representative inputs and outputs variables within other databases that cover competitive priorities as well as business results.

The inherent continuity of this research is the promotion of the performance frontier analysis methodology using the defined set of input and output variables. Yet, Innovativeness is not presented as a reflexive (latent) construct in this research work, which can represent either a lack of respondent understanding about the concept or a characteristic of the variable. Future studies are recommended to clarify this question.

Still, we hope that this study will contribute to the definition of operations strategy inputs and outputs performance indicators as well as to the process of defining it, therefore, facilitating further empirical study regarding performance frontier identification on operations strategy context. From the operations strategy market-based view perspective, this work may represent an evolution in the study of border analysis, through the definition of a generic rather than a contextual model.

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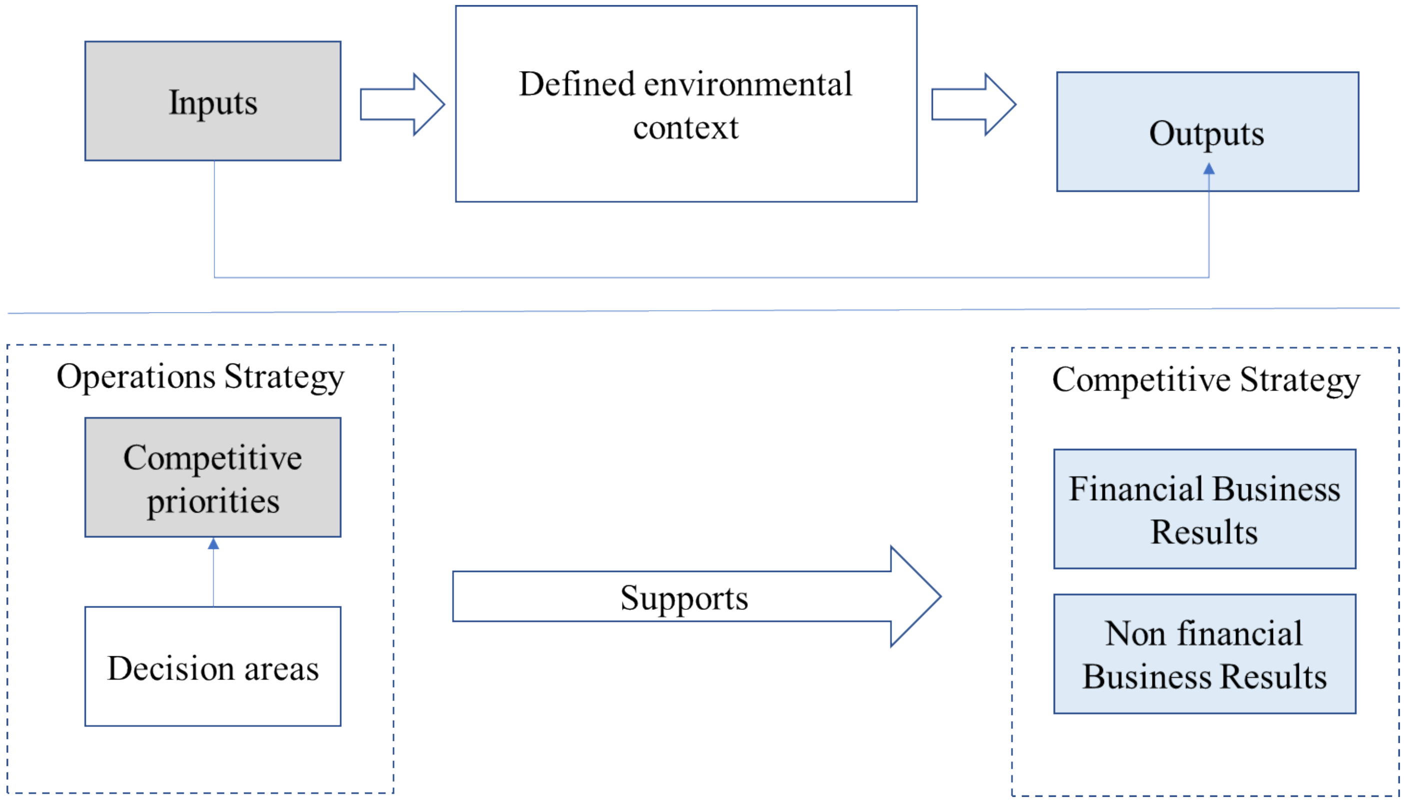
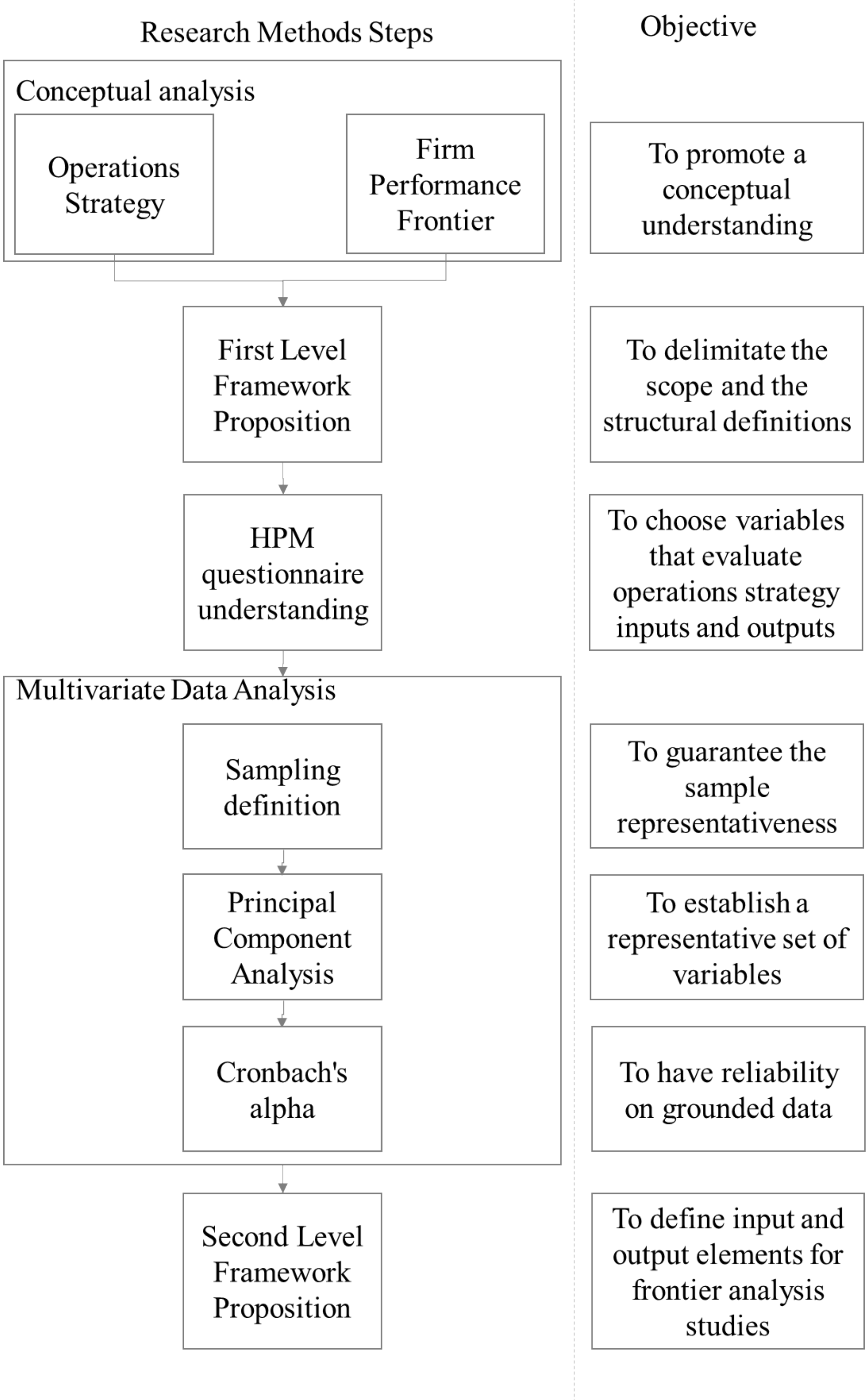

Inputs
Defined environmental context
Outputs
Operations Strategy
Competitive priorities
Decision areas
Supports
Competitive Strategy
Financial Business Results
Non financial Business Results


Research Methods Steps
Objective
Conceptual analysis
Operations Strategy
Firm Performance Frontier
To promote a conceptual understanding
First Level Framework Proposition
To delimitate the scope and the structural definitions
HPM questionnaire understanding
To choose variables that evaluate operations strategy inputs and outputs
Multivariate Data Analysis
Sampling definition
To guarantee the sample representativeness
Principal Component Analysis
To establish a representative set of variables
Cronbach's alpha
To have reliability on grounded data
Second Level Framework Proposition
To define input and output elements for frontier analysis studies

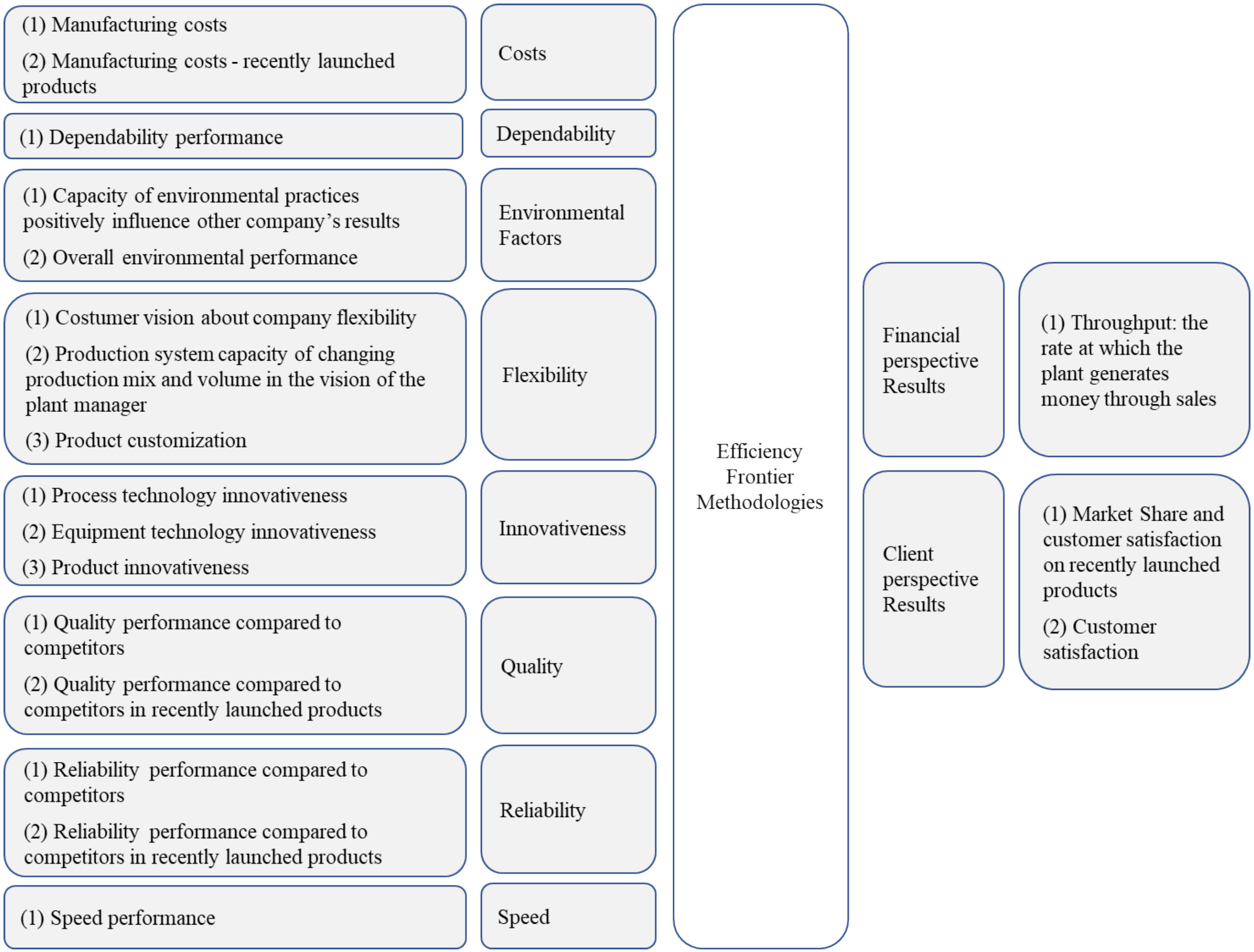
Category	Number of variables	Sample Size	Ratio SS/ Variable
Costs	9	117	13.0
Dependability	5	241	48.2
Flexibility	18	212	11.8
Quality	17	210	12.3
Innovativenes s	13	202	15.5
Speed	7	181	25.8
Reliability	4	261	65.3
Environmental factors	10	249	24.9
Financial Results	1	271	271
Clients Results	10	241	24.1

Category	KMO	Bartlett's Test of Sphericity (Sig)
Costs (C)	0.749 (middling)	0.000
Dependability (D)	0.646 (mediocre)	0.000
Environmental factors (E)	0.852 (meritorious)	0.000
Flexibility (F)	0.735 (middling)	0.000
Innovativeness (I)	Not applicable	Not applicable
Quality (Q)	0.844 (meritorious)	0.000
Reliability (R)	0.572 (miserable)	0.000
Speed (S)	0.799 (middling)	0.000
Financial results (FO)	Not applicable	Not applicable
Clients results (CO)	0.775 (middling)	0.000

Cat.	Component	Previous Variables (Weight)	EV
C1	Manufacturing costs	Product selling price (17.4%) / Unit cost of manufacturing (18.9%) / Labor cost (42.5%) / Operating expense (21.2%)	3.21
C2	Manufacturing costs - recently launched products	recently launched products success - Unit manufacturing cost (49.6%) / recently launched products success - Unit manufacturing cost (50.4%)	2.06
D1	Dependability performance	The promises that our plant makes to its customers are reliable (35.6%) / On time delivery performance (29.7%)/ Our customers can rely on us for punctual delivery (34.7%)	1.97*
E1	Capacity of environmental practices positively influence results	Cost advantages (16.2%)/ Cost savings by improving environmental quality (16.8%)/ Enter lucrative new markets by adopting environmental strategies (17.6%)/ Increase market share by making our current products more environmentally friendly (17.3%)/ Quality improvement (14.5%)/ Differentiation from competitors (17.5%)	4.00
E2	Overall environmental performance	Environmental performance (35.8%)/ Regulatory performance (34.3%)/ Overall environmental performance - compare to competitors (30.0%)	1.98
F1	Costumer vision about flexibility	Our customers select us because we deliver flexible for their needs (32.6%) / Our customers can rely on us for flexibility (31.8%) / We are selected by our customers because of our reputation for flexibility (35.6%)	2.20
F2	Changing mix/ volume Capacity	Flexibility to change product mix (49.4%) / Flexibility to change volume (50.6%)	1.90
F3	Product customization	We are highly capable of large-scale product customization (35.2%) / We can easily add significant product variety without increasing cost (27.9%) / We can customize products while maintaining high volume (37.0%)	1.70
I1	Process technology innovativeness	Quickly adoption of new technologies (14.3%)/ We often fail to achieve the potential of new process technology (14.3%)/Modification of production technology as new technologies emerge (14.3%)/ There are no substitutes for our production technology (14.3%)/ Our plant stays on the leading edge of new technology in our industry (14.3%)/ Our current production technology is protected by patents (14.3%)/ Posture toward new processes (14.3%).	N.A.
I2	Equipment technology innovativeness	We frequently modify equipment to meet our specific needs (25%)/ In order to improve equipment performance, we sometimes redesign equipment (25%)/ We produce a substantial amount of our equipment in-house (25%)/ We actively develop proprietary equipment (25%).	N.A.
I3	Product innovativeness	Product innovativeness (50%)/ Posture toward new products (50%)	N.A.
Q1	Quality performance compared to	Overall product quality perceived by customers (17.8%)/Conformance to established standards (17.6%)/ Primary product performance characteristics (17.0%)/Secondary options or features (15.6%)/ Aesthetics (15.8%)/ Serviceability; ease of repair (16.2%)/	3.72
Q2	Quality in recently launched products	Conformance quality (29.3%)/ Performance - functionality (36.0%)/ Features (34.7%)	2.11
R1	Reliability performance	Durability (life expectancy) (50.3%)/ Reliability (time between failures) (49.7%)	1.74
R2	Recently launched products reliability	Durability (50.2%)/ Reliability of the product (49.8%)	1.74
S1	Speed performance	Fast delivery (24.8%)/ Speed of new product introduction into the plant (23.8%)/ Agile manufacturing (25.4%)/ Cycle time (26.1%)	2.71*
FO1	Financial Performance	Throughput (100.00%)	N.A.
CO 1	Market Share recently launched products	Market share, compared to competitors (36.2%)/ Market share (38.5%)/ Customer satisfaction (25.3%)	3.09
CO 2	Customer satisfaction	Satisfaction of requirements and expectations of our customers (25.2%)/ Our customers are pleased with the products and services we provide for them (26.4%)/ Our customers have been well satisfied with the quality of our products, over the past three years (25.2%)/ Responsiveness to customer problems (23.3%)	1.99

* Extraction Sums of Squared Loadings

TV
45.92
75.33
65.62*
44.43
66.39
27.52
51.27
71.55
N.A.
N.A.
N.A.
41.36
64.8
43.55
86.96
67.63*
N.A.
44.16
72.55


(1) Manufacturing costs
(2) Manufacturing costs - recently launched products
Costs
(1) Dependability performance
Dependability
(1) Capacity of environmental practices positively influence other company's results
(2) Overall environmental performance
Environmental Factors
(1) Costumer vision about company flexibility
(2) Production system capacity of changing production mix and volume in the vision of the plant manager
(3) Product customization
Flexibility
(1) Process technology innovativeness
(2) Equipment technology innovativeness
(3) Product innovativeness
Innovativeness
(1) Quality performance compared to competitors
(2) Quality performance compared to competitors in recently launched products
Quality
(1) Reliability performance compared to competitors
(2) Reliability performance compared to competitors in recently launched products
Reliability
(1) Speed performance
Speed
Efficiency Frontier Methodologies
Financial perspective Results
(1) Throughput: the rate at which the plant generates money through sales
Client perspective Results
(1) Market Share and customer satisfaction on recently launched products
(2) Customer satisfaction

Appendix A-5 – Research Paper 5

Title: Assessing manufacturing performance through operations strategy lenses.

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Abstract: Manufacturing operations performance requirements are being continuously reviewed in times of a dynamic environment and rapid changes. This paper aims to propose and test a process to measure, assess, and improve organizations' manufacturing performance according to their operations strategy. A five-steps procedural framework based on the supper-efficiency data envelopment analysis (DEA) supports the improvement recommendations. Secondary data of the 4th round of the High-Performance Manufacturing (HPM) survey grounds the benchmarking analysis and assessment. The proposed framework is tested in an in-depth case with a company from the Brazilian automotive industry. The results led to insights into the identification of the main gaps to a target company become the leader in the market, through the enhancement of its operations strategic positioning. Improvement recommendations related to the needed area of improvements are developed based on the gap analysis of the input variables. The paper promotes its contribution by providing a deeper understanding of frontier estimation on the operations strategy context, strengthening the concept of competitive priorities.

Assessing manufacturing performance through operations strategy lenses

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Assessing manufacturing performance through operations strategy lenses

Abstract
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Keywords - competitive-priorities, supper-efficiency, data envelopment analysis, benchmarking.

1. Introduction

The business environment is facing unpredictable changes in the last two decades, generating a risk of unexpected disruptions, which can result in poorer operational and financial performance (Lotfi and Saghiri, 2018). The new dynamic business scenario increases the complexity of the organizational context, enhancing the need for understanding and capitalizing operations function opportunities. To Soosay et al. (2016) changes in technology and customer expectations also contribute to this dynamism and enhance the complexity of design operations strategy. To Abassi and Kaviani (2016), an optimal operations performance, provided by the operations strategy effectiveness, can lead the company to organizational excellence.

Additionally, given the economic limitations present in the markets, obtaining assertiveness in the operations strategy design is of paramount importance. Since Farrel (1957) it is well known that in the context of economic planning, it is essential to know to what extent a company can expect to increase its output solely by growing its efficiency without absorbing other sources of resources. In a resource-limited and complex scenario, the right decision on wheatear emphasize or not in a competitive criterion must be taken. Cai and Yang (2014) argue that the extent to which a company must emphasize a competitive priority depends on its operating frontier. In this sense, companies need to be aware of the relevant order-winners and qualifiers and the size of the gap in this criterion, as well as the investment, to close this gap. Božič and Cvelbar (2016) point out that unearth the drivers of firm performance is an ongoing issue evoking considerable interest among academics and practitioners.

The concept of firm performance efficiency frontier can support the identification of competitiveness drives, by the specification of the maximum performance that can be achieved by a given set of inputs. The frontier methods imply the performance through an efficiency score, which is calculated as the distance from the organization to the best practice frontier, through the observation of inputs and outputs of each organization (Chen et al., 2015). This paper approaches a case that integrates the concept of performance efficiency frontier and operations strategy, to assess and address improvement opportunities into the studied company operations strategy. Indeed, the competitive priorities are explored to benchmark the competitive environment and to inscribe the improvement recommendations.

This approach contributes to the scientific community on exploring the market-based view (MBV) perspective through the competitive priorities concept. Until now, the performance frontier methodologies are mainly applied to operations strategy with a focus mainly on resource-based view (RBV) and capabilities approach (e.g. Ramanathan et al., 2016; Yu et al., 2014; Nath et al., 2010; Ahmed, et al., 2014). Therefore, the lack of the exploitation of the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. Such a gap is explored in this paper. The importance of this proposal is supported by Hult et al. (2004) who state that translating market requirements into action is part of a strategic plan that supports the decision-making process to orient internal changes. Industrial firms with a market orientation are likely to devise and adapt products, services, and processes to continuously meet customer needs. To Okoshi et al. (2019) and Phusavat and Kanchana (2008), the appropriate choice of competitive priorities reflects on the future direction of a firm and has fundamental importance to the achievement of its competitive advantage which may lead to business performance increasing. Although some researchers such as Abassi and Kaviani (2016) and Bulak et al. (2016) use competitive priorities to determinate the operations strategy performance frontier, they not define focal points of improvement to enhance competitive position.

From the managerial point of view, the presence of a dynamic external environment is a factor that also contributes to increasing the density of the organizational context. Nowadays, there are multiple factors that compose the operations strategy (e.g., changes in technology and customer expectations), growing the complexity of its design (Soosay et al., 2016). The support of mathematical methods to choose the key factors that can contribute to the strategic planning assertiveness. Chen et al. (2015) state that identifying companies that have a competitive advantage is an easy exercise if performance can be captured by a single performance indicator, however, in the context of multiple metrics – our existent reality – this is no longer a trivial matter.

To Bititci et al. (2011) the dynamics of the market make some organizations fail in seeing or recognizing threats and opportunities until is too late to act. To Melnyk et al. (2014) in today's dynamic and turbulent environment, changes in either the business environment or the business strategy can lead to the need for new or revised measures and metrics. Establishing a systematic process to identify the production frontier can provide more accurate information for the establishment of emerging strategies and to increase the decision-making agility. Ahmed et al. (2014) defend that efficiency scores should be updated periodically, increasing the relevance of the existence of a process. In the current dynamic competitive environments, a static model to describe the relation of inputs and outputs will have limited use and feasibility in periods of instability (Samoilenko and Osei-Bryson, 2012).

In this study, the supper-efficiency data envelopment analysis (DEA) is used to identify the best-practice company concerning the operations strategy capacity to positively influence organization results. The benchmarking dataset includes the data of the 4^{th} round of the HPM Project, encompassing 77 automotive companies from 14 countries. The results define the supper-efficiency score and the enhancements needed for the studied firm becoming better positioned in the analyzed sector. To do so, this paper proposes and tests a process to measure, assess, and improve organizations' manufacturing performance according to their operations strategy. The framework enables the suggestion of recommendations to companies to have their operations strategies better-positioned face to competitors, contributing to developing a sustainable competitive advantage. The concept of competitive priorities is used to position the target company ahead of competitors.

A general view of the efficiency frontier analysis concept is first provided. Second, the integration of this concept with the operation strategy is given by the presentation of a conceptual framework. The procedural framework is then proposed and tested in a Brazilian automotive company, called 'Company A', for which improvement recommendations are outlined.

2. Supper-efficiency Frontier Analysis

The production frontier is a function that gives the maximum possible values of the output variables from the value of input factors. This discussion was first placed by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society (Farrel,1957, Khezrimotlagh and Chen, 2018). The frontier is estimated based on the company's inputs and outputs variables. It is a ratio between outputs and inputs, results smaller than 1 represent inefficient firms. When a point is technically inefficient, at least one of its input or output factors can be improved to reach the efficiency frontier (Khezrimotlagh and Chen, 2018, Bulak et al., 2016).

The entities for which the efficiency is calculated are called 'decision-making units' (DMU) (e.g. a firm). They are defined as any group of entities that receive the same inputs and produce the same outputs (Golany and Roll, 1989). The Data Envelopment Analysis (DEA) is the method used in this study to estimate the production frontier of a DMU group. The DEA is a non-parametric method proposed by Charnes, Cooper, and Rhodes (1978) which the original DEA constant return to scale (CRS) model, later extended by Banker, Charnes, and Copper (1984) to variable return to scale (VRS). In DEA, the performance frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to evaluate the performance of organizations based on multiple metrics (Bulak et al., 2016). The DEA aims to measure the efficiency where the DMU with the highest index is considered relatively efficient. DEA envelops the data set with the frontier of the most efficient DMU. The DEA allows the conversion of several inputs and outputs into a single efficiency measure. The objective is to build a performance frontier, whose points represent efficient combinations of inputs to produce a given product, from a set of production possibilities that covers all possible combinations of products, using a given set of inputs (Chen et al., 2015).

Some authors indicate that a weak point of the DEA is that a considerable number of units typically are characterized as efficient. Therefore, DEA does not allow for a ranking of the efficient units themselves (Esmaeilzadeh and Hadi-Vencheh, 2015, Kao, 2017, Bogetoft and Otto, 2011). The model of Anderson and Petersen (1993) presents a concept to rank DMU, called super-efficiency, helping them in discriminating between the firms placed in the frontier.

In cases when the standard DEA model results in score 1 to various companies, the use of supper-efficiency can be useful to differentiate these frontier firms, as they obtain supper-efficiency scores that are greater than one (Coelli et al., 2005). The proposal of Andersen and Petersen (1993) is to eliminate the focal DMU to construct the frontier from the remaining (n-1) DMUs to calculate the supper-efficiency index. This method enables the ranking to efficient DMUs, only. As the DMUs being eliminated are the efficient ones, they will fall outside of the region encompassed by the new frontier, and their efficiency scores calculated based on this frontier will be greater than one. That is why this efficiency index is called “super-efficiency” (Kao, 2017). Indeed, using “supper-efficiency” is interesting to differentiating among the firms with traditional efficiency scores of 1 (Bogetoft and Otto, 2011). The formulation 1 presents the SDEA (super-efficiency DEA) VRS dual model with input orientation, which is the base to the efficiency calculation of this study.

Minimize θ (1)

(θ, λ)

Subject to:

$$\theta\, x_{io} - \sum_{k=1, k\neq 0}^{n} \lambda_k\, x_{ik} \geq 0;\ \forall i \qquad i=1,2,\ldots,r$$

$$\sum_{k=1, k\neq 0}^{n} \lambda_k\, y_{mk} - y_{mo} \geq 0;\ \forall m \qquad m=1,2,\ldots,s$$

$$\sum_{k=1, k\neq 0}^{n} y_k = 1$$

Where y is the quantity of output *m* used by DMU *k*, x is the quantity of input *i* used by DMU *k*. The decision variables are θ (scalar) and λ (weighs) parameter for DMU *k*. *o* represents the DMU under analysis.

3. Efficiency Operations Strategy Analysis

The concepts of operations strategy and performance frontier are closely related. The operations strategy is deployed from the competitive strategy and aims to achieve excellence in performance related to key competitive priorities. The competitive strategy is represented by the business objectives, which are typically set in the form of financial and non-financial targets (Okoshi et al., 2019, Kaplan and Norton, 2000). While the concept of efficiency frontier requires inputs and outputs variables.

The proposed conceptual framework was first proposed by Veiga et al. (2019a) and takes the outputs as the desired result of the business, which is defined through a competitive strategy. These results are achieved through action in operations, represented by functional strategies. In this way, inputs are defined by the operations strategy competitive priorities (cost, environmental factors, flexibility, innovativeness, quality, speed, and reliability) and the dependent (output) variables, are approached by the financial and non-financial business results (Bulak et al. 2016, Abbasi and Kaviani, 2016). These inputs and outputs are segregated into detailed variables to make measurement tangible, as could be seen in Figure 1.

Figure 1 – Conceptual Framework (Veiga et al., 2019).

The presented conceptual framework is proposed by Veiga et al. (2019b). The model indicates the constructs for measuring operations strategy effectiveness, which can significantly represent the input and output performance measures for operations strategy. The variables were proposed based on an in-depth multivariate statistical analysis based on the Principal Component Analysis (PCA) technique.

4. Methodology

Once the operations strategy concept under the leans of performance frontier methodologies is of clear understanding, the next step is to operationalize the performance frontier study to recognize the operations strategy efficiency. A five-steps procedural framework is proposed to identify the efficiency of a target DMU with the competitive scenario. The competitive scenario is represented by a benchmarking data set. The target DMU data is collected and analyzed through a structured procedure.

4.1. Research Instrument

The proposed framework, presented in Figure 2, encompasses first the data collection in the target DMU to identify both, operations strategy positioning and performance in the input and output variables. Second, the competitive scenario must be represented by benchmarking data; in this step, such a data is studied and interpreted. Next, the operations strategy of the target DMU is understood. The fourth step is about the performance of frontier identification itself. To conclude, the final step indicates improvement recommendations on behalf of operations strategy and performance frontier, focusing on improving the position among benchmarked companies.

Figure 2 - Five-steps procedural framework

The framework organized the steps in the sequence they must be performed, and the arrows indicate the relation between them.

4.2. Benchmarking data set

The competitive scenario is represented by a secondary benchmarking data based on the 4th round of the HPM (High-Performance Manufacturing Project) project. The HPM Project seeks to identify the practices adopted by high-performance organizations. HPM research includes machinery and equipment industries, electronics, and automotive with at least 100 employees (Flynn, 1997). Round 4 was held between 2013 and 2018 (Park and Paiva, 2018, Phan et al. 2019), and this research counts with data from 14 countries.

4.3. Data Collection and analysis procedure

This research uses the HPM dataset with the sample restricted to automotive companies. Some questions from the HPM questionnaire were selected for each of the input and output variables (indicated in Figure 2). The questions selection was based first on semantic analysis, seeking to define only variables related to the input and output delimitation, and second, in the Principal Component Analysis (PCA) procedure (Ueda and Hoshiai, 1997, Fabrigar et al., 1999, Nataraja and Johnson, 2011). PCA was used to consistently reduce the number of variables as this method allows the original variables to be expressed as linear combinations of the factors (Rencher and Christensen, 2012; Hair et al., 2009; Alder and Golany, 2001). The PCA conducted the reduction of 97 original variables in 17 new variables of 7 input and 2 output categories. Those original variables were weighted to form the new variables. The weights are based on the PCA rotated component matrix, with the varimax rotation method. The affordable number of 19 variables allows the DEA study.

To perform the super-efficiency DEA analysis, data of 77 automotive companies from the HPM dataset was taken to depict the performance in each of the 97 selected original variables, and hence, in the 17 new variables. Next, the same questions were answered by the managerial team of the DMU under analysis (Company A). The primary means of data collection in Company A were interviews and document analysis. The selected people to the interview followed the same attribution of respondents in the HPM project questionnaires, to allow a homogeneous comparison. The assigned people include the managerial team in charge of plant management, quality, product development, environmental affairs, process, and downstream supply chain.

The analysis procedure is mainly based on the mathematical results obtained with the framework implementation. The last framework step only depends on qualitative data, which are obtained through unstructured meetings with the managerial team involved in the case research.

5. Implementing the Protocol to Identify Operations Strategy Efficiency

The procedural framework is implemented in a case seeking to verify the application feasibility, utility, and usability in a real organizational context. The case study was promoted in the Brazilian site of a multinational company belonging the automotive chain, called 'Company A.'

5.1. Data Collection

The required data were collected through the application of two questionnaires (operations strategy questionnaire and competitive criteria performance questionnaire). The operations strategy questionnaire identifies the operations strategic positioning of the studied company (target DMU), based on a perception 1-9 scale, whereas the smaller, the best. To each competitive criterion, the respondent must assess the company's A performance, and the importance that the clients gave to the analyzed criterion. The data was collected through individual interviews with people from the above-mentioned roles.

The competitive criteria performance questionnaire frames performance according to input and output variables. The questions are allocated respecting to respondents' expertise. So, at this stage, each question is addressed to a single respondent. The questions are based on a five-point Likert scale, whereas the bigger the best. The full questionnaire and historical data could be found in Veiga and Pinheiro de Lima (2019).

5.2. Depicting the benchmarking dataset

This section presents descriptive statistics for each component. The performance frontier considers data from 77 automotive companies of the benchmarking dataset. Only respondents with less than 30% of missing data in the interested variables were included. That's because it is possible to remediate missing data until 30%, as observed by Hair et al. (2009) and Rencher and Christensen (2012), the replacement procedure by the average was adopted to the remaining missing values. Table 1 summarizes the main descriptive data to input and output variables. The data are on a 5-point Likert scale, where the bigger the best.

Table 1 – Summary of components descriptive

In the meaning, descriptive statistics of data indicate the strong and weak points of the studied industry sector concerning competitive priorities. By looking at the average values of the input variables, this sector is good at overall environmental performance. On the other hand, it faces some issues about manufacturing cost and process technology innovativeness. The graphs of Figure 3 compare the sector historical data with the target company performance.

Figure 3 - Industry sector x target company performance on input and output variables

It is possible to recognize that Company A is performing better than the industry average in half of the competitive priorities variables. To ENV_F1 Company A exceed in more than 1 point the industry average. On the other hand, Company A is more than 1.5 points weak than the industry average in FLE_F3 and SPE_F1.

Looking at the output variables, Company A is better positioned than the industry average to all of them. An important advantage is found in CLI_F1, to which Company A exceeds the industry average in more than 1 point or 22%. CLI_F2 and FIN_F1 don't have a significant difference. Company A advantage is 12% and 10%, respectively.

5.3. Operations Strategy Identification

The expected result of this step is to recognize the operations strategy of the target DMU. To do so, the collected data is analyzed. The index presented in Table 2 considers the mean of the responses gathered in the operations strategy questionnaire and, based on this, a classification is promoted seeking to identify the performance (better, the same or worse than competitors) and the importance (order-winning, qualifying, and less important objectives).

Table 2 - Importance and performance indexes

In Company A, the answers are given by 7 managers, and there were found good concordance in answers to most criteria. Looking at the importance, the criteria of 'Cost' and 'Environmental Factors' are the ones with smaller consensus among participants. The analysis of the performance scale reveals a lack of consensus on the innovativeness variable. The consensus among participants is bigger to the performance scale, which is a reasonable result since most of the participants do not have direct interaction with final costumers.

Figure 4 presents a comparison of importance and performance classification in a graph form, where it is possible to identify if the company is performing behind or ahead of the required level of expectation from customers.

Figure 4 - Importance x Performance Radar Graphic

From the graph, the cost is order-winning, but the company's performance is not consistent with this importance. The same behavior, but more smoothly, occurs to speed and flexibility criteria. The opposite behavior is found in environmental factors. To those, the customer doesn't attribute so much importance, but the organization's performance is exceeding expectations. Still, it cannot be neglected to consider that the importance of attribution for the cost and environmental factors criteria had a dispersion worse than the expected. This fact may have influenced the result, so caution should be taken in assessing these criteria.

5.4. Performance Frontier Identification

Some preliminary definitions must be taken to determine the DEA model of the study. At first, the selection of the target set of DMUs that composes the benchmarking dataset, which requires heterogeneity in terms of the period of analysis, type of business, and the number of employees. The benchmarking data encompasses automotive companies with 100 or more employees, considering the 4th round of the HPM database.

The definition of the variables is also a preliminary step. In the proposed framework, the input variables include the order winning criteria identified in the foregoing step, since the objective of the model is to provide a benchmarking relative to the aimed DMU operations strategy. To Company A, the input variables include cost, flexibility, innovativeness, quality, reliability, and speed. The input variables have their scale inverted to allow the recommendation focusing on their enhancement since it is an input-oriented model.

The number of variables influence on sample size. There are plenty of approaches that define the minimum number of DMUs. The gold rule of Banker et al. (1989) is the adopted criterion since it is usually more demanding. The gold rule states that the number of DMUs should be at least three times the sum of the number of involved variables (inputs and outputs) or at least equal to the product of the number of input variables and the number of output variables, adopting the criterion associated to the greater number of required DMUs. To Company A, the estimation is promoted with 12 input variables – from 6 competitive criteria – and three output variables – from two business objectives. According to this, the minimum required data is 51 DMU.

The performance frontier is implemented through the supper-efficiency concept. The VRS dual model with input orientation is used to the efficiency calculation. The ranking of the supper-efficiency model is indicated in Table 3. Company A is positioned in the thirty-second position. The index means that 1304, which has a supper-efficiency index of 2.99, is better than the ones with lower scores because the former is further ahead of its peers.

Table 3 – Supper-efficiency from DEA VRS dual input-oriented model

The improvement recommendations are given based on the three best-positioned DMUs: 1304, 1924, and1909. This analysis seeks to recognize the performance drivers of the best-positioned DMUS and strategies to Company A to improve its position in the raking. Figure 5 shows the performance of Company A compared to the three best-positioned DMUs.

Figure 5 – Comparison of input and output variables performance

As could be seen, there is no detached performance among top-ranked organizations. The advantage varies according to the variable. The same behavior occurs to output variables. There is a performance gap between Company A and the first positioned DMUs in some variables, which removes the studied company from the top positions in the ranking. To become the first position of the ranking, Company A must improve some input variables' performance, as well as to get a better result from the current performance of the output variables. Table 4 indicates the performance gap. To each of the input and output variables, the Company A current performance level is indicated, as well as the suggested performance level, which is based on the higher index of the three-best positioned DMU. Based on this, the gap (shortage) is then calculated.

Table 4 – Shortage of inputs and outputs

There are improvement opportunities in all the input and output variables. The biggest gap between Company A and suggested performance is for FLE_F3 (product customization), to this variable, Company A is 269% behind of DMU 1924 (the best performing DMU) and is behind of all the three references DMUs. The other flexibility variables also present call for improvement, but more smoothly. FLE_F1 (customer vision about company flexibility) is about one point behind DMU 1924 (28%), and

FLE_F2 (production system capacity of changing production mix and volume) is only 0.5 points behind. To FLE_F1, Company A performs better than DMU 1304.

Speed represents the second-biggest gap, whereas Company A is 148% behind the suggested index. COS_F1 (manufacturing cost) also presented an important gap of 80% of the suggested level, which is coherent with the operations strategy questionnaire, where cost received the worse attribution. To both competitive priorities, Company A is worse than all the reference DMUs.

To innovativeness, Company A is not behind all the leading companies; however, all the innovativeness variables presented a significative gap; INO_F2 (equipment technology innovativeness), INO_F1 (process technology innovativeness) and INO_F3 (product innovativeness), presented gaps of 50%, 33.3%, and 25%, respectively.

Looking at quality and reliability, despite these competitive priorities received the highest performance rating in the operations strategy questionnaire, two variables presented a gap equal to or bigger than 25%. QUA_F2 (quality performance in recently launched products) and RE_F2 (reliability performance compared to competitors) presented a gap of 26.58% and 25%, respectively. QUA_F1 (quality performance compared to competitors) and RE_F1 (reliability performance in recently launched products) presented a smaller gap of 22.7% and 11.1%, in this order.

On behalf of outputs, it is possible to identify a smaller difference between Company A and the best performing DMUs. The biggest gap is to F1_FIN (throughput), with 25%- or 1-point difference.

5.5. Improvement Recommendations

The higher-ranked firms should improve the effectiveness of their operations in the competitive environment to hold their positions among the best practitioners of the market. The lower-ranked companies should benchmark the high ranked organizations to identify ways of improving their operational performance. Based on the assessment previously demonstrated, company A findings into the input and output categories are presented in Table 5.

Table 5 - Findings

Based on these findings, general improvement recommendations are provided to deal with the critical input and output categories. The call for improvement is delineated mainly to a shortage of bigger than 25%. Table 6 presents the improvement recommendations to enhance Company A strategic positioning. A discussion involving the respondents that participated in the data collection was promoted to confirm those findings and recommendations. It is up to the managerial team to determine how to turn the improvement recommendations into detailed actions.

Table 6 - Improvement Recommendations

To Company A, it is possible to identify that the urgent areas of needed improvement are cost and speed. Improvement in flexibility would also contribute to improving the company's competitive position, mainly in product customization. Besides that, the shared managerial understanding of the operations' strategy should be improved concerning the company initiatives related to the innovativeness, and the importance attributed to clients to cost and environmental factors.

6. Discussion

This study gives insights into the strategic positioning of the operations function through the proposition of a benchmarking model. Such a model identifies the operations strategy of the target company, compares its performance with a competitive database, employing the competitive criteria, to finally determine the gap to the studied company to become leader, contributing then to their competitive positioning enhancement.

Some authors already explored the firm production frontier concept to study the operations strategy; however, most of them use RBV as background, linking superior performance to firm resources and capabilities (Ahmed et al., 2014, Hemmati et al., 2016, Yu et al., 2014, Samoilenko, 2013). The MBV approach is not widely explored by literature although scholars also have found a strong relationship between competitive priorities and business performance in the manufacturing and service industries (Avella and Vázquez-Bustelo, 2010). The contribution of this research relies, therefore, on the exploitation of the MBV approach through the concepts of competitive priorities, seeking to identify how the operations strategy contributes to the business results. Bulak and Turkyilmaz (2014) have a similar proposal, working with competitive priorities. They measure and assess the operations strategy performance efficiency using the DEA. However, the authors set the gaps concerning the minimization of the inputs, establishing the opposite point of view to delineate improvement recommendations. Also, their work doesn't detail the suggestions to become a leader, concentrating singularly on the gap definition.

A second explored research opportunity is related to the lack of focus on a generic process perspective in studies related to operations strategy and performance efficiency frontier analysis. The existing process-oriented papers generally propose frameworks for specific purposes (Seol et al., 2011; Achillas et al.; 2014; Samoilenko and Osei-Bryson, 2013). From the procedural perspective, another point that enhances the contribution of this research is the fact of the implemented framework being context-driven which differs for each company being studied, this perspective was not approached by any of the few authors that focused on competitive priorities approach. Prior to calculating the ranking position, the operations strategy of each company must be studied, seeking to identify the order winning criteria, which in turn, define the input variables of the DEA framework. The proposed procedural framework contributes to identifying in which of the order-winning criteria the organization should perform better, based on the behavior of the sector of competition. That is, in what of the competitive criteria the compensation can be affordable, and in what of those it is necessary to overcome the trade-offs barrier by being simultaneously efficient.

To company A, the results demonstrated that the good results in quality and reliability must be sustained and, at the same time, improvements are required in speed and costs. The trade-offs among these competitive criteria and innovativeness and environmental factors can be maintained. Therefore, as practical implications, the results establish insights into the Company A operations strategy and the main gaps to become the leader in the market, through the improvement of its operations strategic positioning.

The performance frontier revealed that Company A is at the thirty-second position of 77 DMUs. The improvement opportunities are delineated through the relationship with the first three positioned DMUs. It is possible to recognize that there is no detached performance among the organizations in the top-ranking position. The advantage varies according to the variable. To company A, an urgent call for improvement relies on cost, speed, and flexibility, which are key criteria in the current competitive environment. Cost is historically a criterion that impacts on competitive advantage. To Lotfi and Saghiri (2018), it is broadly accepted that the firm's operations need to be cost-efficient; and according to Chang et al. (2015), firms that focus on cost leadership give more magnitude to production efficiency to achieve competitive advantage. Speed and Flexibility, in their turn, are increasingly important in the current competitive environment. The competitive advantage is related to the flexibility due to the need to cope with ever-changing market demands (Asadi et al., 2017, Singh et al., 2017). Anand and Ward (2004) reinforce that the unpredictability or the volatility aspects of environmental dynamism requires for manufacturing flexibility strategies. The turbulent environment also requires for agile manufacturing practices in the vision of Vázquez-Bustelo et al. (2007), reinforcing the renewed importance of speed criterion.

In relation to environmental factors, the performance of Company A is above expected by customers since the perception is that they not devote such importance to this criterion. However, the natural course leads to environmental factors to be increasingly valued in the long term so that this current excess can bring advantage in the future. Wang (2019) indicates that the public concern about the natural environment is rapidly growing, and this fact transforms the competitive landscape. To Famiyeh et al. (2018), the investments in environmental practices must not be faced as a cost to avoid but rather an opportunity to create value for firms and their customers. The authors develop their contribution indicating that environmental management practices have a positive effect on competitive operational performance. Wang (2019) also reinforces the impact of green culture on the performance advantage.

It is of clear understanding that Company A detaches in the competitive market by its quality and reliability performance. And the depiction of the competitive criteria data, by comparing with the best positioned DMUs, confirmed this perception. Concerning the output variables, Company A is better than the sector average to all variables. However, a point of attention is that the financial output variable is the one with the smaller index, which may indicate that the good performance in costumer output doesn't turn into as good a financial result as it could be. The references DMU 1304 and 1924, for example, have both a lower performance in customer output, but this result is enough to become a better financial benefit.

7. Conclusion

This study presented a novel operations performance assessment framework to benchmark organizations' operations strategies. Based on the input and output variables delimitated by the given conceptual framework, a process to measure, assess, and improve the operations strategy efficiency is proposed and tested, fully attending the paper aim. The framework was applied in a case to demonstrate its utilization and benefits from the managerial and scientific perspective.

The proposed procedural model establishes the steps for identifying the competitive position of the target DMU operations strategy. To do so, firstly, it was necessary to identify the studied company operations strategy, since the contribution befalls on benchmarking the competitive criteria for the interested company. Having the order winning criteria defined, the supper-efficiency index was calculated, generating a ranking that classifies the DMUs according to the efficiency of their operations strategy. The procedural model also allows the identification of the size of the gap to the target company becomes the leader in the market. Based on the gaps, the improvement recommendations were delineated. Those recommendations were defined to the gaps bigger than 25% and with the managerial team contribution.

This paper provides a contribution to both theory and practice. The proposed framework has a contribution to covering the gap of the market-based concept of competitive priorities, revealing new insights about how to benchmark the operations strategy. Such a perspective is an innovation for the scientific community since, until now, the existent pieces of literature focused mainly on the RBV approach, lacking in identifying how the operations strategy contributes to business results.

From the managerial perspective, valuable information is provided to understand if the organization's efforts are contributing to the attainment of a favorable competitive position. Besides, the results give insights to determine the focal points for improvement so that efforts made yield better results. Which is primary of importance as the right strategic choices in response to environmental uncertainty has become a great challenge due to conditions of the turbulent and complex external environment. Such a fact increases the density of the organizational context and requires multiple performance metrics. The support of mathematical methods to choose the key factors that can contribute to the strategic planning assertiveness and to the sustainable competitive advantage.

The conceptual and processual framework can be implemented by other companies and helping the understanding of the operations strategy as well as support the establishment of strategies to enhance its competitive positioning. As a limitation, we indicate that the performance frontier is estimated based on the responses gathered from a perceptive Likert scale. Therefore, the reliability of the data depends on the participants' awareness of the analyzed business. The existence of a single financial output variable is also a limitation, as it constraints the gathering of financial performance. However, it was not possible to define more representative variables due to the lack of secondary data. Finally, the framework requires an updated database to represent the competitive environment. When the 4th round of the HPM data becomes outdated, other data must be considered.

A future opportunity of study is the continuation of the proposed process seeking to close the PDCA loop. To do so, having the need areas of improvement identified through the assessment, it is necessary to define specific improvement actions to each of the indicated improvement recommendations, to implement those actions and to verify the effectiveness of the propositions by measuring again the competitive ranking position. A procedure to define, implement and control the operations strategy improvements can be proposed. Such a procedure can integrate the presented quantitative analysis together with the experience and knowledge of the studied company managerial team. Besides that, the generation of a database of improvement recommendations to each of the competitive criteria can contribute to this end. This recommendation can be developed through an in-depth statistical study of the HPM dataset since this wide database focus not only on the performance but also on the manufacturing practices.

The implementation of the proposed framework with quantitative data, based on the evidenced collection, is also a research opportunity that would require a joint effort to capture benchmarking data from a representative set of DMUs. This suggestion would overcome the limitation presented by this work in assessing manufacturing performance with data based on the managerial perception. By the end, the implementation of the proposed procedural model in more cases is important to ensure that the proposed process is affordable.

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Figure 1 - Conceptual Framework (Veiga et al., 2019)

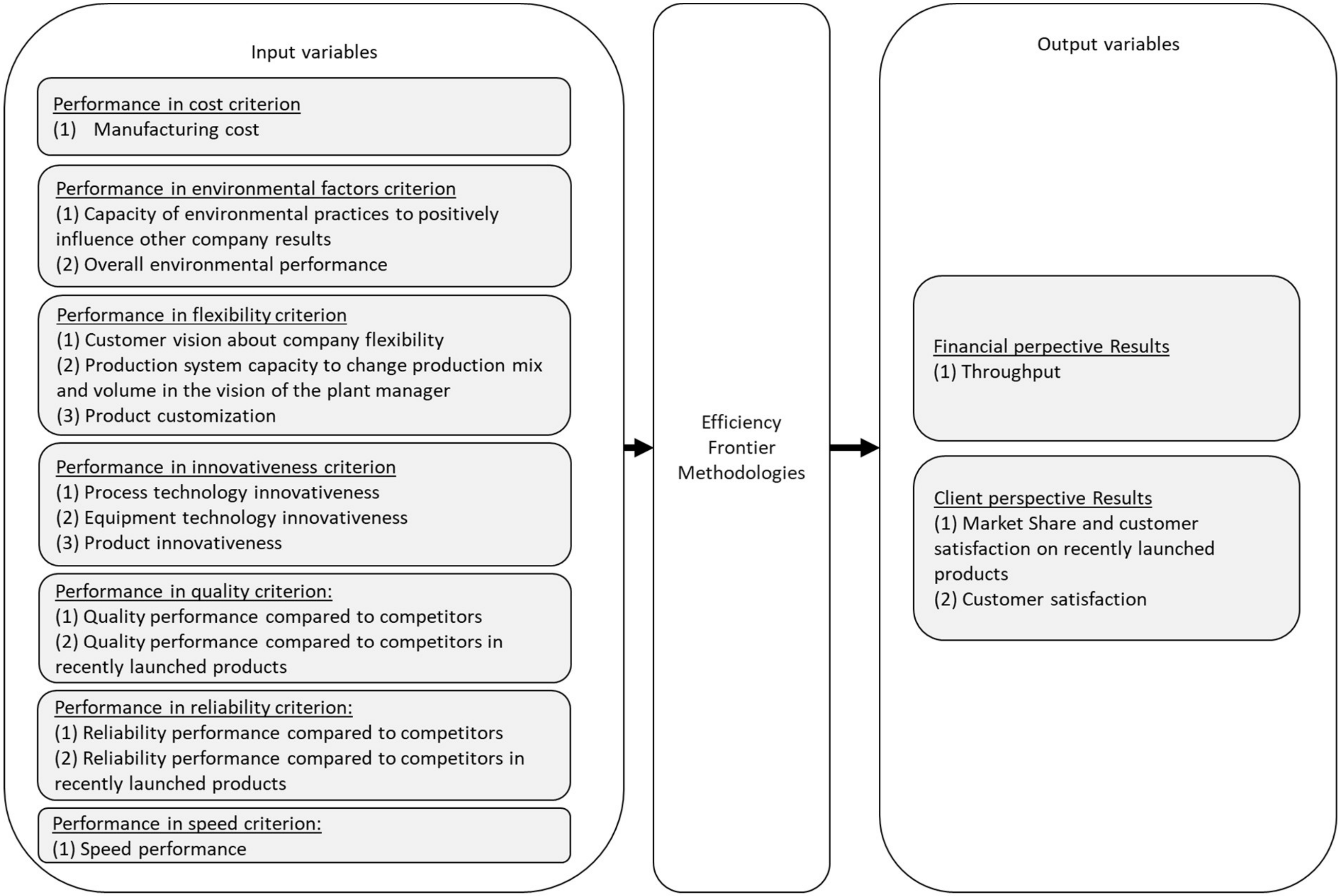

Figure 1 – Conceptual Framework (Veiga et al., 2019)

Figure 2 - Five-steps procedural framework

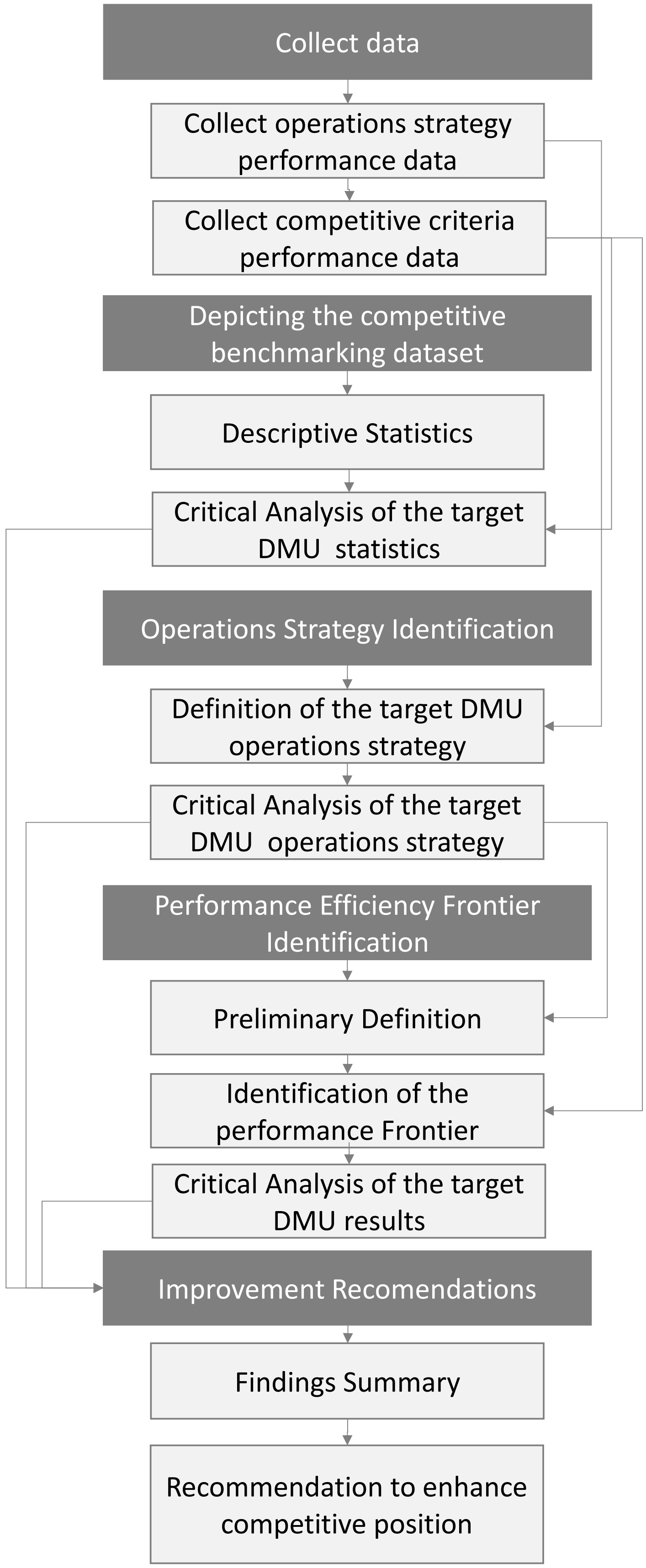

Figure 2 - Five-steps procedural framework

Table 1 - Summary of components descriptive

Table 1 – Summary of components descriptive

Category	Factor or not observed variable	N	Mean	Median	Std Deviation
Costs	COS_F1: Manufacturing costs, including operating expense	77	3.22	3.09	0.70
Environmental factors	ENV_F1: Capacity of environmental practices positively influence other company's results	77	3.41	3.39	0.79
	ENV_F2: Overall environmental performance	77	4.11	4.04	0.58
Flexibility	FLE_F1: Costumer vision about company flexibility	77	3.89	3.85	0.63
	FLE_F2: Production system capacity of changing production mix and volume	77	3.82	3.99	0.71
	FLE_F3: Product customization	77	3.47	3.55	0.78
Innovativeness	INO_F1: Process technology innovativeness	77	3.24	3.21	0.51
	INO_F2: Equipment technology innovativeness	77	3.55	3.70	0.69
	INO_F3: Product innovativeness	77	3.86	3.80	0.66
Quality	QUA_F1: Quality performance compared to competitors	77	3.76	3.79	0.51
	QUA_F2: Quality performance compared to competitors in recently launched products	77	3.89	3.83	0.53
Reliability	RE_F1: Reliability performance compared to competitors in recently launched products	77	3.80	3.75	0.61
	RE_F2: Reliability performance compared to competitors	77	3.83	3.82	0.66
Speed	SPE_F1: Speed performance	77	3.65	3.47	0.65
Client Output	CLI_F1: Market Share and customer satisfaction on recently launched products	77	3.61	3.56	0.72
	CLI_F2: Customer satisfaction	77	3.94	3.92	0.63
Financial Output	FIN_F1: Throughput: the rate at which the plant generates money through sales	77	3.60	3.55	0.86

Figure 3 - Industry sector x target company performance on input

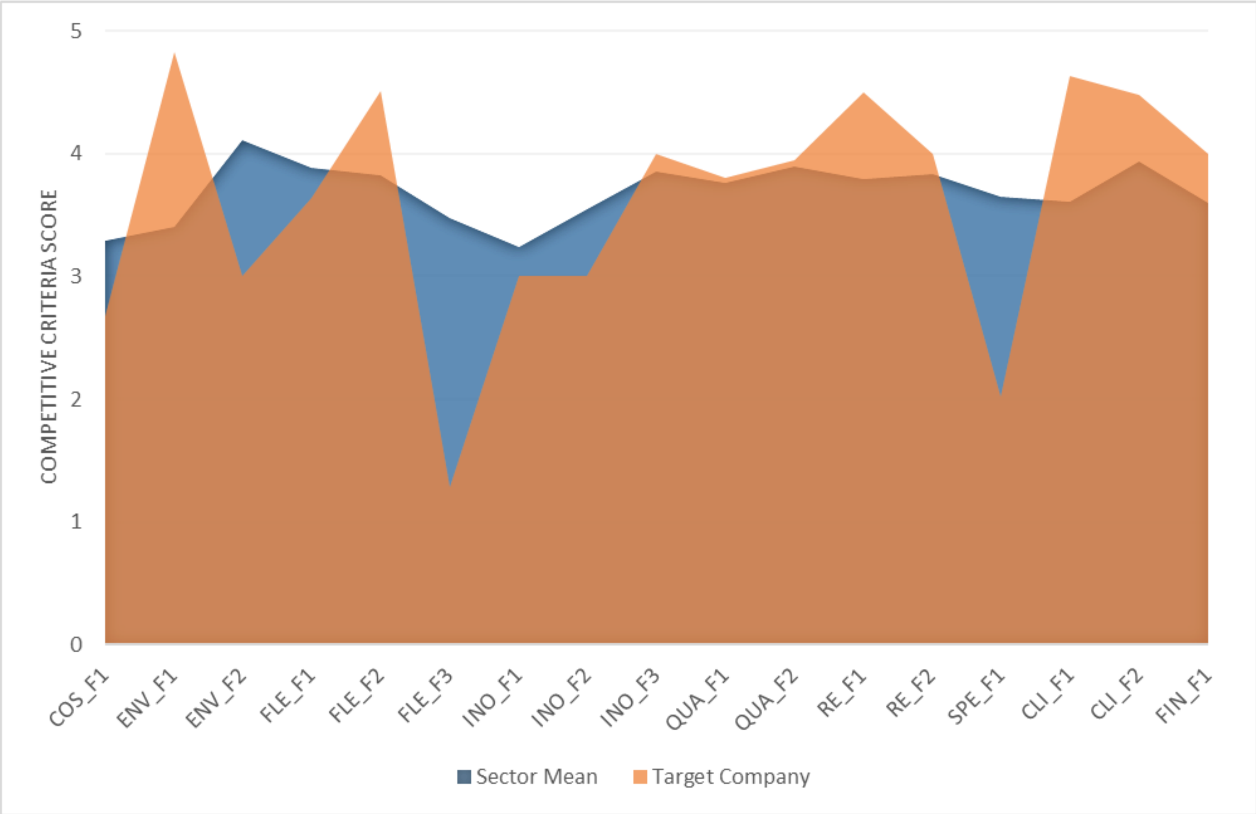

Figure 3 – Industry sector x target company performance on input and output variables

Figure 4 - Importance x Performance Radar Graphic

Figure 4 - Importance x Performance Radar Graphic

Figure 5 - Comparison of input and output variables performance

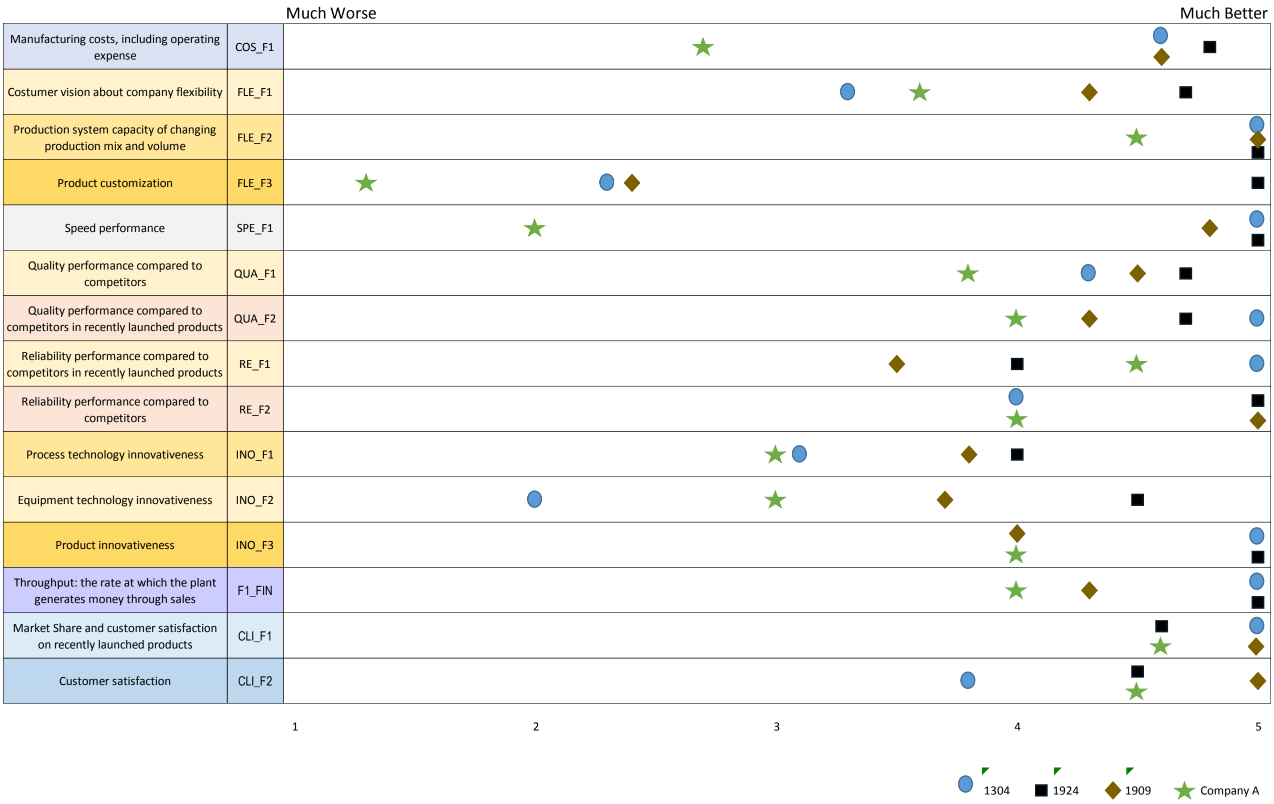

Figure 5 – Comparison of input and output variables performance

Table 2 - Importance and performance indexes

Table 2 - Importance and performance indexes

Operations Strategy Performance Criteria		Importance			Performance		
		Mean	Std Dvt	Classification	Mean	Std Dvt	Classification
1)	Cost	2.60	1.82*	Oder-winning	6.29	1.11	The same as competitors
2)	Reliability	2.40	1.34	Oder-winning	2.17	1.17	Better than competitors
3)	Flexibility	2.80	1.30	Oder-winning	4.00	0.82	The same as competitors
4)	Innovativeness	3.80	1.30	Oder-winning	3.57	1.72*	Better than competitors
5)	Quality	2.20	1.30	Oder-winning	1.86	0.90	Better than competitors
6)	Speed	3.00	1.22	Oder-winning	4.83	1.33	The same as competitors
7)	Environmental factors	5.80	1.79*	Qualifying	2.29	0.76	Better than competitors

* worse than the target result

Table 3 – Supper-efficiency from DEA VRS dual input-oriented model

Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency
1	1304	2.999	27	315	0.998	53	905	0.676
2	1924	2.419	28	504	0.982	54	1216	0.673
3	1909	2.025	29	1809	0.981	55	606	0.664
4	502	1.999	30	1718	0.968	56	1204	0.663
5	922	1.744	31	407	0.966	57	813	0.658
6	1724	1.674	32	Company A	0.963	58	1328	0.649
7	1905	1.633	33	320	0.953	59	910	0.646
8	327	1.626	34	1709	0.943	60	411	0.642
9	703	1.551	35	714	0.919	61	920	0.640
10	1215	1.371	36	808	0.900	62	1207	0.633
11	330	1.366	37	814	0.888	63	0403	0.631
12	1904	1.311	38	702	0.875	64	1902	0.619
13	1801	1.256	39	805	0.864	65	1201	0.607
14	1920	1.250	40	807	0.841	66	903	0.603
15	816	1.200	41	803	0.839	67	921	0.601
16	822	1.178	42	409	0.828	68	1310	0.599
17	107	1.178	43	1723	0.823	69	415	0.596
18	1914	1.132	44	918	0.823	70	1704	0.594
19	902	1.060	45	914	0.797	71	904	0.591
20	1910	1.041	46	428	0.777	72	1327	0.559
21	106	1.040	47	101	0.768	73	926	0.503
22	503	1.033	48	406	0.746	74	1413	0.494
23	501	1.007	49	1220	0.735	75	421	0.469
24	1719	1.000	50	1211	0.691	76	810	0.464
25	901	1.000	51	1308	0.681	77	412	0.457
26	1716	1.000	52	1401	0.680	78	704	0.444

Table 4 - Shortage of inputs and outputs

Table 4 – Shortage of inputs and outputs

	Company A Performance	Suggested Level	Shortage	Shortage %
Inputs				
FLE_F3	1.28	4.72	3.44	269.22%
SPE_F1	2.02	5.00	2.98	148.03%
COS_F1	2.66	4.79	2.13	80.24%
INO_F2	3.00	4.50	1.50	50.00%
INO_F1	3.00	4.00	1.00	33.33%
FLE_F1	3.64	4.68	1.04	28.47%
QUA_F2	3.95	5.00	1.05	26.58%
RE_F2	4.00	5.00	1.00	25.00%
INO_F3	4.00	5.00	1.00	25.00%
QUA_F1	3.81	4.67	0.86	22.67%
RE_F1	4.50	5.00	0.50	11.06%
FLE_F2	4.51	5.00	0.49	10.97%
Outputs				
F1_FIN	4.00	5.00	1.00	25.00%
CLI_F2	4.48	5.00	0.52	11.51%
CLI_F1	4.64	5.00	0.36	7.80%

Table 5 - Findings

Table 5 - Findings

Competitive Criteria	Findings	Description
Innovativeness	Lack of operations strategy consensus (performance scale)	The criterion of 'Innovativeness' has a low consensus among participants, presenting a standard deviation index of 1.72.
Cost	Lack of operations strategy consensus (importance scale)	The criterion of 'Cost' has a low consensus among participants, presenting a standard deviation index of 1.82.
Environmental Factors		The criterion of 'Environmental Factors' has a low consensus among participants, presenting a standard deviation index of 1.79.
Cost	Urgent Call for improvement in Cost	Cost is important to customers, but the company's performance is not consistent with this importance.
		COS_F1 presented an important gap of 80% of the suggested level, which is coherent with the operations strategy questionnaire, where cost received the worse attribution.
Speed	Urgent Call for improvement in Speed	Speed is important to customers, but the company's performance is not consistent with this importance.
		Company A is more than 1.5 points worse than the industry average, to 'SPE_F1: Speed performance.'
		Company A is 148% behind the suggested index and worse than all the reference DMUs.
Environmental Factors	'Excess' zone to Environmental Factors	Customer doesn't attribute so much importance to Environmental Factors, but the organization performance is exceeding expectations.
		To ENV_F1, Company A exceeds more than 1 point the industry average. However, the Environmental factor is not an order winning criterion for competition.
Flexibility	Urgent call for improvement in 'product customization.'	FLE_F3 (Product customization) has the biggest gap. Company A is behind the three-top positioner, with a performance of 269% smaller than the highest index.
		Company A is more than 1.5 points worse than the industry average, to 'FLE_F3: Product customization.'
	Call for improvement in Flexibility	The flexibility performance in behind the importance devoted by customers.
		FLE_F1 is one point behind DMU 1924 (28%).
Innovativeness	Call for improvement in innovativeness variables	Company A has all the innovativeness variables with an important gap, INO_F2 (Equipment technology innovativeness), INO_F1 (Process technology innovativeness), and INO_F3 (Product innovativeness), with gaps of 50%, 33.3%, and 25%, respectively.
Quality	Call for improvement in 'serviceability' and 'Features.'	Serviceability and Features in recently launched products had a poor performance perception in the Competitive criteria performance questionnaire.
	Not urgent call for improvement in Quality performance in recently launched products	Although this competitive priority received the highest performance rating in the operations strategy questionnaire, QUA_F2 presented a gap of 26.58%. QUA_F1 presented a smaller gap of 22.7%.
Reliability	Not urgent call for improvement in Reliability	Although this competitive priority received a high-performance rating in the operations strategy questionnaire, RE_F2 presented a gap of 25%. RE_F1 presented a smaller gap of 11.1%.
Output results	Good result	Company A is better positioned than the sector average to all of the output variables. An important advantage of 22%, is found in CLI_F1. CLI_F2 and FIN_F1 don't have a significant difference. Company A advantage is 12% and 10%, respectively.
Financial results (output)	Call for improvement in Financial results	The lowest output rate is to F1_FIN.

Table 6 - Improvement Recommendations

Table 6 - Improvement Recommendations

Improvement Recommendation	Input / Output criterion	Findings
Participant Consensus (shared understanding)		
Internal alignment of company initiatives	Innovativeness	Lack of operations' strategy consensus (performance scale)
Strengthen the sharing and discussion of costumer's reports (e.g., market share and customer satisfaction)	Costs	Lack of operations' strategy consensus (importance scale)
	Environmental Factors	
Performance in key competitive criterion		
Performance in key competitive criteria	Performance in key competitive criteria	Performance in key competitive criteria
Determinate strategies to improve performance in the criteria that are considered important by clients	Costs	Urgent Call for improvement in Costs
	Speed	Urgent Call for improvement in Speed
Discuss the strategic positioning of being outperforming in environmental factors. If it represents a long-term strategy, it can be maintained.	Environmental Factors	'Excess' zone to Environmental Factors
Determinate strategies to improve performance in the criteria with low performance	Flexibility	Urgent call for improvement in 'product customization.'
		Call for improvement in Flexibility
	Innovativeness	Call for improvement in innovativeness variables
	Quality	Call for improvement in 'serviceability' and 'Features.'
		Not urgent call for improvement in Quality performance in recently launched products
	Reliability	Not urgent call for improvement in Reliability performance
Sustain the result in market share and customer satisfaction	Client results	Good result
Determinate strategies to convert good satisfaction into financial results	Financial results (output)	Call for improvement in Financial results

Appendix A–6 - Research Paper 6

Title: Developing a procedure to asses and improve Operations Strategy.

Journal: Journal of Operations Management

Developing a procedure to assess and improve operations' performance

Journal:	*Journal of Operations Management*
Manuscript ID	Draft
Wiley - Manuscript type:	Research Article
Topics:	Performance frontier, Manufacturing/Production, Competitive Advantage
Methods:	Case study research, Secondary data, Econometrics
Additional Keywords:	operations strategy, competitive priorities

Abstract:	Defining performance criteria for company operations is no easy task due to the complexity and dynamics of the competitive arena. Conciliating internal and external demands in terms of performance information is an important element in companies' strategic agendas. Performance data explosion and the need to focus on what is really important are driving company awareness in terms of designing and selecting their performance metrics. This paper implements a procedure to measure, assess, and improve a manufacturing company's performance by identifying its operations strategy. Performance frontier methodologies support the procedural framework, which enables recognition of gaps in competitive priorities of operations strategy. The proposed process is context-dependent and fits the target company's strategic operations priorities. The research shown applies the procedural framework developed in interpreting eight cases within the Brazilian automotive industry. The paper concludes that specific process contributes to continually adapting the operations strategy according to the competitive behavior. When the process is fed by an accurate strategic performance framework, competitive priority gaps can be qualified and quantified. This provides important insights for managerial decision-making. Additionally, the paper provides a complete understanding of competitive performance priorities in the companies studied.

Developing a procedure to assess and improve operations' performance

Defining performance criteria for company operations is no easy task due to the complexity and dynamics of the competitive arena. Conciliating internal and external demands in terms of performance information is an important element in companies' strategic agendas. Performance data explosion and the need to focus on what is really important are driving company awareness in terms of designing and selecting their performance metrics. This paper implements a procedure to measure, assess, and improve a manufacturing company's performance by identifying its operations strategy. Performance frontier methodologies support the procedural framework, which enables recognition of gaps in competitive priorities of operations strategy. The proposed process is context-dependent and fits the target company's strategic operations priorities. The research shown applies the procedural framework developed in interpreting eight cases within the Brazilian automotive industry. The paper concludes that specific process contributes to continually adapting the operations strategy according to the competitive behavior. When the process is fed by an accurate strategic performance framework, competitive priority gaps can be qualified and quantified. This provides important insights for managerial decision-making. Additionally, the paper provides a complete understanding of competitive performance priorities in the companies studied.

Keywords: operations strategy, competitive priorities, multiple case studies, performance frontier methodology.

1. Introduction

Despite the growing importance given to operating strategy research topics, there is still a lack of integration between organizational and business strategies, which consequently does not allow the potential of operations to be properly exploited and does not contribute to achieving of a better competitive position (Brown and Blackmon, 2005; McAdam et al., 2017; Melnyk et al.; 2014). According to Schroeder and Flynn (2001), operations strategy supports competitive advantage by providing manufacturing capabilities or performance outputs to customers, covering: the dimensions of quality, cost, delivery, flexibility, and time.

Several models have developed their contribution to integrating operating and business strategies (Leong et al., 1990; Brown and Blackmon, 2005; Anand and Gray, 2017; Slack and Lewis, 2018). According to Veiga et al. 2019ab, the performance frontier model could also be considered a way for integrating operations strategy to business results, given the existence of a causal relationship between them, enabling the establishment of the input-output relation required for the performance frontier techniques (Schmenner and Swink, 1998). The excellence organizational performance is not reached unless it achieves optimal operations performance which is provided by the operations strategy effectiveness (Modi and Mishra, 2011; Abassi and Kaviani, 2016). The efficiency approach of integrating operations and business strategies plays a distinctive role in the current competitive scenario of recession and the ensuing dynamic conditions, where the resources for improvement and innovation must bring returns given the limited resources constraints for investment (Amoako-Gyampaha and Boye, 2001).

The efficiency frontier methodologies to study operations strategy performance are approached by some authors, but they focus mainly on a single approach to operations strategies, exploring the capability resource-based concept (Ramanathan et al., 2016; Cai and Yang, 2014; Hemmati et al., 2016; Yu et al., 2014). However, scholars also have found a strong relationship between competitive priorities and business performance in the manufacturing and service industries (Avella and Vázquez ‐ Bustelo, 2010). Although some researchers such as Abassi and Kaviani (2016) and Bulak et al. (2016) use competitive priorities to determine the operations strategy performance frontier, their assessments were not performed from a perspective of operations strategy, since they not proceed to develop recommendations for the enhancement of competitive positions. This paper develops its contribution to the gap of the market-based concept of competitive priorities to study operations strategy performance frontier. The importance of this proposal is supported by Hult et al. (2004) who state that translating market requirements into action is part of a strategic plan that supports the decision-making process to orient internal changes. Industrial firms with a market orientation are likely to devise and adapt products, services, and processes to continuously meet customer needs.

In this sense, Veiga et al. (2019b) propose a process to measure, assess, and improve operations strategy efficiency by deploying a ranking based on the supper-efficiency data envelopment analysis (DEA). Therefore, improvement recommendations are established according to the external performance as well as market needs. The framework proposed encompasses steps to define the target company operations strategy first, then assess the operations strategy efficiency, enhancing the contribution from the perspective of the targeted company strategic position. This paper uses this context-driven framework to interpret the operations strategy of eight Brazilian automotive companies. For this purpose, the manufacturing competitive priorities perspective is taken into consideration for any improvement needed in business performance. The framework proposed contributes to better positioning the companies studied within the global competitive environment, represented by data from the 4th round of High-Performance Manufacturing (HPM) Project that is explained in Flynn et al. (2001). The consumed data includes figures from 77 automotive companies from 14 countries.

2. Strategic Competitive Priorities to Operations Strategy

In 1969, Skinner's seminal work disseminated the concept of manufacturing strategy by proposing a framework that emphasizes the need to consider the production function in the development of the corporate strategy. Since then, the importance of the operations function has grown. Not just because the operations function is large and, in most businesses, represents the majority of its assets and its people, but because the operations function gives the ability to compete by providing the ability to respond to customers and by developing the capabilities that will keep it ahead of its competitors in the future (Slack and Lewis, 2018, Pinheiro de Lima et al., 2008, Skinner, 1969).

According to Schroeder and Flynn (2001), the operations strategy supports the competitive advantage by providing manufacturing capabilities and competitive priorities criteria, which are responsible for reconciling the two-operations strategy approaches based on resource and market-based views. Market perspective is where an understanding of the market is developed, and the translation of its needs is used in developing operations strategies (Caves and Porter, 1977; Porter, 1979). While in the resource perspective, new strategic options emerge naturally because of the resources of the organization (Wernerfelt, 1984; Barney, 1991; Prahalad and Hamel, 1990; Hitt et al., 2016). The firm’s internal resources and its external market power are fundamentally intertwined (Hill and Hill, 2017; Makhija, 2003). This research deals with the market-based approach based on competitive priorities to study the efficiency of the operations strategy, seeking to explore a research gap identified by Veiga et al. (2019b). The connection between operations strategy concept and firm performance frontier is approached by the literature mainly with the resource-based view perspective Vastag (2000). Abassi and Kaviani (2016), Bulak et al. (2016), Ramanathan et al. (2016), Cai and Yang (2014), Hemmati et al. (2016); Yu et al. (2014), Ahmed et al. (2014), Akdeniz et al. (2010), Nath et al. (2010), Nevo et al. (2007), Dutta et al.(2005) are all working with the capabilities concept from resource-based view theory, as can be seen in the works of Miller and Ross (2003), Maslen (1997), Prahalad and Hamel (1990), Barney (1991), and Wernerfelt (1984).

The dearth in exploring the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. For Okoshi et al. (2019) and Phusavat and Kanchana (2008), the appropriate choice of competitive priorities reflects on the future direction of a firm and has fundamental importance in achieving the competitive advantage which may lead to business performance improvement.

There are several approaches to defining the most important competitive dimensions. According to Slack and Lewis (2018), the five most common performance objectives are quality, costs, dependability, flexibility and speed. These five generic performance objectives have meaning for all types of operations and are related to satisfying customer requirements.

Beyond the traditional competitive priorities, recent literature has dealt with other criteria due to the current dynamic context as a reflex of the businesses' digital transformation, and a socioeconomic paradigm based on sustainable development. Innovativeness is recognized as a new competitive priority to compete in global markets (Laosirihongthong et al., 2014; Hult et al., 2004; Bouranta and Psomas, 2016). The advent of digital transformation enhances the importance of innovation in the current scenario (Khin and Ho, 2019; Ferreira et al., 2019; Vial, 2019). The contribution of innovation’s to opening of new markets or expand existing ones is widely accepted (Hult et al., 2004; Pallas et al., 2013; Rubera and Kirca, 2012), which is of primary importance in the environment of increasing competition. Cho and Pucik (2005) also prove that innovativeness impacts market value through growth and profitability.

Wang (2019) and Díaz-Garrido et al. (2011) also included the environment as a recent concern and incude this priority together with the classical competitive priorities. Vivares-Vergara et al. (2016) suggest environmental protection as a competitive priority in their study in relation to human resources management. Wang (2019) indicates that the public concern about the natural environment is rapidly growing and this fact transforms the competitive landscape. To Famiyeh et al. (2018), investments in environmental practices must not be faced as a cost to avoid but rather as an opportunity to create value for firms and their customers. Environmental performance is part of the definition of sustainability, since Gavronski (2012) currently considers it as being an important competitive dimension. According to Elkington (1997) and Kleindorfer et al. (2005), sustainability is a multidimensional concept that encompasses environmental, social and economic perspectives that contribute to forming a vision of performance. The current focus of some companies is still on the economic dimension, but some are already promoting sustainability as a whole, especially taking into account the informal system, as can be seen in Epstein et al. (2015). Mura et al. (2018) contribute with the integration of the sustainability concept within the organizational context, by identifying applications of sustainability metrics in terms of integrating sustainability-related information in management control and performance measurement systems.

Reliability is approached as a criterion detached from quality by some authors. Narkhede (2017) indicates that reliability is an important approach mainly for the USA, Europe, Japan, and India, being explored by various authors in manufacturing practices. This research includes innovativeness, reliability, and environmental factors as important competitive priorities in the current dynamics of competition. Innovativeness is defined by Hult et al. (2004), as the capacity to engage in innovation, which in turn is related to the introduction of new processes, products or ideas in organizations. Díaz-Garrido et al. (2011) consider that environmental factors include the production process and product items that interfere in the environment. Table 1 contains the definition of the competitive criteria approached.

Table 1 – Competitive criteria definition

Competitive Priority	Definition	Authors
Cost (C)	Offer products at lower costs than competitors or be cost-efficient. Costs are about the ability to optimize the utilization of manufacturing resources.	Slack and Lewis (2018), Lotfi and Saghiri (2018), Sansone et al. (2017).
Dependability (D)	Fulfill the promises of deadline delivery. Besides on-time delivery, it also Includes delivery date estimation and communication.	Slack and Lewis (2018), Yusuf et al. (2014).
Environmental Factors (E)	Items of the production process and product that interfere in the protection of the environment.	Vivares-Vergara et al. (2016), Díaz-Garrido et al. (2011).
Flexibility (F)	Have the capacity to adapt the operation whenever necessary and quickly enough, either by changes in demand or by needs of the production process. Cope with ever-changing market demands.	Slack and Lewis (2018), Slack and Brandon-Jones (2018), Asadi et al. (2017), Dey et al. (2019).
Innovativeness (I)	Capacity to engaging in innovation, which in turn is related to the introduction of a new process, products, and ideas in the organization.	Hult et al. (2004), Laosirihongthong et al. (2014).
Quality (Q)	Offer products according to the design specifications.	Slack and Lewis (2018), Bernroider et al. (2014), Chen and Tan (2013).
Reliability (R)	Quality of being trustworthy or of performing consistently well. Reliability is approached as a criterion detached from quality from some authors.	Slack et al. (1997). Narkhede (2017).
Speed (S)	Deliver to the customer faster than competitors.	Slack and Lewis (2018), Vázquez - Bustelo et al. (2007).

According to Slack and Lewis (2018), organizations must recognize the performance criteria to which they compete, and then develop objectives to address them inside their operations. The competitive priorities are segregated into qualifying, order-winning and less important criteria. The order-winning criteria are those in which the company must seek to outperform its competitors to win customers. The qualifying criteria are those in which the organization must achieve the minimum level of performance accepted by the market to qualify to compete in it. Having a higher level of performance in the qualifying objectives does not contribute to increasing the company's competitive power. Lastly, the least important criteria are those on which the customer's purchasing decision is not based.

Based on such a definition, the importance and performance matrix proposed by Slack et al. (2018) enables the recognition of the relative importance of each of the manufacturing performance objectives according to the client-specific priorities, which should become the manufacturing priorities. The matrix allows the evaluation of the actual performance achieved by the production function by comparing the performance of the organization with that of the competition. Therefore, it becomes possible to recognize the gaps between what is important to the operation and what performance is being achieved by classifying it into four zones, as can be seen in Figure 1. Identifying this gap provides guidance for choosing and implementation of improvement plans.

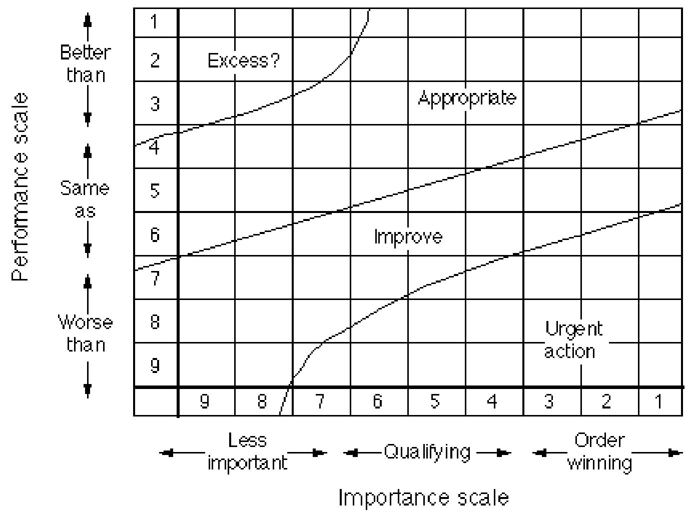

Figure 1 - importance and performance matrix (Slack et al., 2018)

In the appropriate zone, the performance objectives considered as satisfactory are classified. The improvement zone covers the relevant improvement objectives but does not represent urgent cases. The urgent action zone, however, reveals the objectives that must be improved quickly, because their performance is below expectation, due to the importance attributed by clients. The excess zone may represent that you are achieving better performance than is required and recognized by customers (Slack et al., 2018).

3. Efficiency Frontier Analysis

The firm production frontier discussion was first approached by Farrel in 1957 with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society. A Production function (production frontier) is a function that gives the maximum possible values of the output factors from the value of input factors (Farrel, 1957; Emrouznejad and Witte, 2010; Khezrimotlagh and Chen, 2018). Chen et al. (2015) consider that the frontier is estimated based on the observation population of the company's inputs and outputs or a representative sample (it is a ratio between outputs and inputs). Results smaller than 1 represent inefficient firms. The frontier estimation includes the constraint that it is not possible to exceed the result of 1 (Bulak et al., 2016; Anjos, 2005).

There are various methods for calculating technical efficiency in the literature. The Data Envelopment Analysis (DEA) is a non-parametric method proposed by Charnes, Cooper and Rhodes (1978) which the original DEA constant return to scale (CRS) model, later extended by Banker, Charnes, and Copper (1984) to variable return to scale (VRS). In DEA, the production frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to evaluate the performance of organizations based on multiple metrics (Ferreira and Gomes, 2009; Bulak et al., 2014; Coelli et al., 2005). It can be considered a technique that aims to compare the operational performance of production units. It is a measure of relative efficiency, as it considers the data presented, therefore, determining an absolute efficiency value, outside the group of analysis, is not possible (Anjos, 2005; Golany and Roll, 1989). The objective of the methodology is building a production frontier, whose points represent efficient combinations of inputs to produce a given product, from a set of production possibilities that covers all possible combinations of products, using a given set of inputs. The model allows the conversion of several inputs and outputs into a single efficiency measure, enabling verifying which units are efficient and which are not (Anjos, 2005).

The traditional DEA methods, CCR (Charnes, Copper and Rhodes, 1978) and BCC (Banker, Charnes and Copper, 1984) use clear and specific data for inputs and outputs. One difference between the models is in connection with productive components; the CCR model is used to calculate the scale efficiency indicator and the BCC model the technical efficiency (Anjos, 2005). Both aim to measure the efficiency of a decision-making unit (DMU). Any group of entities that receives the same inputs and produces the same outputs can be designated as DMU (e.g., a firm). For Golany and Roll (1989) the analysis group must include a homogeneous set of DMUs, wherein comparison makes sense. A homogeneous group is one where: the units under consideration perform the same tasks and have similar objectives; all the units are under the same set of 'market conditions' and the inputs and outputs are the same.

The comparison generates a ranking of a given DMU in terms of its relative efficiency, where the DMU with the highest ranking is considered relatively efficient. DEA envelops the data set with the frontier of the most efficient DMU (Liu et al., 2018). DMUs that achieve 100 percent efficiency are considered efficient, while DMUs with efficiency scores below 100 percent are inefficient (Chen et al., 2015; Bulak et al., 2016). Esmaeilzadeh and Hadi-Vencheh (2015) indicate that a score smaller than 100 percent (to input orientation models) means that a linear combination of other units from the sample could produce the same vector of outputs using a smaller vector of inputs.

Some authors indicate that a weak point of the DEA model is that a considerable number of units typically are characterized as efficient. Therefore, DEA does not allow for a ranking of the efficient units themselves (Esmaeilzadeh and Hadi-Vencheh, 2015; Kao, 2017; Bogetoft and Otto, 2011). The Anderson and Petersen (1993) model presents the most popular concept to rank DMU, called super-efficiency, helping them to discriminate among frontier firms. The term "supper-efficiency" is related to the DEA model in which the firms can obtain an efficiency score higher than one. In cases when the standard DEA model results in a score of 1 for various companies, the use of supper-efficiency can be useful to differentiate these frontier firms, as they obtain supper-efficiency scores that are greater than one. The efficiency score of the non-efficient firms does not change from the efficiency to the supper-efficiency model, as they were not part of the original DEA frontier (Coelli et al., 2005).

The Andersen and Petersen (1993) proposal is to eliminate the focal DMU to construct the frontier from the remaining (n-1) DMUs to calculate the supper-efficiency index. The data of the DMU analyzed is removed from the model constraints. This method enables the ranking to efficient DMUs, only. Since the DMUs being eliminated are the efficient ones, they will fall outside of the region encompassed by the new frontier, and their efficiency scores calculated based on this frontier will be greater than one. That is why this efficiency index is called "super-efficiency" (Kao, 2017; Ferreira and Gomes, 2009). Indeed, using "supper-efficiency" is interesting to differentiate among the firms with traditional efficiency scores of 1 (Bogetoft and Otto, 2011).

4. Methodology

The efficiency frontier of operations strategy is studied for eight cases, thought the use of Veiga et al. (2019b) process to measure, assess and improve the operations strategy efficiency. The selection of the companies studied respects the HPM criterion of having more than 100 employees and being from the automotive sector. Additionally, prominent companies in their segments, with quality assurance, were prioritized. A final criterion is the availability of six representatives in the roles of plant manager, supply chain management, process engineering, product development, quality management, and environmental affairs.

In this section, the definition of the measures to link competitive manufacturing priorities to outputs is dealt with first. Next, the research instrument that defines the framework process is detailed. This section also presents the descriptive data of the benchmarking dataset.

4.1. Measures

The concept of operations strategy and performance frontier are closely related (Abassi and Kaviani; 2016; Bulak et al., 2016; Cai and Yang, 2014; Hemmati et al., 2016). Operations strategy is the deployment from the corporate strategy and aims to achieve excellent performance in the key competitive priorities (Leong et al., 1990; Brown and Blackmon, 2005; Slack and Lewis, 2018). While the concept of efficiency frontier is a function that indicates the maximum level of result attainable for a corresponding quantity of inputs, the frontier is estimated based on the observation of inputs and outputs of a population of companies (Farrel, 1957; Emrouznejad and Witte, 2010; Liu et al., 2018; Khezrimotlagh and Chen, 2018).

As for output measures, plenty of authors define the business performance as measures related to customer and financial results (Kaplan and Norton, 2000; Rubera and Kirca, 2012; Bulak et al., 2016, Abbasi and Kaviani, 2016). For Hult et al. (2004) business performance is defined as the attainment of organizational goals for profitability and growth in market share, as well as the accomplishment of general strategic objectives of the company. These results are achieved through actions in operations, represented by functional strategies. The operations function has its strategy composed of the competitive priorities, supported by the action in the decision areas (Leong et al., 1990; Slack and Lewis, 2018). In this way, inputs are defined by competitive priorities. Figure 2 establishes the relationship between operations strategy, competitive priorities, and business results in an efficiency methodology frame.

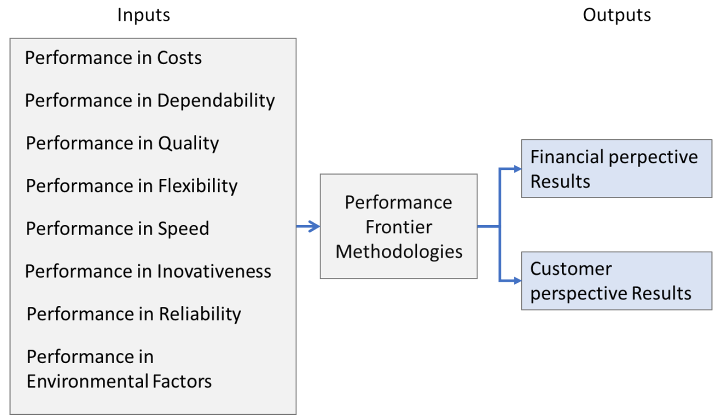

Figure 2 – Performance Frontier methodology frame

A generic frontier model is given, however, the input variables for each case depend on the studied company' operations strategy.

4.2. Research Instrument

A five-step procedural framework is developed to identify the efficiency of a target DMU operations strategy, and, with this result, establish the focus and initiatives for the target DMU to become the leader in the desired competitive market. In the first step, the data of the target DMU must be taken. The data required is collected by applying two questionnaires: operations strategy questionnaire (see appendix A) and competitive criteria questionnaire (see appendix B). The aim of the first one is to identify the operations strategy positioning of the company being studied. The second one collects the performance in each of the input and output variables. The surveys were answered, in individual interviews, by at least six representatives in the roles of plant manager, supply chain management, process engineering, product development, quality management, and environmental affairs.

The operations strategy questionnaire is based on Slack and Lewis's (2018) performance and importance matrix. The competitive criteria questionnaire definitions are based on a statistical analysis of the HPM questionnaire, grounded in both, semantic analysis and Principal Component Analysis (PCA) techniques (Hair et al., 2009; Veiga et al., 2019a).

The second step encompasses the comparison of the target DMU performance with the competitive environment, represented by benchmarking data based on the 4th round of the HPM project. The third step, called operations strategy identification, is to identify how the target DMU positions itself in the competitive scenario. To do so, the answers to the first questionnaire are analyzed in order to define the operations strategy of the target company and map the most important competitive priorities. The fourth deals with efficiency calculation through the super-efficiency DEA with input orientation, as formulation 1. This step is named performance frontier identification.

Minimize θ (1)

(θ, λ)

Subject to:

$$\theta\, x_{io} - \sum_{k=1, k\neq 0}^{n} \lambda_k x_{ik} \geq 0; \forall i \qquad i = 1,2,\ldots,r$$

$$\sum_{k=1, k\neq 0}^{n} \lambda_k y_{mk} - y_{mo} \geq 0; \forall m \qquad m = 1,2,\ldots,s$$

$$\sum_{k=1, k\neq 0}^{n} y_k = 1$$

Where: y is the outputs, x is the inputs, λ the weightings. The decision variables are θ (scalar) and λ (weighs).

The supper-efficiency index is calculated considering the data from the company being studied and the data from the 77 companies comprising the benchmarking dataset. The DEA is obtained considering the only the order winning competitive priority, so the less important criteria do not influence the results. A ranking is generated to understand the target DMU position among the companies in the dataset.

Finally, the fifth step refers to the definition of improvement recommendations based on both, operations strategy definition and its positioning among the benchmarking data. The gap in each of the input and output variables are defined considering the best positioned DMU.

The analysis procedure of all the steps is mainly based on the mathematical results obtained with the framework implementation, as described in Table 2.

Table 2 – Framework analysis procedure

Step	Evaluated Item	Aimed behavior
Operations strategy Identification – Step 3	- Gaps between importance and performance - Position in the matrix	Befalls in the appropriate zone
	- Importance and performance answer consistency	Standard deviation smaller than 1.5
Performance Frontier Identification – Step 4	- Supper-efficiency index	No targeted position, but the higher, the better.
Improvement recommendations – Step 5	- The difference between the target company and the best index among the five best positioned	Gaps smaller than 50%

The target behavior was defined by analyzing the results obtained in the cases. Standard deviation bigger than 1.5 can influence the average response, moving results from one level to another. In the same way, a difference of 50% between the target DMU results and the target index, can significantly modify the ranking position.

4.3. Competitive environment statistics

The competitive environment is represented using benchmarking data from the 4th round of the HPM project. The dataset includes information from 77 companies of the automotive industry from 14 countries Brazil, Germany, Finland, Sweden, United States, China, Italy, Switzerland, Vietnam, Spain, Japan, Taiwan, North Korea, and the United Kingdom. The data was collected with a 5-points Likert scale where the higher, the better. The descriptive statistics which represent the sector performance are presented in Table 3.

Table 3 – competitive environment statistics

Category	Variable	CA	N	Mean	Median	Std Deviation
Costs (C)	COS_F1: Manufacturing costs, including operations expense	0.880	77	3.22	3.09	0.70
	COS_F2: Customer vision of company costs	0.828	77	3.06	3.00	0.72
Dependability (D)	DEP_F1: Dependability Performance	0.775	77	4.06	4.05	0.65
Environmental factors (E)	ENV_F1: Capacity of environmental practices to positively influence other company results	0.899	77	3.41	3.39	0.79
	ENV_F2: Overall environmental performance	0.722	77	4.11	4.04	0.58
Flexibility (F)	FLE_F1: Customer vision of company flexibility	0.818	77	3.89	3.85	0.63
	FLE_F2: Production system capacity of change production mix and volumes	0.775	77	3.82	3.99	0.71
	FLE_F3: Product customization	0.702	77	3.47	3.55	0.78
Innovativeness (I)	INO_F1: Process technology innovativeness	0.585	77	3.24	3.21	0.51
	INO_F2: Equipment technology innovativeness	0.739	77	3.55	3.70	0.69
	INO_F3: Product innovativeness	-0.692	77	3.86	3.80	0.66
Quality (Q)	QUA_F1: Quality performance as compared to competitors	0.876	77	3.76	3.79	0.51
	QUA_F2: Quality performance as compared to competitors in recently launched products	0.763	77	3.89	3.83	0.53
Reliability (R)	RE_F1: Reliability performance as compared to competitors in recently launched products	0.851	77	3.80	3.75	0.61
	RE_F2: Reliability performance as compared to competitors	0.847	77	3.83	3.82	0.66
Speed (S)	SPE_F1: Speed performance	0.839	77	3.65	3.47	0.65
Client Output (CO)	CLI_F1: Market Share and customer satisfaction in recently launched products	0.751	77	3.61	3.56	0.72
	CLI_F2: Customer satisfaction	0.882	77	3.94	3.92	0.63
Financial Output (FO)	FIN_F1: Throughput: the rate at which the plant generates money through sales	N.A.	77	3.60	3.55	0.86

A statistical understanding of this data can help to picture the competitive environment and identify critical competition issues. The variables presented in Table 3 were defined using PCA, which generated 16 input variables and 3 output variables, reduced from 63 questions of the HPM questionnaire.

Cronbach's alpha (CA) coefficients are used to check the internal reliability of variables comprising each of the input and output measures, which ranged from 0.72–0.90, except for the innovativeness variables, therefore endorsing they are not reflexive construct (latent variables). As expected, the categories generated by PCA have an acceptable Cronbach alpha, confirming the consistency among variables within the same component. The financial category does not require PCA since it has only one variable.

5. Results

The process to measure, assess, and improve operations strategy was implemented in interpreting eight cases in the Brazilian automotive industry. Comparative analysis enabled process validation as well as the understanding of the contribution framework. The first two framework steps are in connection with data collection and understanding of benchmarking data, both required to perform steps 3, 4 and 5, which will be the focus of the demonstration of the results.

The case studies' results will be shown in a comparative format. However, it is important to highlight that each case was run independently, that is, the data from one company is not used in establishing the comparative data for the other cases. Additionally, it is also important to highlight that the context analysis for each case is dependent on each company's business and operations strategy. The performance frontier is calculated considering only the order-winning criteria used by the company being studied, characterized as a context-driven framework.

5.1. Critical analysis of Operations Strategy

This step targets promoting a critical analysis of the answers collected by the first questionnaire, which intends to identify each company's strategic position. The index considers the average of the responses gathered and based on this; a classification is undertaken seeking to identify the performance level (better, the same or worse than competitors) and the importance (order-winning, qualifying, and less important objectives). Table 4 presents the comparative importance scale of attributes for the eight cases.

Table 4 – Importance scale comparison

Target DMU	Order Winning	Qualifying	Less Important	Answer consistency Issue*
Company A	C*, F, I, Q, R, S	E*	none	2
Company B	C*, D, F*, Q, R*	E, I*, S*	none	5
Company C	C, D*, F*, Q, R, S	E, I*	none	3
Company D	C, D, F*, I, Q, R	S	E*	2
Company E	C, D*, I, Q*, R*, S	E, F, S	none	3
Company F	C, D, Q, R, S*	E, F, I	none	1
Company G	C, D, Q, R	E*, F, I*, S*	none	3
Company H	C, D, I, Q, R, S	E*, F*	none	2

* Standard deviation higher than 1.5 (in a response scale of 9 points)

Dependability is a competitive criterion included as an improvement from case A to case B. The results of the importance scale show that most of the criteria are 'Order Winning' from the eight companies' perspective, which means that companies must outperform their competitors to win customers, given that customers consider these criteria in making their buying decision.

From the comparison among the companies under study, some similarities were found, which might be representative of the Brazilian automotive sector's behavior. All companies consider costs, dependability, quality, and reliability to be order-winning. In the other end of the spectrum, none of the companies consider environmental factors as order-winning. Environmental features were either qualifying or less important criteria, meaning that customers do not acknowledge this feature yet. Innovativeness and speed were both considered qualifying by three companies, and flexibility was considered qualifying by two companies.

Table 5 present the comparison of the performance scale. Most of the companies under study face some issues on costs Performance, as this criterion had a high incidence in 'the same as competitors' performance index, which reinforces the performance of the competitive sector. Looking at the descriptive statistics of the competitive environment, the two cost variables (COS_F1 and COS_F2) are among the criteria with the lowest evaluation.

Table 5 – Performance scale comparison

Target DMU	Better than competitors	The same as competitors	Worse than competitors	Answer consistency Issue*
Company A	E, I*, Q, R	C, F, S	none	1
Company B	D, E*, F, I*, Q, R, S*	C*	none	4
Company C	D, E*, I*, Q, R	C*, F, S*	none	4
Company D	C, D, E, F*, Q, R, S*	I	none	2
Company E	D*, E, I*, Q, R	C, F*, S	none	3
Company F	C, F, R	D, E, I, Q, S	none	0
Company G	C, D, E, F, Q, R, S	I	none	2
Company H	C, S	D, E*, F, I*, Q*, R*	none	4

* Standard deviation higher than 1.5 (in a response scale of 9 points)

Another point for attention is that, despite environmental factors being classified as a qualifying or less important criterion for all the companies under study, at the same time, the performance is better than competitors for most of them. From this, companies are performing above the customer expectation, as can be seen in Table 6, which presents the improvement priorities by identifying the importance-performance matrix zone. The table shows that environmental criterion falls into the excess zone for several companies.

Table 6 – Importance x Performance zone comparison

Target DMU	Excess	Appropriate – Maintain	Improve	Urgent Action
Company A	E,	F, I, Q, R	C, S	none
Company B	none	D, E, F, I, Q, R, S	C	none
Company C	none	D, E, F, I, Q, R, S	C	none
Company D	E	C, D, E, F, Q, R, S	I	none
Company E	E	D, E, Q, R, S	F	C
Company F	none	C, E, F, I, R, S	D, Q	none
Company G	none	C, D, E, F, I, Q, R, S	none	none
Company H	none	C, D, E, F, I, S	Q, R	none

Also, this table confirms that costs are an issue for most of the companies under study, falling in the improvement or urgent action zone. The other competitive criteria performance vary according to the company.

Tables 4 and 5, shown previously, also indicated consistency issues among answers. Indexes with a standard deviation higher than 1.5 are highlighted and, from this, some patterns were recognized. First, the respondents found more issues in answering the questionnaire targeted at identifying the importance attributed by customers. Overall, the managerial awareness of company performance is higher than their awareness of the importance given by the customer. Second, companies with more issues in consistency among answers can be identified. Company B presented five consistency problem in the importance evaluation and four in the performance evaluation. Company C presented three consistency problems in the importance evaluation and four, in performance.

5.2. Performance frontier critical analysis

The performance frontier analysis is developed through the DEA technique. Specifically, the VRS dual model, with input orientation. It is considered the super-efficiency in order to rank DMU seeking to identify the best-performing companies. The variables include the order winning criteria identified in the step above, which characterizes the process as a context-driven framework, seeking to compare the criteria that are part of the operations strategy of each company. A ranking is calculated with a supper-efficiency index that positions the company being studied among the competitive environment. The ranking is calculated considering the answers gathered in the second questionnaire, which intends to identify the performance in the competitive criteria.

The optimization model varies according to the company being studied, since the respective input variables are different. In addition, inclusion of the company being studied in the data interferes with the results, since DEA envelops the data set with the frontier of the most efficient DMU, and the group of DMUs is used to generate the ranking (Liu et al., 2018). Even with these variations of the optimization models for each company studied, the DMUs in the top position are recurrent, although their ranking positions vary. Table 7 provides the supper-efficiency index, the ranking position, and the five best-positioned DMUs for each of the case studies.

Table 7 – Summary of the super-efficiency analysis

Target DMU	Supper-efficiency Index	Ranking Position	Best positioned DMUs
Company A	0.96	32	1304, 1924, 1909, 502 and 922
Company B	2.00	3	1304 and 1924
Company C	1.16	17	1304, 922, 1924, 1909 and 502
Company D	1.48	11	1304, 922, 1924, 1909 and 502
Company E	0.88	32	1304, 922, 502, 1924 and 1724
Company F	0.73	37	1304, 922, 1924, 502 and 1909
Company G	1.70	5	1304, 922, 502 and 1924
Company H	0.54	68	1304, 922, 1924, 502 and 1909

Comparing, specifically, managerial awareness with ranking position in the operations strategy questionnaire displays another pattern of behavior. Companies with a high-ranking position have less awareness of their operations strategy. The scatter plot in Figure 3 relates the ranking position (axis y) with the total of the issues in answer consistency (axis x, which is the sum of problems in the importance and performance attribution). The answer consistency issues are mainly related to the criteria with issues in answer consistency (e.g. standard deviation higher than 1.5.).

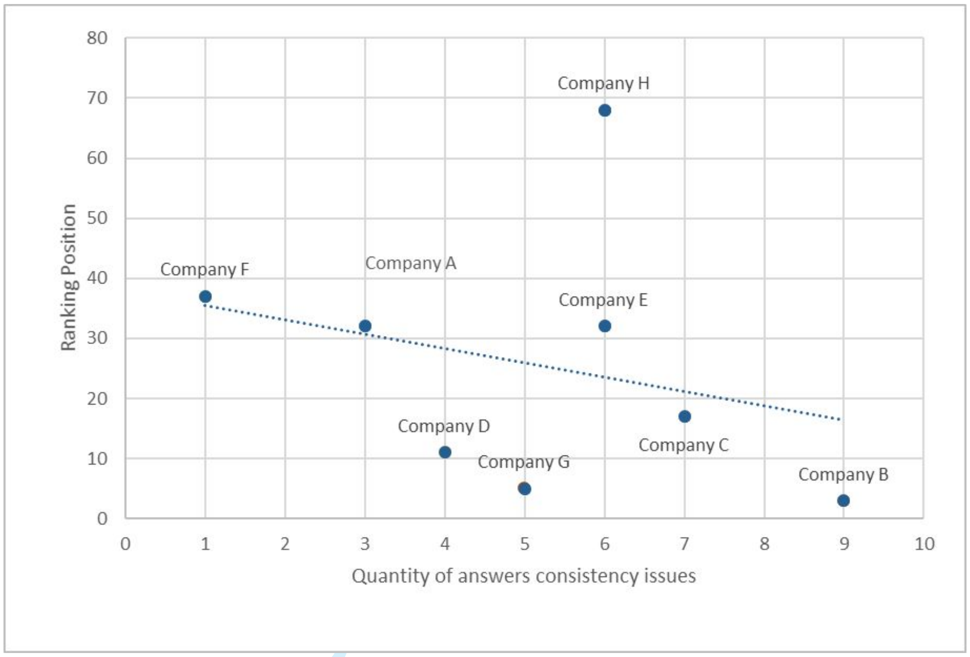

Figure 3 - scatter plot, ranking position x answer consistency

The chart shows that company B which ranked third in a ranking with another 77 companies, does not display strategic consensus among the managerial team (a total of 9 issues in answer consistency). Company C, ranked seventeenth, displayed 7 incidences of lack of shared understanding. Company A and Company F placed only in the thirty-second and thirty-seventy positions respectively, have managerial teams with materially higher awareness of the company strategy. Company H positions as an outlier, the company has significant issues in answer consistency, as some respondents attribute good indexes but most of them indicated low-performance indexes.

5.3. Improvement recommendation

The supper-efficiency score of the target DMU and its position in the ranking drives the definition of improvement recommendations. Improvement recommendations are developed considering the gap between the DMU studied and the best index among the five-best positioned DMU. Table 8 demonstrates the gap between the current and the target index for each company being studied. The ranking was generated considering the order-winning criteria for each DMU being studied, keeping the less important criteria from producing bias in the results. The not available (N.A.) variables are not order-winning ones. Management attention should be drawn to gaps larger than 50%.

Table 8 – Shortage into the best ranking position

Code	Variable	A	B	C	D	E	F	G	H
Inputs									
COS_F1	Manufacturing costs, including operations expense	80%	33%	61%	8%	72%	74%	47%	70%
COS_F2	Manufacturing costs - recently launched products	N.A.	13%	150%	11%	100%	43%	25%	53%
DEP_F1	Dependability performance	N.A.	8%	0%	23%	14%	49%	0%	35%
FLE_F1	Customer vision of company flexibility	28%	27%	0%	1%	N.A.	N.A.	N.A.	N.A.
FLE_F2	Production system capacity in changing production mix and volume	11%	0%	43%	0%	N.A.	N.A.	N.A.	N.A.
FLE_F3	Product customization	269%	30%	11%	52%	N.A.	N.A.	N.A.	N.A.
SPE_F1	Speed performance	148%	N.A.	67%	N.A.	N.A.	99%	N.A.	54%
QUA_F1	Quality performance compared to competitors	23%	12%	8%	40%	16%	16%	27%	46%
QUA_F2	Quality performance compared to competitors in recently launched products	27%	7%	35%	8%	37%	37%	7%	42%
RE_F1	Reliability performance compared to competitors in recently launched products	11%	25%	11%	0%	43%	43%	25%	24%
RE_F2	Reliability performance compared to competitors	25%	0%	43%	11%	43%	43%	25%	66%
ENV_F1	Capacity of environmental practices to positively influence other company's results	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
ENV_F2	Overall environmental performance	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
INO_F1	Process technology innovativeness	33%	N.A.	N.A.	17%	27%	N.A.	N.A.	33%
INO_F2	Equipment technology innovativeness	50%	N.A.	N.A.	50%	100%	N.A.	N.A.	20%
INO_F3	Product innovativeness	25%	N.A.	N.A.	67%	11%	N.A.	N.A.	33%
	Outputs								
F1_FIN	Throughput: the rate at which the plant generates money through sales	25%	25%	67%	0%	25%	67%	0%	150%
CLI_F1	Market Share and customer satisfaction for recently launched products	8%	0%	63%	37%	133%	8%	29%	81%
CLI_F2	Customer satisfaction	12%	0%	25%	45%	6%	11%	5%	42%

*COS_F2 is a variable included from case A to case B as an improvement of the conceptual framework.

A performance gap may be perceived between the DMUs studied and those first positioned in the variables, which removes the company being studied from the top positions in the ranking. To become the first position of the ranking, companies must improve performance in some input variables, as well as get a better result from the current performance of the output variables. By eradicating the shortfall indicated, the companies under study can become market leaders, considering the benchmarking dataset.

Cost is a point of attention for all companies. In addition, both INO_F2 (Equipment technology innovativeness) and Speed presented issues in all the companies having these criteria as order-winning. Companies should evaluate whether they have large gaps in the order-winning criteria. These should become the managerial priority in establishing improvement actions.

6. Discussion

This paper implements a framework used to measure, assess and improve operations strategy through super-efficiency DEA in eight cases. The optimization model varies according to the company being studied, since input variables and reference data differ. However, even with these variations of the optimization models for each company studied, the DMUs in the top position are recurrent, although the respective ranking positions vary.

The framework implemented is context-driven and, therefore, differs for each company being studied. Prior to calculating the ranking position, the operations strategy of each company is studied, seeking to identify the order winning criteria, which in turn, define the input variables of the DEA framework. Some patterns were found based on the critical analysis of operations strategy and performance frontier of the eight cases. The results of the importance scale show that most of the criteria are 'Order Winning'. From this, it is possible to confirm the literature findings of Soosay et al. (2016), Lotfi and Saghiri (2018), Melnyk et al. (2014), among others, that are indicative of a highly competitive and dynamic environment. In such an environment, the bargaining power lies in with customer, who may demand more from their suppliers, given they can choose among them. In this scenario, considering most of the criteria as being order-winning is reasonable, enhancing the complexity for companies to achieve a market standout position. This behavior brings into attention the discussion of Slack et al. (2018) emphasizing the need for increasing the "effectiveness" of the operation by overcoming trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others.

Four of the classic competitive criteria are considered order-winning by all of the companies under study - cost, dependability, quality, and reliability. Confirming that these criteria remain important over time.

In recent literature environmental factors have been approached as an important coopetition criterion due to the current dynamic context (Wang, 2019; Díaz-Garrido et al., 2011; Vivares-Vergara et al., 2016). However, despite being considered important by literature, Environmental factors are only perceived by companies as qualifying criteria. Therfore, their understanding is that customers do not attribute so much importance to environmental factors. Even so, environmental factor performance is better than competitors for most of the companies under study. This means that they are generating a performance that exceeds customer expectation. According to literature, the natural course of events leads environmental factors to being increasingly valued in long term so companies may be anticipating a standout position in this criterion, and this current excess can bring advantage in future (Famiyeh et al. 2018; Wang, 2019). Environmental performance is part of the sustainability definition, as established in Elkington's (1997) seminal concept. And for some authors, sustainability is now being considered in the three proposed dimensions, and not only in the economic dimension as most companies used to consider (Epstein et al., 2015; Mura et al., 2018).

In cost performance, despite being considered order-winning by customers, most of the companies under study face some issues, which are also encountered by other companies in the sector. This fact can alleviate the negative impact of this difficulty since this it is a shared issue within the sector. On the other hand, a company that can excel in this criterion may have a competitive advantage, as there is consensus on costs being considered as order winning. Narkhede (2017) reveals costs as the most important competitive criterion among the manufacturing industry's competitive criteria. And according to Lotfi and Saghiri (2018), it is widely accepted that the firm's operations need to be cost-efficient.

Innovativeness and speed were both considered qualifying by three companies, and flexibility was considered qualifying by two companies. Rubera and Kirca (2012) promoted a study that indicates that firm innovativeness affects its market and financial position. Cho and Pucik (2005) also prove that innovativeness interferes with market value by means of growth and profitability. However, for automotive companies in Brazil, innovativeness does not seem to be a decisive criterion from the customers' perspective, and, in the scenario studied, innovativeness may not contribute to enhancing financial position. Innovativeness may be a worldwide criterion but it is not fully recognized in the Brazilian automotive competitive scenario. Speed, in its turn, may not be considered an order-winning criterion for being a parameter defined in the supplier contract, according to the comments made by the managers participating in the study.

Reliability is the single competitive criterion in the appropriate zone for all of the companies under study, which may be indicative that this is a criterion for current managerial attention. The serviceability advent may contribute to enhance the company focus on reliability performance (Szász and Seer, 2018; Benedettini et al., 2015; Baines et al., 2013).

The patterns in answer consistency (evaluated through the standard deviation among the responses) demonstrated that the managerial awareness of company performance is higher than their awareness of the importance given to the customer, a reasonable result since most of the participants do not have direct interaction with end customers, particularly when the company does not play a first-tier position. From this behavior, proximity with the customer and deeper understanding of the competitive environment would be positive in strengthening the business awareness and, thus, the quality of decision-making. Therefore, the usability of the framework proposed depends on the managerial awareness of their business and operations strategy as well as their awareness in providing answers to issues.

The comparison among case studies also demonstrated that companies with a high-ranking position have less awareness of their operations strategy. From this, the high position of company B is questionable, since the managerial team does not display a shared vision with respect to the importance or performance of competitive criteria. There cannot be any certainty about the reliability of the answers. Therefore, the lack of knowledge about the company strategy and performance on the market can become a constraint in deploying the result of the framework proposed.

7. **Conclusion**

This study presented an operational performance appraisal framework based on the efficiencies of organizations' operations strategies. Eight cases were developed to implement the Veiga et al. (2019b) framework, which employs a ranking based on the super-efficiency DEA.

The perspective of approaching operations strategy results as input to the business performance, by means of the efficiency frontier approach, is not fully explored by literature and can bring an important contribution to both the academia and practitioners. This paper explores a gap in literature in covering the competitive priorities concept to study the operations strategy using performance frontier methodologies, given that the most widely used approach in this kind of research is the resource-based view.

This new framework offers companies under study improvement opportunities in their competitive priorities. Each company's efficiency score is calculated, and enhancements needed for becoming an efficient firm or sector in the analysis are reported. The results provide information about which firms have reached satisfactory levels in strategic competitive priorities for business performance and provide managers with an opportunity to manage the firms at the desired level. The framework implementation enhances the managerial awareness of each company's competitive position.

Managers of higher-ranked firms should improve the effectiveness of their operations in the competitive environment to attain maximum efficiency and hold their positions among the best practices in the market. Additionally, lower-ranked companies should benchmark against the higher ranking organizations and improve their operations performance. Moreover, changing the current operations strategy and exploiting the trade-offs between the eight competitive priorities may lead to achieving a higher ranking.

The paper concludes that specific processes contribute to continually adapting the operations strategy driven by the competition's behavior. When the process is properly fed in an accurate strategic performance framework, competitive priorities gaps can be qualified and quantified providing important insights for managerial decision-making. The implementation of the framework demonstrated feasibility since the only requirement is answering a questionnaire which takes about 30 minutes for each person in charge of the answers. This then enables the implementation of the framework in a dynamic manner promoting agility in decision-making for the company in alignment with internal and external demands.

As a limitation of this study, we indicate that the performance frontier is the estimated base through a perceptive Likert scale for the responses collected. Therefore, the reliability of the data depends on the participants' awareness of the business being analyzed. Future opportunities in quantitative analysis to define the recommended practices to achieve the leading position are also a further opportunity. This recommendation can also be developed considering the HPM dataset since this wide database does not only focus on the performance but also on the manufacturing practices.

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Appendix A: Survey to identify the Operations Strategy

Step 1: Operations Strategy Identification Collect operations strategy performance data		
Focused product line:		
Focused client vision:		
Please, considers the competitive criteria definition as follows		
Competitive Priority	**Definition**	
Costs	Offer products at lower costs than competitors or be cost-efficient. Costs are about the ability to optimize the utilization of manufacturing resources.	Slack and Lewis (2018), Lotfi and Saghiri (2018), Sansone et al. (2017).
Dependability	Fulfill the promises of deadline delivery. Besides on-time delivery, it also Includes delivery date estimation and communication.	Slack and Lewis (2018), Yusuf et al. (2014).
Environmental Factors	Items of the production process and product that interfere in the protection of the environment	Vivares-Vergara et al. (2016); Díaz-Garrido et al. (2011).
Flexibility	Have the capacity to adapt the operation whenever necessary and quickly enough, either by changes in demand or by needs of the production process. Cope with ever-changing market demands.	Slack and Lewis (2018), Slack and Brandon-Jones (2018), Asadi et al. (2017), Dey et al. (2019).
Innovativeness	Capacity to engaging in innovation, which in its turn is related to the introduction of a new process, products, and ideas in the organization	Hult et al. (2004), Laosirihongthong et al. (2014).
Quality	Offer products according to the design specifications.	Slack and Lewis (2018), Bernroider et al. (2014), Chen and Tan (2013).
Reliability	Quality of being trustworthy or of performing consistently well. Reliability is approached as a criterion detached from quality from some authors.	Slack et al. (1997). Narkhede (2017).
Speed	Deliver to the customer faster than competitors	Slack and Lewis (2018), Vázquez Bustelo et al. (2007)

Importance Scale

According to the Nine-point Importance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Order-winning objectives	1. Provide a crucial advantage with customers - they are the main thrust of competitiveness;
	2. Provide an important advantage with most customers - they are always considered by customers;
	3. Provide a useful advantage with most customers - they are usually considered by customers;
Qualifying objectives	4. Need to be at least up to good industry standard;
	5. Need to be around the median industry standard;
	6. Need to be within close range of the rest of the industry;
Less important objectives	7. Do not usually come into customers' consideration, but could become more important in the future;
	8. Very rarely come into customers' considerations;
	9. Never come into consideration by customers and are never likely to do so.

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

According to the Nine-point Performance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Better than competitors	1. Consistently considerably better than our nearest competitor;
	2. Consistently clearly better than our nearest competitor;
	3. Marginally better than our nearest competitor;
The same as competitors	4. Often marginally better than most competitors;
	5. About the same as most competitors;
	6. Often within striking distance of the main competitors;
Worse than competitors	7. Usually marginally worse than most competitors;
	8. Usually worse than most competitors;
	9. Consistently worse than most competitors?

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

Appendix B: Survey to identify the competitive criteria performance

Step 3: Frontier Identification Collect input/output performance data							
Fator/Variavel original	Question	1	2	3	4	5	People in Charge
	Question	Options					People in Charge
Manufacturing costs, including operating expense	Question	1	2	3	4	5	People in Charge
Manufacturing Costs	How do your plant's products compare to its leading competitors, on Product selling price?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Unit cost of manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Labor cost ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing costs - recently launched products	Question	1	2	3	4	5	People in Charge
Manufacturing costs - recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas? Unit manufacturing cost	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Manufacturing costs - recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors (Unit cost of manufacturing)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Dependability performance	Question	1	2	3	4	5	People in Charge
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: The promises that our plant makes to its customers are reliable.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Dependability performance	How does your plant compare with its competitors in its industry, on a global basis, on On-time delivery performance?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for punctual delivery	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Question	1	2	3	4	5	Respondent
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers select us because we deliver flexibly for their needs	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: We are selected by our customers because of our reputation for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Production system capacity of changing production mix and volume in the vision of the plant manager	Question	1	2	3	4	5	Respondent
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change product mixt ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change volume?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product customization	Question	1	2	3	4	5	Respondent
Product customization	Indicate the extent to which you agree or disagree with The statement: We are highly capable of large scale product customization.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can easily add significant product variety without increasing cost.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can customize products while maintaining high volume.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Speed performance	Question	1	2	3	4	5	Respondent
Speed performance	How do your plant's products compare to its leading competitors, on Fast delivery?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Speed of new product introduction into the plant (development lead time)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Agile manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Cycle time (from raw materials to delivery)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management

Quality performance compared to competitors	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Overall product quality perceived by customers?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Conformance to established standards?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Primary product performance characteristics?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Secondary options or features; characteristics that supplement the basic functioning of the product?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Aesthetics; how the product looks, feels, sounds, tastes or smells?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant’s products compare to its competitors’ products on Serviceability; ease of repair?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors in recently launched products	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Conformance quality?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Performance (functionality)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Features?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors in recently launched products	How does the quality of your plant’s products compare to its competitors’ products on Durability; amount of use before the product deteriorates or needs to be replaced?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability performance compared to competitors in recently launched products	How does the quality of your plant’s products compare to its competitors’ products on Reliability of the product; probability of failure in a specified time?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors – quality management vision’	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Durability (life expectancy)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability performance compared to competitors – quality management vision’	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Reliability (time between failures)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Capacity of environmental practices positively influence other company’s results’	Question	1	2	3	4	5	Respondent
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Being environmentally conscious can lead to substantial cost advantages for our plant.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can enter lucrative new markets by adopting environmental strategies.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can increase market share by making our current products more environmentally friendly.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Reducing the environmental impact of our plant’s activities will lead to a quality improvement in our products and processes.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company’s results	Indicate the extent to which you agree or disagree with each of the statement: Better environmental performance can differentiate our plant from our competitors.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Overall environmental performance	Question	1	2	3	4	5	Respondent
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Environmental performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Regulatory performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How does your plant compare to others in your global industry, in Overall environmental performance?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs

Process technology innovativeness	Question	1	2	3	4	5	Respondent
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We quickly adopt new technologies by applying what we learn from our customers.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We often fail to achieve the potential of new process technology.	Strongly agree	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Strongly disagree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: As new technologies emerge, we modify our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: There are no substitutes for our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our plant stays on the leading edge of new technology in our industry.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our current production technology is protected by patents.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Which term best describes the plant's posture toward new processes?	Never adopts new processes	Usually among the last to adopt new processes	Adopts new processes when it becomes more or less the general rule	Among the first to adopt new process, but not the leader	Leader in new processes	Process Engineering
Equipment technology innovativeness	Question	1	2	3	4	5	Respondent
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We frequently modify equipment to meet our specific needs.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We produce a substantial amount of our equipment in-house.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: In order to improve equipment performance, we sometimes redesign equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We actively develop proprietary equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product innovativeness	Question	1	2	3	4	5	Respondent
Product innovativeness	How does your plant compare with its competitors in its industry, on a global basis, on Product innovativeness?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product innovativeness	Which term best describes the plant's posture toward new products?	Never adopts new products	Among the last to adopt new products	Adopts new products when it becomes more or less the general rule	Among the first to adopt new products, but not the leader	Leader in new products	Product Development
Throughput: the rate at which the plant generates money through sales	Question	1	2	3	4	5	Respondent
Financial Performance	How does your plant compare with its competitors in its industry, on a global basis, on Throughput: the rate at which the plant generates money through sales?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Plant Management
Market Share and customer satisfaction on recently launched products	Question	1	2	3	4	5	Respondent
Market Share and customer satisfaction on recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Customer satisfaction?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Customer satisfaction	Question	1	2	3	4	5	Respondent
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our plant satisfies or exceeds the requirements and expectations of our customers.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers are pleased with the products and services we provide for them.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers have been well satisfied with the quality of our products, over the past three years.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers seem happy with our responsiveness to their problems.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management

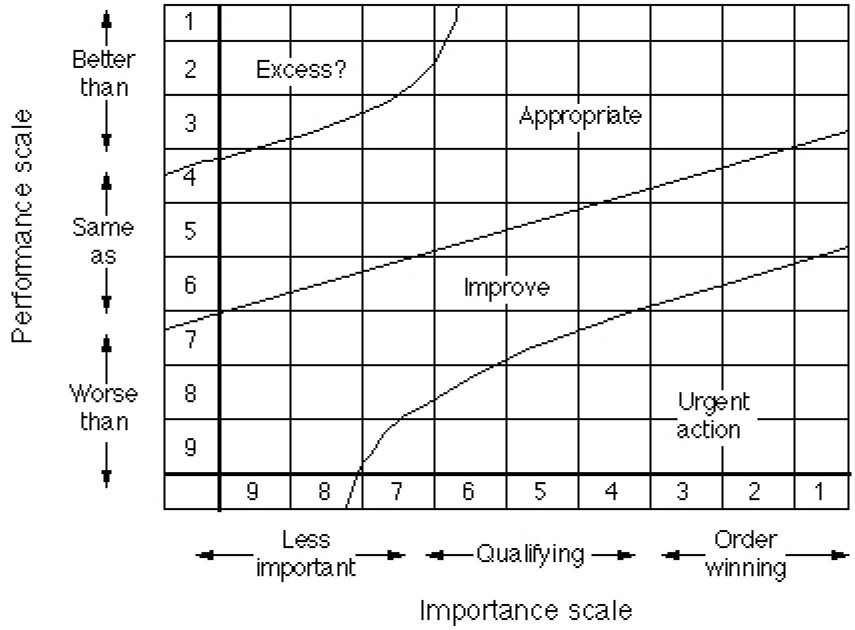
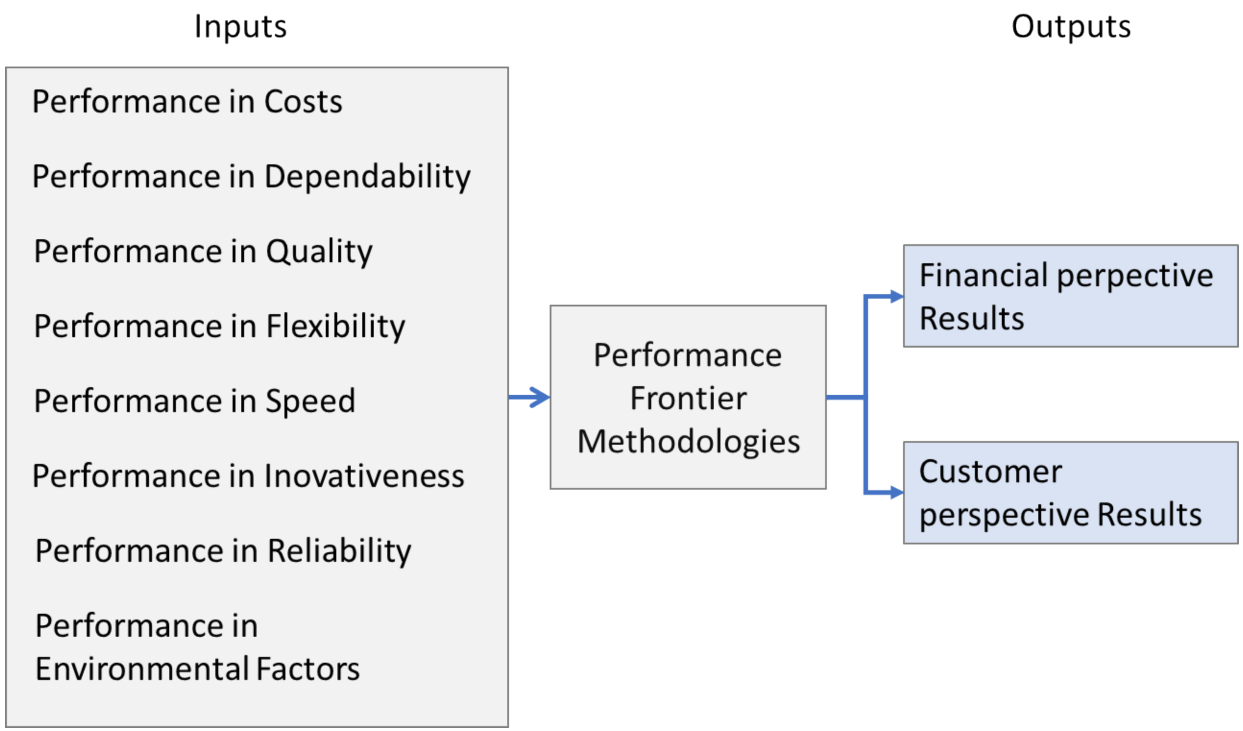


Figure 1 - importance and performance matrix (Slack et al., 2018

155x117mm (72 x 72 DPI)


Inputs
Outputs
Performance in Costs
Performance in Dependability
Performance in Quality
Performance in Flexibility
Performance in Speed
Performance in Inovativeness
Performance in Reliability
Performance in Environmental Factors
Performance Frontier Methodologies
Financial perpective Results
Customer perspective Results

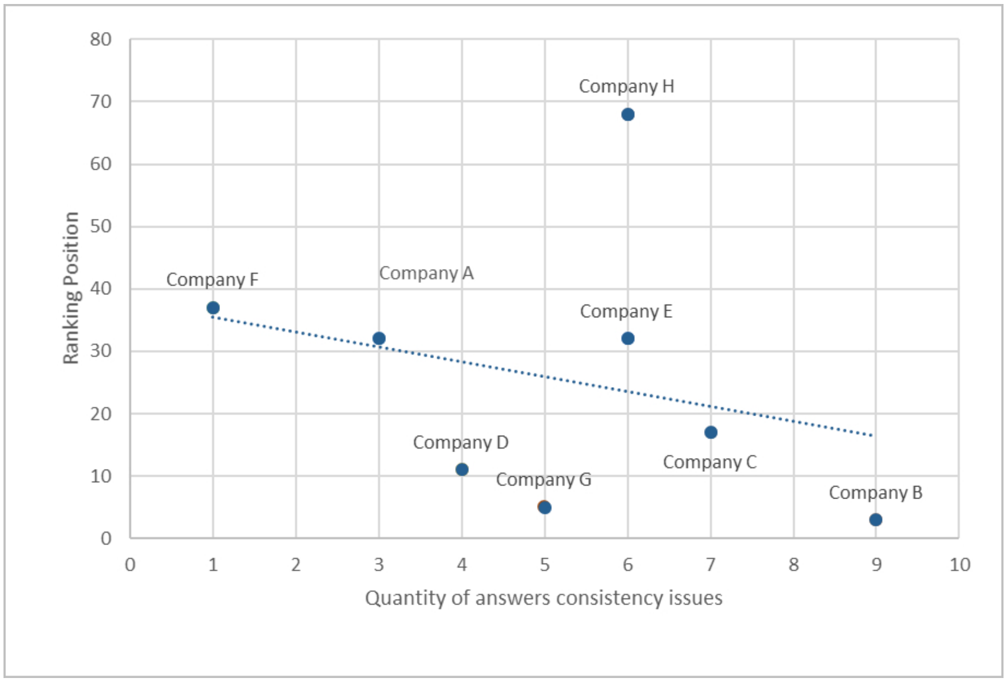


Figure 3 - scatter plot, ranking position x answer consistency

Appendix A: Survey to identify the Operations Strategy

Step 1: Operations Strategy Identification Collect operations strategy performance data		
Focused product line:		
Focused client vision:		
Please, considers the competitive criteria definition as follows		
Competitive Priority	**Definition**	
Costs	Offer products at lower costs than competitors or be cost-efficient. Costs are about the ability to optimize the utilization of manufacturing resources.	Slack and Lewis (2018), Lotfi and Saghiri (2018), Sansone et al. (2017).
Dependability	Fulfill the promises of deadline delivery. Besides on-time delivery, it also Includes delivery date estimation and communication.	Slack and Lewis (2018), Yusuf et al. (2014).
Environmental Factors	Items of the production process and product that interfere in the protection of the environment	Vivares-Vergara et al. (2016); Díaz-Garrido et al. (2011).
Flexibility	Have the capacity to adapt the operation whenever necessary and quickly enough, either by changes in demand or by needs of the production process. Cope with ever-changing market demands.	Slack and Lewis (2018), Slack and Brandon-Jones (2018), Asadi et al. (2017), Dey et al. (2019).
Innovativeness	Capacity to engaging in innovation, which in its turn is related to the introduction of a new process, products, and ideas in the organization	Hult et al. (2004), Laosirihongthong et al. (2014).
Quality	Offer products according to the design specifications.	Slack and Lewis (2018), Bernroider et al. (2014), Chen and Tan (2013).
Reliability	Quality of being trustworthy or of performing consistently well. Reliability is approached as a criterion detached from quality from some authors.	Slack et al. (1997). Narkhede (2017).
Speed	Deliver to the customer faster than competitors	Slack and Lewis (2018), Vázquez Bustelo et al. (2007)

Importance Scale

According to the Nine-point Importance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Order-winning objectives	1. Provide a crucial advantage with customers - they are the main thrust of competitiveness;
	2. Provide an important advantage with most customers - they are always considered by customers;
	3. Provide a useful advantage with most customers - they are usually considered by customers;
Qualifying objectives	4. Need to be at least up to good industry standard;
	5. Need to be around the median industry standard;
	6. Need to be within close range of the rest of the industry;
Less important objectives	7. Do not usually come into customers' consideration, but could become more important in the future;
	8. Very rarely come into customers' considerations;
	9. Never come into consideration by customers and are never likely to do so.

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

According to the Nine-point Performance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Better than competitors	1. Consistently considerably better than our nearest competitor;
	2. Consistently clearly better than our nearest competitor;
	3. Marginally better than our nearest competitor;
The same as competitors	4. Often marginally better than most competitors;
	5. About the same as most competitors;
	6. Often within striking distance of the main competitors;
Worse than competitors	7. Usually marginally worse than most competitors;
	8. Usually worse than most competitors;
	9. Consistently worse than most competitors?

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

Appendix B: Survey to identify the competitive criteria performance

Step 3: Frontier Identification
Collect input/output performance data

Fator/Variavel original	Question	1	2	3	4	5	People in Charge
	Question	Options					People in Charge
Manufacturing costs, including operating expense	Question	1	2	3	4	5	People in Charge
Manufacturing Costs	How do your plant's products compare to its leading competitors, on Product selling price?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Unit cost of manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Labor cost ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing costs - recently launched products	Question	1	2	3	4	5	People in Charge
Manufacturing costs - recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas? Unit manufacturing cost	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Manufacturing costs - recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors (Unit cost of manufacturing)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Dependability performance	Question	1	2	3	4	5	People in Charge
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: The promises that our plant makes to its customers are reliable.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Dependability performance	How does your plant compare with its competitors in its industry, on a global basis, on On-time delivery performance?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for punctual delivery	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Question	1	2	3	4	5	Respondent
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers select us because we deliver flexibly for their needs	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: We are selected by our customers because of our reputation for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Production system capacity of changing production mix and volume in the vision of the plant manager	Question	1	2	3	4	5	Respondent
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change product mixt ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change volume?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product customization	Question	1	2	3	4	5	Respondent
Product customization	Indicate the extent to which you agree or disagree with The statement: We are highly capable of large scale product customization.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can easily add significant product variety without increasing cost.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can customize products while maintaining high volume.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Speed performance	Question	1	2	3	4	5	Respondent
Speed performance	How do your plant's products compare to its leading competitors, on Fast delivery?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Speed of new product introduction into the plant (development lead time)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Agile manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Cycle time (from raw materials to delivery)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management

Quality performance compared to competitors	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Overall product quality perceived by customers?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Conformance to established standards?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Primary product performance characteristics?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Secondary options or features; characteristics that supplement the basic functioning of the product?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Aesthetics; how the product looks, feels, sounds, tastes or smells?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Serviceability; ease of repair?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors in recently launched products	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Conformance quality?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Performance (functionality)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Features?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Durability; amount of use before the product deteriorates or needs to be replaced?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Reliability of the product; probability of failure in a specified time?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Durability (life expectancy)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Reliability (time between failures)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Capacity of environmental practices positively influence other company's results'	Question	1	2	3	4	5	Respondent
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Being environmentally conscious can lead to substantial cost advantages for our plant.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can enter lucrative new markets by adopting environmental strategies.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can increase market share by making our current products more environmentally friendly.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Better environmental performance can differentiate our plant from our competitors.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Overall environmental performance	Question	1	2	3	4	5	Respondent
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Environmental performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Regulatory performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How does your plant compare to others in your global industry, in Overall environmental performance?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs

Process technology innovativeness	Question	1	2	3	4	5	Respondent
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We quickly adopt new technologies by applying what we learn from our customers.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We often fail to achieve the potential of new process technology.	Strongly agree	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Strongly disagree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: As new technologies emerge, we modify our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: There are no substitutes for our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our plant stays on the leading edge of new technology in our industry.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our current production technology is protected by patents.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Which term best describes the plant's posture toward new processes?	Never adopts new processes	Usually among the last to adopt new processes	Adopts new processes when it becomes more or less the general rule	Among the first to adopt new process, but not the leader	Leader in new processes	Process Engineering
Equipment technology innovativeness	Question	1	2	3	4	5	Respondent
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We frequently modify equipment to meet our specific needs.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We produce a substantial amount of our equipment in-house.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: In order to improve equipment performance, we sometimes redesign equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We actively develop proprietary equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product innovativeness	Question	1	2	3	4	5	Respondent
Product innovativeness	How does your plant compare with its competitors in its industry, on a global basis, on Product innovativeness?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product innovativeness	Which term best describes the plant's posture toward new products?	Never adopts new products	Among the last to adopt new products	Adopts new products when it becomes more or less the general rule	Among the first to adopt new products, but not the leader	Leader in new products	Product Development
Throughput: the rate at which the plant generates money through sales	Question	1	2	3	4	5	Respondent
Financial Performance	How does your plant compare with its competitors in its industry, on a global basis, on Throughput: the rate at which the plant generates money through sales?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Plant Management
Market Share and customer satisfaction on recently launched products	Question	1	2	3	4	5	Respondent
Market Share and customer satisfaction on recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Customer satisfaction?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Customer satisfaction	Question	1	2	3	4	5	Respondent
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our plant satisfies or exceeds the requirements and expectations of our customers.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers are pleased with the products and services we provide for them.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers have been well satisfied with the quality of our products, over the past three years.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers seem happy with our responsiveness to their problems.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management

Appendix A–7 Research Paper 7

Title: A Procedure for assessing and improving operations strategy.

Journal: Production Planning and Control

A procedure for assessing and improving operations strategy

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Keywords:	operations strategy, procedural framework, data envelopment analysis, benchmarking

A procedure for assessing and improving operations strategy

This paper aims to describe a procedural framework for identifying the operations strategy efficiency frontier, and, from this, determinate initiatives to improve the competitive position for a given company. Each of the framework steps is presented in an explicative manner, including the recommendation about how the results should be interpreted. Empirical data is used to exemplify the procedural framework implementation. The process contributes to knowing the up to date needs, supporting agile decision making. The contribution also befalls on enabling the mapping of the competitive environment in a dynamic manner, allowing an up to date picture of the industry competitive context and support the establishment of emergent strategies. Two literature gaps are covered, first the lack of focus on the process to identify the performance frontier in the context of operations strategy. Second, the exploitation of the competitive priorities in a market-based view approach.

Keywords - operations strategy, procedural framework, data envelopment analysis, benchmarking.

Introduction

Many firms, no matter how large or small, are increasingly confronted with external environmental turbulence and complexity, in this scenario how to properly adopt strategic choices in response to environmental uncertainty has become a great challenge (Okoshi et al., 2019, Narkhede, 2017, Machado et al., 2017). The changes in technology and customer expectations, which are increasingly common, are responsible for generating a complex and dynamic competitive environment (Samoilenko and Osei-Bryson, 2012, Soosay et al., 2016). Lotfi and Saghiri (2018) defend that the unpredictable changes that the business environment is facing in the last two decades, generate a risk of unexpected disruptions which can result in poorer operational and financial performance outcomes.

Due to the operational and managerial difficulties, it is challenging to develop an operations strategy to compete on a global basis. In this situation, is even more important to use the resources effectively. The firm frontier identification, which is a concept already known in the literature, can be used to boost the results in the operations function. To Liu et al. (2018) efficiency frontier methodologies allow the examination of performance in operational processes and help organizations to test their assumptions about performance, productivity, and efficiency in operations decisions. According to Cai and Yang (2014), the extent to which a company must emphasize a competitive priority depends on its asset and operating frontier. To Hill and Hill (2018) companies need to be aware of the relevant order-winners and qualifiers and the size of the gap in this criterion, as well as the investment, to close this gap. Measuring operational performance promotes managers' awareness of the efficiencies of their operations strategies, enabling accurate strategic and operational decisions to increase performance (Abbasi and Kaviani, 2016).

While efficiency in operations strategy is critical to competitive success, as observed by Narkhede (2017), there exist research gaps from perspectives of operations strategy performance and efficiency frontier analysis. First, a lack of focus on the procedure to identify the performance frontier in the context of operations strategy is found. Additionally, performance frontier methodologies are applied to operations strategy with a focus on RBV and capabilities approach (e.g. Ramanathan et al., 2016; Yu et al., 2014; Nath et al., 2010; Ahmed, et al., 2014). The market-based concept of competitive priorities, as presented in the seminal works of Caves and Porter (1977) and Porter, (1979), is not fully explored.

The lack of the exploitation of the competitive criteria to study operations strategy efficiency is a gap since the literature on manufacturing strategy shows that strategic alignment of competitive priorities to business strategy improves the business performance of the manufacturing organization. To Okoshi et al. (2019) and Phusavat and Kanchana (2008), the appropriate choice of competitive priorities reflects on the future direction of a firm and has fundamental importance to the achievement of its competitive advantage which may lead to business performance improvement.

Our research objective is to present a detailed procedure to conduct and analyze the performance frontier identification within the context of operations strategy. We apply a Data Envelopment Analysis (DEA) model to assess operations strategy of the automotive suppliers' industry, using data from the High-Performance Manufacturing Project. The procedure allows the assessment of the company's operations strategy in a dynamic way, which can enable the companies to know the most current needs, helping them to stay in a prominent competitive position. To Samoilenko and Osei-Bryson (2012) in the current dynamic competitive environments, a static model to describe the relation of inputs and outputs will have limited use and feasibility in periods of instability. Ahmed et al. (2014) defend that efficiency scores should be updated periodically, increasing the relevance of the existence of a process. A process for the frontier estimation in the context of operations strategy can provide to managers important information for a more accurate and agile decision making to the development of emerging strategies

After a brief introduction of current empirical research and the foundation of the DEA technique, the proposed procedural framework is presented, and them, each of its steps implementation is explained, including the recommendation about how the results should be interpreted. The guideline to analyze the result was developed through the lessons learned from eight cases of implementation (Veiga et al., 2019b). Empirical data from various cases is used to exemplify the procedural framework steps implementation.

Relevant Empirical Research

There is a literature that integrates the concept of operations strategy to firm production frontier. Several authors use the resource-based view (RBV) concept as background for performance frontier study, since its theory link superior performance to firm resources and capabilities. Capabilities are the ability of a company to transform a set of inputs (resources) into certain outputs (objectives) for sustainable advantage (Akdeniz et al, 2010; Dutta et al., 2005; Ahmed et al., 2014). The RBV designates how an individual firm's resources (e.g. tangible and intangible assets and organizational capabilities) affect its financial performance (Barney, 1991; Wernerfelt, 1984; Peteraf, 1993, Prahalad and Hamel, 1990).

Dutta et al. (2005) exemplify the measurement of R&D capabilities in the semiconductor and computer equipment industries. Akdeniz et al. (2010) work discuss benchmarking marketing capabilities as a source of sustainable advantage. Hemmati et al. (2014) develop a framework based on RBV and dynamic capabilities theory. Specifically, strategic agility is used as a dynamic capability. There are papers that focus on marketing and operations capabilities (Nath et al., 2010; Yu et al., 2014; Ahmed et al., 2014; Ramanathan et al. 2016). Ahmed et al. (2014) look at how the impact of attributed importance given to operations and marketing function impacts capabilities and consequently, firm performance. Also, explore capabilities behavior in different economic conditions. Yu et al. (2014) also look at financial performance and investigate the relationship between marketing capabilities, operational capabilities and financial performance within retail UK firms. Similarly, Nath et al. (2010) seek to identify the impact of functional marketing and operations capabilities and diversification strategies on the organization's financial results. Ramanathan et al. (2016) include environmental capability and diversification strategy to the study.

Another stream of empirical literature looks at evaluating the contribution of specifics elements to production efficiency. Chang et al. (2015) approach the relationship between strategic positioning - cost leadership and differentiation - and production efficiency. Jayanthi et al. (1999) presented a conceptual framework that identifies and classifies the competitiveness drivers in structural terms (e.g. plant size, capacity, age of equipment, etc.) and infrastructural ones (e.g. policies, the introduction of new products, variety of products, etc.). Seol et al. (2013) use DEA as a foundation to identify new business opportunities, based on the assessment of the technological strength of firms among potential business opportunities.

Other authors approach the concept of operations strategy and analysis of the performance frontier in more specific contexts. Achillas et al. (2015) work within the field of additive manufacturing, in which the objective is to propose a methodological model that combines multi-criteria decision aid (MCDA) and DEA for determining the optimum operations strategy aligned to focused factory concept. Nevo et al. (2007) compare the impact of internal and external IT capabilities on productivity. Jacobs et al. (2016) examine the relationship between operational productivity, corporate social performance, financial performance, and risk. Mahmood et al. (2011) study how the type of ties between businesses can affect the development of capabilities, specifically research and development.

The market-based view (MBV) orientation is less explored within performance frontier studies. Abassi and Kaviani (2016), Bulak et al. (2016) and Cai and Yang (2014) are an example of the few pieces of research that are market-oriented, exploring the concept of competitive priorities. Abassi and Kaviani (2016) seek to propose a performance assessment framework for evaluating and ranking the organizations based on the effectiveness of their operations strategies. To do so, input variables are the operations strategy performance objectives or competitive priorities. While the output variables include financial indicators as ROA and ROI and non-financial indicators as market share. Bulak et al. (2016) measure and assess the efficiency of Turkey's electrical small and medium machinery manufacturing. The study's aim is to determinate whether competitive priorities, defined as inputs, maximizes firm performance, or outputs. Cai and Yang (2014) seek to explore the link between business environment and competitive priorities which are based on manufacturing strategy concept.

Even exploring the MBV concept, these works don't translate the frontier studies into recommendations to improve the aimed company competitive position, from a procedural perspective. Bulak and Turkyilmaz (2014) come closer to this proposal, working with competitive priorities to identify the improvement opportunities to operations strategy. However, the authors set the gaps concerning the minimization of the inputs, not allowing the establishment of improvement recommendations. Also, their work doesn't connect the operations strategy positioning of the aimed companies within the performance frontier study.

In doing so, the focus on competitive criteria streams to evaluate and improve the operations strategy of a given company detaches the proposed framework from existing literature. The MBV vies of operations strategy is the explored approach in the proposed procedural framework. This concept is next explored.

Market-based View approach to Operations strategy

The MBV has its foundation of Porter's structural studies on competitive strategy (Caves and Porter, 1977; Porter, 1979). At the MBV approach, companies proactively identify where market advantage could be gained by outperforming the current norms on the relevant market drivers and then allocating resources to this end (Hill and Hill, 2018). To Soosay et al. (2016) MBV has the strategic plan defined from an assessment of the market trends and its potential evolution. To Hult et al. (2004), market orientation is related to concern for markets that should be part of the organizational culture, with a market orientation are likely to develop and adapt products, services, and processes that to meet continuously the market needs.

The concept of competitive priorities could translate customer demands into manufacturing objectives, enabling the MBV approach. The traditional competitive priorities embrace quality, costs, speed, dependability, and flexibility as listed by Slack and Lewis (2018). Beyond that, other criteria have been recently approached by the literature due to the current dynamic context. Innovativeness is recognized as a new competitive priority to compete in global markets (Laosirihongthong et al., 2014; Hult et al., 2004; Bouranta and Psomas, 2016). To Hult et al. (2004) and Pallas et al. (2013) innovativeness is a competitive priority with the rising importance since it contributes to the opening of new markets or expands existing ones, which is of primary importance in the environment of ascending competition. Reliability is approached as a criterion detached from quality from some authors. Narkhede (2017) indicates that reliability is an important approach, being explored by various authors on manufacturing practices. Environmental is also bringing this priority together with the classical competitive priorities (Wang, 2019; Díaz-Garrido et al., 2011; Voon-Hsien Lee et al., 2015; Vivares-Vergara et al., 2016). According to Gavronski (2012), environmental performance is a key part of the sustainability definition, which demonstrates as being an important competitive dimension nowadays. Elkington (1997), frame sustainability as encompassing environmental, social, and economic aspects, which could lead to a new definition of value proposition for companies.

Data envelopment Analysis

According to Khezrimotlagh and Chen (018, the production function or production frontier gives the maximum possible values of the output factors from a set of input factors. The firm production frontier discussion was first placed by Farrel (1957) with the publication of the seminal paper "The measurement of productive efficiency" in the Journal of Royal Statistical Society. The frontier is estimated based on the observation population of the company's inputs and outputs or a representative sample (Chen et al., 2015). It is a ratio between outputs and inputs. Results smaller than '1,0' represent inefficient firms, as commented by Bulak et al. (2016).

The DEA is a non-parametric method to calculate technical efficiency (Cooper and Rhodes, 1978, Banker et al., 1984). At DEA, the production frontier is obtained through a mathematical optimization model based on linear programming that provides comparative results to assess the performance of organizations based on multiple metrics (Bulak et al., 2014). It can be considered a technique that aims to compare the operational performance of production units. It is a measure of relative efficiency, as it considers the presented data, therefore, it is not possible to determine an absolute efficiency, outside the group of analysis (Golany and Roll, 1989).

The DEA aims to measure the efficiency of a decision-making unit (DMU). Any group of entities that receive the same inputs and produce the same outputs could be designated as DMU (e.g., a firm). The group of analysis must include a homogeneous set of DMUs, where comparison makes sense. A homogeneous group is one where: the units under consideration perform the same tasks and have similar objectives; all the units are under the same set of 'market conditions' and the inputs and outputs are the same (Golany and Roll, 1989). Additionally, the bigger the size, the better the investigation of the inputs and outputs relation. A rule is that the quantity of DMU should be at least two times higher than the considered number of input and output variables (Golany and Roll, 1989). Another rule is the Golden Rule of Banker et al. (1989), which state that the number of DMUs should be at least three times the sum of the number of involved variables (inputs and outputs) or at least equal to the product of the number of input variables and the number of output variables, adopting the criterion associated to the greater number of required DMU.

Some authors indicate that a weak point of the DEA is that a considerable number of units typically are characterized as efficient. Therefore, DEA does not allow a ranking of the efficient units by themselves (Esmaeilzadeh and Hadi-Vencheh, 2015; Kao, 2017; Bogetoft and Otto, 2011). The Anderson and Petersen (1993) model presents the most popular concept to rank DMU, called super-efficiency, helping them to discriminate between firms' frontier. The authors propose is to eliminate the focal DMU to construct the frontier from the remaining (n-1) DMU to calculate the supper-efficiency index (Kao, 2017). This method enables the ranking of efficient DMU. Indeed, using "supper-efficiency" is interesting to differentiating among the firms with traditional efficiency scores of '1.0' (Bogetoft and Otto, 2011).

Database

The DEA is the approach used to this benchmarking study and requires data to represent the competitive environment. In this research, such data considers the fourth round of the HPM project. The HPM project seeks to identify the practices adopted by high-performance organizations and applies a survey with companies in 14 various countries. The survey includes 1597 questions answered by different people inside the organization. The HPM includes machinery manufacturers, vehicle component manufacturers and electronics manufacturers companies with at least 100 employees (Flynn et al., 1997). The 4th round was realized between 2012 and 2018 (Park and Paiva, 2018; Phan et al., 2019).

A screening process was promoted to select variables that represent the studied purpose. Semantic analysis, exclusion of variables with missing data and principal component analysis are used in the process of defining variables and the conceptual model construction (Veiga et al., 2019a; Nataraja and Johnson, 2011; Hair et al., 2009; Fabrigar et al., 1999; Ueda and Hoshiai, 1997). As a result, eight competitive priorities were represented by 16 variables, and two output results, by three variables. Table 1 demonstrates the descriptive statistics of those variables. Data from 77 DMUs from 14 countries are used to identify the automotive companies' performance.

Table 1. Competitive environment data

Category	Factor or not observed variable	N	Mean	Median	Std Deviation
Input variables					
Costs	COS_F1: Manufacturing costs, including operating expense	77	3.22	3.09	0.70
	COS_F2: Costumer vision about company costs	77	3.06	3.00	0.72
Dependability	DEP_F1: Dependability performance	77	4.06	4.05	0.65
Environmental factors	ENV_F1: Capacity of environmental practices positively influence other company's results	77	3.41	3.39	0.79
	ENV_F2: Overall environmental performance	77	4.11	4.04	0.58
Flexibility	FLE_F1: Costumer vision about company flexibility	77	3.89	3.85	0.63
	FLE_F2: Production system capacity of changing production mix and volume	77	3.82	3.99	0.71
	FLE_F3: Product customization	77	3.47	3.55	0.78
Innovativeness	INO_F1: Process technology innovativeness	77	3.24	3.21	0.51
	INO_F2: Equipment technology innovativeness	77	3.55	3.70	0.69
	INO_F3: Product innovativeness	77	3.86	3.80	0.66
Quality	QUA_F1: Quality performance compared to competitors	77	3.76	3.79	0.51
	QUA_F2: Quality performance compared to competitors in recently launched products	77	3.89	3.83	0.53
Reliability	RE_F1: Reliability performance compared to competitors in recently launched products	77	3.80	3.75	0.61
	RE_F2: Reliability performance compared to competitors – quality management vision'	77	3.83	3.82	0.66
Speed	SPE_F1: Speed performance	77	3.65	3.47	0.65
Output variables					
Client	CLI_F1: Market Share and customer satisfaction on recently launched products	77	3.61	3.56	0.72
	CLI_F2: Customer satisfaction	77	3.94	3.92	0.63
Financial	FIN_F1: Throughput: the rate at which the plant generates money through sales	77	3.60	3.55	0.86

The availability of reliable data is an important assumption for this research. The procedural framework next presented, consume this data to assess and to improve the operations strategy efficiency.

Procedural Framework

A five-step procedural framework, shown in Figure 1, is developed to establish the sequence to perform and analyze the results of frontier studies within the context of the operations strategy.

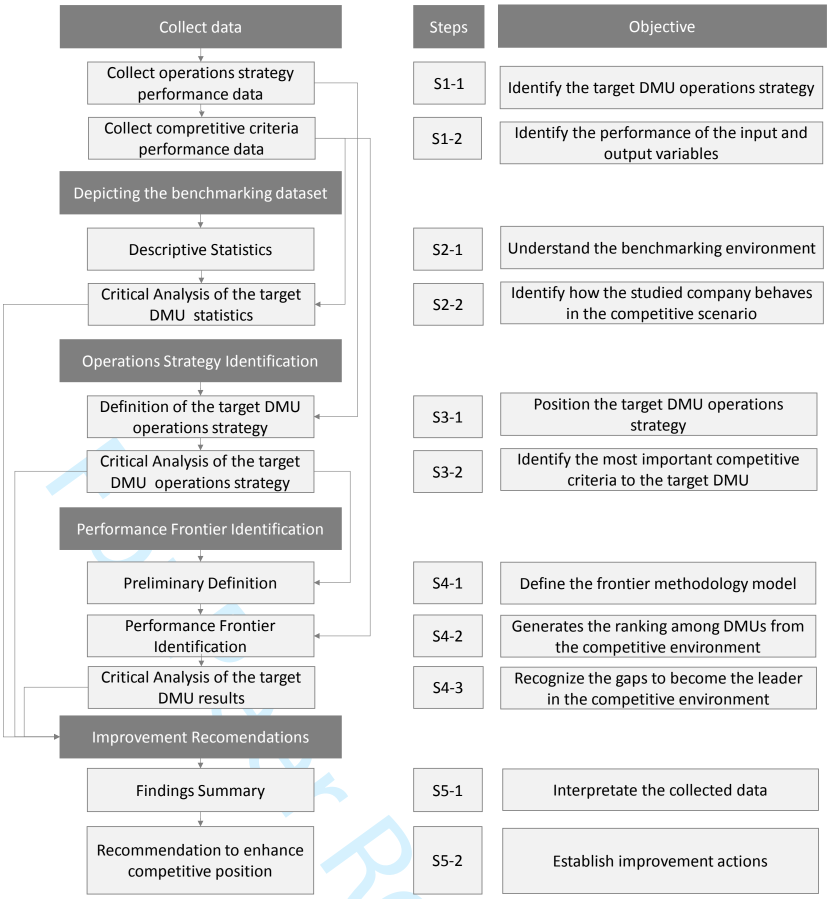

Figure 1. Procedural framework

The framework demonstrates the steps in the sequence they must be performed, and the arrows indicate the relation between them. The operations strategy data, collected in the target DMU (S1-1), is later used to define its operations strategy positioning (S3-1). The step S3-1 in its turn allows the definition of the interest variables for the target DMU (S4-1). The competitive priority data collected in the target DMU (S1-2) is used first to compare the target DMU performance with the benchmarking dataset in the S2-2 and second, to perform the supper-efficiency estimation (S4-2). All steps feed the definition of improvement recommendation. Each of the steps is next detailed, including the recommended analysis procedure. The procedural framework was implemented in eight cases, whereas the first was the pilot, to refining the procedure, and the next seven to test the procedure. One example is provided to help the understanding of the framework, the given examples are not interconnected, as each step has an example for a different case of implementation. However, the focus is not to understand the studied company performance, but the framework steps as well the analysis enabled for its implementation. The exploration of the content can be found in Veiga et al. (2019b).

Collect Data

As this study refers to the integration of two concepts, operations strategy and firm performance frontier, the data collection is made in two fronts. First, data to identify the operations strategy is required. Next, the performance in the studied competitive criteria needs to be framed. In doing so, two questionnaires are proposed. Both have to be answered by at least six people in the company: plant manager, downstream supply chain management, process engineering, product development, quality management, and environmental affairs.

The first questionnaire, of step S1-1, is based on the importance and performance matrix that allows the recognition of the relative importance of each of the manufacturing performance objectives according to clients' priorities, which should be aligned to manufacturing priorities. The matrix allows the assessment of the present performance achieved by the production function by comparing the performance of the organization with that of the competition. Therefore, it is possible to recognize the gaps between what is important to the operation and what performance is being achieved by classifying it into four zones. Identifying this gap provides the direction of choices and implementation of improvement plans (Slack et al., 2018). A nine points scale, presented in Table 2, is used to evaluate each of the competitive priorities, concerning the importance and the performance. All the respondents should promote this evaluation. The full worksheet can be found in appendix A.

Table 2. Operations strategy questionnaire scale

Importance Scale	Performance Scale
Order-winning objectives	*Better than competitors*
1. Provide a crucial advantage with customers - they are the main thrust of competitiveness;	1. Consistently considerably better than our nearest competitor;
2. Provide an important advantage with most customers - they are always considered by customers;	2. Consistently clearly better than our nearest competitor;
3. Provide a useful advantage with most customers - they are usually considered by customers;	3. Marginally better than our nearest competitor;
Qualifying objectives	*The same as competitors*
4. Need to be at least up to good industry standard;	4. Often marginally better than most competitors;
5. Need to be around the median industry standard;	5. About the same as most competitors;
6. Need to be within close range of the rest of the industry;	6. Often within striking distance of the main competitors;
Less important objectives	*Worse than competitors*
7. Do not usually come into customers' consideration, but could become more important in the future;	7. Usually marginally worse than most competitors;
8. Very rarely come into customers' considerations;	8. Usually worse than most competitors;
9. Never come into consideration by customers and are never likely to do so.	9. Consistently worse than most competitors?

Source: Slack et al., 2018

The questions of the second questionnaire, of step S1-2, derivate from the 4th round of the HPM Project. A five-point Likert scale guides the answers, whereas the bigger the response index, the best. The scale content depends on the question and the questionnaire can be found in Appendix B. Each of the six respondents has a set of questions based on their whole in the studied company.

Depicting the benchmarking dataset

This step aims to understand the competitive environment represented by the benchmarking data, and, from this, to identify how the studied company behaves in comparison with the competitors. The descriptive statistics (S2-1) was previously presented. By looking at the average performance of the benchmarked DMUs, it is possible to recognize the sector standard, e.g. in what variables the sector performs well and what are the critical ones. The studied automotive sector is good at overall environmental performance and dependability performance. On the other hand, it faces some issues about costs and process technology innovativeness.

In the S2-2, the studied company is compared with the average performance of the competitive data, to recognize detaching and poor performance. The variables are measured in 5 points Likert scale, whereas the bigger, the best. The analysis procedure calculates the gap from the target DMU performance and the average performance of benchmarking data. Gaps bigger than 20% should be brought to managerial attention. Positive values mean that the target company performs better than the sector average, likewise, negative values represent that the studied DMU is worse than the sector average. Table 3 shows an example of this analysis in a given company.

Table 3. Example of S2-S result

Factor or not observed variable	Sector Average	Target DMU	Gap	% Gap	Status
COS_F1: Manufacturing costs, including operating expense	3.29	2.98	-0.31	-10%	worse than the sector average
COS_F2: Manufacturing costs - recently launched products	2.99	2.00	-0.99	-50%*	worse than the sector average
DEP_F1: Dependability performance	4.06	5.00	0.94	19%	better than the sector average
ENV_F1: Capacity of environmental practices positively influence other company's results	3.41	3.47	0.07	2%	better than the sector average
ENV_F2: Overall environmental performance	4.11	4.66	0.54	12%	better than the sector average
FLE_F1: Costumer vision about company flexibility	3.89	5.00	1.11	22%	better than the sector average
FLE_F2: Production system capacity of changing production mix and volume	3.82	3.51	-0.32	-9%	worse than the sector average
FLE_F3: Product customization	3.47	4.26	0.79	18%	better than the sector average
INO_F1: Process technology innovativeness	3.24	3.86	0.61	16%	better than the sector average
INO_F2: Equipment technology innovativeness	3.55	3.25	-0.30	-9%	worse than the sector average
INO_F3: Product innovativeness	3.86	3.00	-0.86	-29%*	worse than the sector average
QUA_F1: Quality performance compared to competitors	3.76	4.33	0.57	13%	better than the sector average
QUA_F2: Quality performance compared to competitors in recently launched products	3.89	3.71	-0.19	-5%	worse than the sector average
RE_F1: Reliability performance compared to competitors in recently launched products	3.80	4.50	0.71	16%	better than the sector average
RE_F2: Reliability performance compared to competitors – quality management vision'	3.83	3.50	-0.33	-9%	worse than the sector average
SPE_F1: Speed performance	3.65	2.99	-0.66	-22%*	worse than the sector average
CLI_F1: Market Share and customer satisfaction on recently launched products	3.61	5.00	1.39	28%	better than the sector average
CLI_F2: Customer satisfaction	3.94	4.00	0.06	2%	better than the sector average
FIN_F1: Throughput: the rate at which the plant generates money through sales	3.60	3.00	-0.60	-20%*	worse than the sector average

* critical results, worse than the established guideline

It is possible to recognize that the target DMU is performing better than the sector average in 8 of the input variables. To FLE_F1 the target DMU exceeds in more than 20% the industry average. On the other hand, the target DMU is performing worse than the sector average in the other 8 input variables. Whereas in two of those, the target DMU is more than 20% weak than the industry average, they are COS_F2, INO_F3, and SPE_F1.

Looking at the output, the target DMU is better positioned than the sector average to all of the client variables, exceeding in more than 20% the performance of variable CLI_F1. The studied company performs 20% worse than the sector average to FIN_F1.

Operations Strategy Identification

A detaching point of the proposed framework is being contextual driven, that is, the performance frontier analysis is developed to the variables that are important to the studied company. Therefore, each of the studied companies will have a particular frontier analysis method. The identification of the important variables is promoted through the recognition of the target company operations strategy (S3-1), by using the performance and importance matrix concept. Once the respondents have attributed the importance and performance index for each of the competitive priorities, the researcher should first evaluate the answers average and the standard deviation to each competitive criterion to both, importance and performance criteria. This is the first analysis made in S3-2. The guideline is that a standard deviation smaller than 1.5 represents a good answer standard. Table 4 presents the classification of the operations strategy and the standard deviation rate.

Table 4. Example of S3-1 and S3-2 result

Competitive Criteria	Average Importance	Standard Deviation	Classification	Average Performance	Standard Deviation	Classification
Costs	1.6	0.89	Oder-winning	4.4	2.41*	The same as competitors
Dependability	2.4	1.52*	Oder-winning	3.0	1.22	Better than competitors
Environmental Factors	4.8	1.30	Qualifying	3.2	1.64*	Better than competitors
Flexibility	3.6	1.82*	Oder-winning	4.4	1.82*	The same as competitors
Innovativeness	4.0	1.87*	Qualifying	2.8	1.30	Better than competitors
Quality	2.6	1.14	Oder-winning	3.8	1.10	Better than competitors
Reliability	2.6	0.89	Oder-winning	3.0	1.22	Better than competitors
Speed	3.2	1.10	Oder-winning	4.0	2.12*	The same as competitors

* worse than the target

It is important to emphasize that the result is based on an opinion survey, and the answers can vary according to the participant's background. Even so, similar answers demonstrate the existence of a shared understanding of the company's strategic positioning. To the company in this example, the respondents demonstrated distinct perceptions regarding the importance attached by customers on the competitive criteria. This behavior occurred mainly for 'dependability', 'flexibility' and 'innovativeness'. The lack of consensus among the managerial team may represent an improvement opportunity in understanding market requirements.

Looking at the performance, it is possible to recognize a smaller shared vision. Four criteria presented a standard deviation bigger than 1.5 (costs, environmental factors, flexibility, and speed). From this, it is recommended the promotion of a shared understanding of how the company behaves concerning critical performance criteria.

The average classification of both, performance and importance, allow the chart a radar graph to easily recognize if business performance is consistent with customer expectations, the second analysis of S3-2. An example is provided in Figure 2.

Figure 2. Example of S3-2 (second analysis) results – radar graph

From the graphic, it is possible to identify that most of the criteria have their performance marginally distant from importance. To costs criterion, the difference is more significant. Cost is important to customers (classification of 1.60 – provide an important advantage with most customers), but the company performance is not consistent with this importance (classification about 4.40 – about the same as most competitors). Two criteria have their performance with a better index than their importance. 'Environmental factors' criterion is considered a Qualifying objective (punctuation of 4.8 - need to be around the median industry standard); however, the studied company performance is 3.20 (marginally better than our nearest competitor). 'Innovativeness' received an importance index of 4.00 (need to be at least up to good industry standard) and has its performance with the punctuation of 2.80 (marginally better than our nearest competitor). The company should analyze whether the resources devoted to achieving such a performance could be used elsewhere or in fact, this outperformance is part of the company's strategic positioning.

The zone interpretation lets for the definition of priority to establish improvement actions. The results should be classified in the matrix, where the axis x is the importance assessment and the axis y the performance ones. The matrix allows the recognition of the relative importance of each of the manufacturing performance objectives according to the clients' priorities, which should be the manufacturing priorities. On the other hand, the matrix also promotes the assessment of the actual performance achieved by the production function by comparing the performance of the organization with that of the competitors. Therefore, it is possible to recognize the gaps between what is important to the operation (based on the client's perspective) and what performance is being achieved by classifying it into four zones. Identifying this gap provides the direction of choices and implementation of improvement plans.

The guideline indicates that an urgent action zone requires improvement in the performance since the criterion is at least qualifying for customers and the performance of the company is poor. The Improve action embraces the candidates for improvement since the performance is lower than the competitor in less relevant criteria or is the same as the competitor is relevant criteria. The appropriate zone, in turn, contains the satisfactory criteria. And the Excess zone includes criteria with high performance, but not particularly important. The company should analyze whether the resources devoted to achieving such a performance could be used elsewhere. Figure 3 provides an example.

Figure 3. Example of S3-2 (second analysis) results – zone interpretation

For the given company, most of the criteria are in the 'appropriate zone'. Cost is in the 'improve zone' since this criterion is order-winning and has its performance at the same level as competitors. The 'improve zone' covers the relevant improvement objectives but does not represent urgent cases. The 'flexibility' and 'quality' criteria are in the 'appropriate zone'; however, they are both closer to the 'improvement zone'. 'Environmental factors' and 'innovativeness' are the criteria closer to the excess zone, but the still being in the 'appropriate zone'.

Performance Frontier Identification

To perform the frontier identification, first, the frontier model must be specified (S4-1). At first, the DMUs under analysis should be defined. It is required homogeneity in terms of the period of analysis, type of business, and the number of employees. The definition of the variables is also a preliminary step. In the proposed framework, the input variables include the order winning criteria identified in the foregoing step, since the objective of the model is to provide a benchmarking relative to the aimed DMU operations strategy, being context-driven or context-dependent.

The number of DMUs that composes the benchmarking data should be higher enough to work with the required variables for the aimed company. The procedural framework uses the most demanding approach between Banker et al. (1989) and Golany and Roll (1989).

The performance frontier is implemented through the super-efficiency DEA with variable return to scale (VRS), the dual model with input orientation, calculates the efficiency. The preliminary frontier model definition worksheet is presented in Figure 4.

Step 4: Frontier Identification
Preliminary Definition Worksheet

DMU selection

Frontier analysis method choice

Data Envelopment Analysis with variable return to scale and output orientation

Definition of the input and outputs variables

Select the variables that you are interested in benchmarking. The order winning criterias should be selected.

Input Variables Selection			Input Variables Selection		
Quality			Flexibility		
	QUA_F1	Quality performance compared to competitors		FLE_F1	Costumer vision about company flexibility
	QUA_F2	Quality performance compared to competitors in recently launched products		FLE_F2	Production system capacity of changing production mix and volume in the vision of the plant manager
				FLE_F3	Product customization
Costs			Reliability		
	COS_F1	Manufacturing costs, including operating expense		RE_F1	Reliability performance compared to competitors in recently launched products
	COS_F2	Costumer vision about company costs		RE_F2	Reliability performance compared to competitors – quality management vision'
Dependability			Speed		
	DEP_F1	Dependability performance		SPE_F1	Speed performance
Innovativeness					
	INO_F1	Process technology innovativeness	Output Variables Selection		
	INO_F2	Equipment technology innovativeness	Financial perpective Results		
	INO_F3	Product innovativeness		F1_FIN	Throughput: the rate at which the plant generates money through sales
Environmental Factors			Client perspective Results		
	ENV_F1	Capacity of environmental practices positively influence other company's results'		CLI_F1	Market Share and customer satisfaction on recently launched products
	ENV_F2	Overall environmental performance		CLI_F2	Customer satisfaction

Definition of the miminum required sample size

Input the number of selected input and outout variables, to see the minimum requires sample size to allow the DEA.

	Number of inputs variables (ki)	ki*ko	0	According to Golany and Roll (1989)
	Number of outputs variables (ko)	(ki+ko)*3	0	According to Banker et. al (1989)

The recommended sample size is:
0 DMUs data

Figure 4. S4-1 worksheet

To the study that is being exemplified, the benchmarking data encompasses automotive companies with 100 or more employees, considering the 4th round of the HPM database. The number of variables varies according to the quantity of order winning criteria in the target DMU. But even performing with all of the 16 initial variables and the 3 output variables, the minimum required sample size is 57 DMUs data. The HPM database counts with a sample size of 77 companies, attending this requirement. Taking a given studied company, the order winning criteria are costs, dependability, flexibility, quality, and reliability, establishing the DEA model presented in Figure 5.

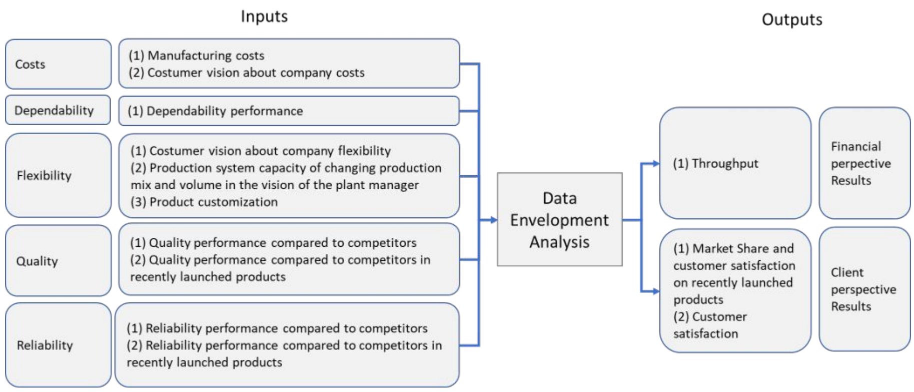

Figure 5. Example of a DEA model (S4-1)

With the formulation 1, of the SDEA (super-efficiency DEA) VRS dual model with input orientation, the efficiency is calculated in the S4-2.

Minimize θ (1)

(θ, λ)

Subject to:

$$\theta\, x_{io} - \sum_{k=1, k\neq 0}^{n} \lambda_k x_{ik} \geq 0; \forall i \qquad i = 1,2,\ldots,r$$

$$\sum_{k=1, k\neq 0}^{n} \lambda_k y_{mk} - y_{mo} \geq 0; \forall m \qquad m = 1,2,\ldots,s$$

$$\sum_{k=1, k\neq 0}^{n} y_k = 1$$

Where: y is the outputs, x is the inputs, λ the weighs. The decision variables are θ (scalar) and λ (weighs).

To perform the linear programming, it is necessary to invert the results of the input variables, using least squares formula, since the linear programming recognizes that the smaller the inputs, the best. The result generates a ranking of the supper-efficiency model. The target company is positioned in the seventeenth position. The index means that 1304, which has a supper-efficiency index of 2.99 is better than the ones with lower scores because the former is further ahead of its peers. Table 5 shows the ranking for a studied DMU, an example of the S4-2 results.

Table 5. Example of S4-2 results

Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency
1	1304	2.999	27	1719	1.000	53	1310	0.678
2	922	2.513	28	1716	1.000	54	101	0.673
3	1924	2.331	29	1809	0.996	55	606	0.669
4	1909	2.021	30	315	0.986	56	411	0.661
5	502	1.999	31	407	0.966	57	1328	0.649
6	1724	1.674	32	814	0.943	58	920	0.645
7	327	1.576	33	1709	0.942	59	1401	0.634
8	1904	1.559	34	320	0.923	60	0403	0.617
9	703	1.551	35	714	0.918	61	1902	0.616
10	1920	1.437	36	702	0.890	62	910	0.611
11	1905	1.424	37	808	0.885	63	921	0.604
12	330	1.370	38	816	0.884	64	1211	0.600
13	1215	1.370	39	803	0.878	65	1704	0.598
14	1801	1.256	40	914	0.867	66	807	0.585
15	504	1.186	41	409	0.828	67	1216	0.580
16	822	1.178	42	1723	0.821	68	415	0.578
17	Target DMU	1.161	43	406	0.800	69	904	0.572
18	503	1.145	44	918	0.799	70	1207	0.567
19	107	1.067	45	905	0.788	71	1201	0.554
20	902	1.059	46	428	0.777	72	926	0.507
21	1910	1.054	47	1220	0.776	73	1413	0.494
22	106	1.040	48	805	0.724	74	810	0.472
23	1718	1.014	49	903	0.713	75	412	0.467
24	501	1.007	50	813	0.696	76	421	0.464
25	1914	1.000	51	1204	0.696	77	1327	0.456
26	901	1.000	52	1308	0.688	78	704	0.444

The critical analysis seeks to recognize the performance drivers of the best-positioned DMUS and strategies to the studied company improve its position in the raking (S4-3). The studied company is in the seventeenth position, with 1.16 of the supper-efficiency indexes. The improvement recommendations are given based on the three-positioned DMUs: 1304, 922 and 1924. The performance of these DMUs in each of the model variables is resumed to allow the individual comparison. The worksheet presented in Figure 6 demonstrates the position of the reference companies with the studied company.

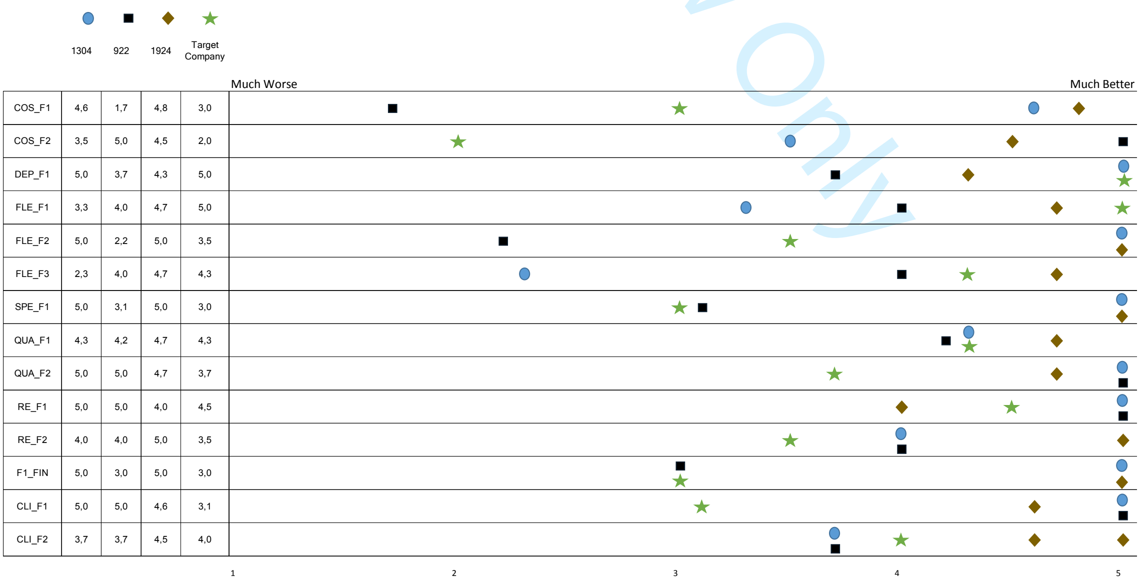

Figure 6. Example of S4-3 results (graph view)

The calculation of the size of the gap complements the previous analysis. The shortage exemplified in Table 6 is the distance from the suggested level (the index of the best performing DMU in the variable) and the performance of the studied company.

Table 6. Example of S4-3 results (shortage analysis)

Code	Variable	Target Company	Suggested Level	Shortage	Shortage %
Inputs					
COS_F1	Manufacturing costs, including operating expense	2.98	4.79	1.81	60.90%*
COS_F2	Manufacturing costs - recently launched products	2.00	5.00	3.00	150.00%*
DEP_F1	Dependability performance	5.00	5.00	0.00	0.00%
FLE_F1	Costumer vision about company flexibility	5.00	5.00	0.00	0.00%
FLE_F2	Production system capacity of changing production mix and volume in the vision of the plant manager	3.51	5.00	1.49	42.63%
FLE_F3	Product customization	4.26	4.72	0.46	10.81%
SPE_F1	Speed performance	2.99	5.00	2.01	67.07%*
QUA_F1	Quality performance compared to competitors	4.33	4.67	0.34	7.89%
QUA_F2	Quality performance compared to competitors in recently launched products	3.71	5.00	1.29	34.87%
RE_F1	Reliability performance compared to competitors in recently launched products	4.50	5.00	0.50	11.06%
RE_F2	Reliability performance compared to competitors	3.50	5.00	1.50	42.72%
Output					
F1_FIN	Throughput: the rate at which the plant generates money through sales	3.00	5.00	2.00	66.67%*
CLI_F1	Market Share and customer satisfaction on recently launched products	3.08	5.00	1.92	62.52%*
CLI_F2	Customer satisfaction	4.00	5.00	1.00	25.01%

* critical results, worse than the established guideline

The guideline recommends gaps over 50% to be the focus of improvement. To be the best-positioned company, the target company has to improve its performance in, at least, the shortage rate. To do so, improvement recommendations are next established.

Improvement Recommendations

The higher ranked firms should improve the effectiveness of their operations in the competitive environment to hold their positions among the best practitioners of the market. The lower-ranked companies should benchmark the high ranked organizations to identify ways of improving their operational performance. This topic summaries the improvement opportunities concerning the operations strategy and the performance frontier analysis. The step S5-1 interprets the results from previous steps and seek to define improvement opportunities based on the guideline presented in Table 7 , which establishes the aimed behavior.

Table 7. Guideline to define improvement opportunities

Step	Evaluated Item	Aimed behavior
Depicting the benchmarking dataset – Step 2	- The difference between the target company and the sector average index	Gaps smaller than 20%
Operations strategy Identification – Step 3	- Gaps between importance and performance - Position in the matrix	Befalls in the appropriate zone
	- Answer consistency in the responses to evaluate the importance of the competitive criteria	Standard deviation smaller than 1.5
	- Answer consistency in the responses to evaluate the performance of the competitive criteria	Standard deviation smaller than 1.5
Performance Frontier Identification – Step 4	- Supper-efficiency index	No aimed position, but the bigger, the best.
Improvement recommendations – Step 5	- The difference between the target company and the best index among the five best positioned (to input and output variables)	Gaps smaller than 50%

The aimed behavior was defined by analyzing the results obtained in eight cases of development. Standard deviation bigger than 1.5 can influence the average response, moving the result from one level to another. In the same way, a difference of 50% between the target DMU results and the aimed index, can expressively modify the ranking position. The objective when comparing the studied DMU to the average sector performance is to have at most 20% of the gap. The difference in performance should be smaller when comparing to the sector average, than when comparing to the best sector index. Table 8 demonstrates the using of these guidelines to develop the improvement priorities for a studied company.

Table 8. example of S5-1

Competitive Criteria	Findings	Description
Participant Consensus (shared understanding)		
Input variables (dependability, flexibility, and innovativeness)	lack of shared understanding (importance scale)	The respondents demonstrated distinct perceptions regarding the importance attached by customers on the competitive criteria. This behavior occurred mainly for 'dependability', 'flexibility' and 'innovativeness', which presented a standard deviation among answers bigger than 1.5.
Input variables (Costs, environmental factors, flexibility, and speed)	lack of shared understanding (performance scale)	Looking at the performance scale of the competitive criteria (see Table 5), it is possible to recognize a smaller shared vision. Four criteria presented a standard deviation bigger than 1.5 (costs, environmental factors, flexibility, and speed).
Performance in key competitive criteria		
Costs	Urgent call for improvement	Cost is important to customers (classification of 1.60 – provide an important advantage with most customers) but the company performance is not along with this importance (classification about 4.40 – About the same as most competitors).
		Cost is in the 'improve zone' since this criterion is order-winning and has its performance at the same level as competitors.
		Target DMU performs more than 20% worse than the sector average to COS_F2: Manufacturing costs - recently launched products flexibility
		The biggest gap between and suggested performance is for COS_F2 (Manufacturing costs - recently launched products), to this variable, the target is 150% behind of DMU 1924 (the best performing DMU) and is behind all of the references DMUs. COS_F1 (Manufacturing costs, including operating expenses) also presented an important difference of 60.9%.
Speed	Call for improvement	Target DMU performs more than 20% worse than the sector average to SPE_F1: Speed performance
		SPE_F1 (Speed performance) is the second variable with a bigger gap, 67% behind the best DMU.
Innovativeness		Target DMU performs more than 20% worse than the sector average to INO_F3: Product innovativeness
Flexibility	Good result Customer vision about company flexibility	Target DMU performs more than 20% better than the sector average to FLE_F1: Costumer vision about company flexibility
		Target DMU is one of the DMUs with the best evaluation for FLE_F1: Costumer vision about company flexibility
Client output variable	Call for improvement	Looking at the output variables, two important calls for improvement is found: - FIN_F1: Throughput: the rate at which the plant generates money through sales (gap of 66.7%) - CLI_F1: Market Share and customer satisfaction on recently launched products (gap of 62.5%)
		Target DMU performs more than 20% worse than the sector average to the financial output.

The improvement recommendations can be detailed by the researcher together with the managerial team, in the S5-2. Table 8 demonstrates generic improvement recommendations for a studied DMU.

Table 9. Example of S5-2

Improvement Recommendation	Competitive Criteria	Findings
Participant Consensus (shared understanding)		
Provide a deeper understanding of customer requirements, by the Strengthen the discussion of customers reports (eg. market share and customer satisfaction)	Input variables (dependability, flexibility, and innovativeness)	lack of shared understanding (importance scale)
Internal alignment of company initiatives	Input variables (costs, innovativeness, environmental factors, and speed)	lack of shared understanding (performance scale)
Performance in key competitive criteria		
Determinate strategies to improve performance in the criteria that are considered important to clients	Costs	Urgent call for improvement
	Speed	Call for improvement
Sustain the good result in the Order Winning criteria	Dependability	Good result
Sustain the good result in the qualifying criteria to remain in the industry standard	Flexibility	Good result Customer vision about company flexibility
Determinate strategies to improve financial results and market share on recently launched products	Financial output variable	Call for improvement
	Market Share and customer satisfaction on recently launched products	
Sustain the result in Customer satisfaction	Customer satisfaction	Good result

The suggestion to get more detailed improvement recommendations is to send the technical report to the participants, to individual assessment. Then, promote a meeting to formally present the results and to discuss strategies to define the priorities as well as to detail the improvement recommendations.

Discussion

The procedural framework enables the assessment and improvement of the operations strategy, based on its efficiency, a rate calculated taking into account the competitive environment in which the studied firm competes. The framework seeks to prioritize the need for improvement in the competitive criteria. After defining the order-winning criteria for the target organization, such a prioritizing is promoted through the understating of the competitive environment performance. Two main analyses ground the prioritizing, the comparison of the average performance of the sector and the performance of the three best-performing companies. After implementing such a process in eight cases, the guidance for analysis was provided. It is recommended that companies with variables more than 20% distant for the average sector performance should be a focus on improvement. When looking at the three best-performing companies in the sector, the improvement opportunities should befall on the variables with 50% or more of shortage of the best index. These targets were defined as lessons learned from eight cases development.

A second lesson learned, from the implementation perspective is the need to define the scope of analysis in each case. Some companies compete in a different segment of business, so it is necessary to first define which segment will be focused on the framework implementation. This definition can interfere the strategic positioning identified in step 3. We recommend the plant manager to be first interview to provide this definition.

The framework development its contribution to identifying in which of the order-winning criteria the organization should perform better, based on the behavior of the sector of competition. Such a proposal is grounded on the trade-off concept, which limits the organization's performance. In other words, improvement in one performance criterion can be achieved only by sacrificing the performance of another

(Skinner, 1974). However, there are two recent visions of trade-offs. The first emphasizes "repositioning" performance goals by compensating for improvements in some goals for reducing the performance in others. The other emphasizes increasing the "effectiveness" of the operation by overcoming the trade-offs so that improvements in one or more aspects of performance can be achieved without any reduction in the performance of others. Most companies, at one time or another, will adopt both approaches (Amoako-Gyampah and Meredith, 2007; Slack and Lewis, 2018; Kathuria et al., 2018; Sarmiento, et al., 2018). This study contributes to understanding in what of the criteria the compensation can be affordable, and in what of those it is necessary to overcome the trade-offs barrier by being simultaneously efficient.

The usability of the framework is enhanced with the fact of the procedural framework being context-driven, enhancing their value from a practical perspective, as a result, fit to a single studied company reality. This singularity is developed thought first identifying the important criteria from the studied company perspective. So, the ranking is generating with the order-winning criteria, only. This avoids the influence of less important criteria in the result.

This context-driven approach is developed because, according to Slack and Lewis (2018) the organizations must recognize the performance criteria to which they compete, and then develop such an objective inside its operations. However, no blind analysis should be developed, since it should be observed that even if a performance objective has little value externally – not being classified as order-winning, the operation may still value high performance in that objective because of the internal benefits it brings.

From the methodological point of view, the usability of the proposed framework depends on the managerial awareness of business and operations strategy as well as their conscious when providing the answers. The implementation of the framework demonstrated feasibility since the requirement is to answers a questionnaire, only. Taking about 30 minutes of each people in charge of answers, allowing then the implementation of the framework in a dynamic manner so the company can have agility in decision making to be alighted with internal and external demands.

Conclusion

This paper has the aim to provide the procedure to perform the frontier study in the operations strategy context, and with this, improve a given company operations strategy competitive position. The findings indicate that it is possible to define a process to calculate the operations strategy efficiency in a timely manner. To the theoretical point of view, the presented procedural framework contributes to facilitating future implementations to strengthen the market-based view approach. From a practical perspective, the integration of the performance frontier approach to study the operations strategy effectiveness can contribute to the strategic decision-making assertiveness. This is even more important given the economic limitations are present in the markets, as resources for improvement and innovation are limited and, once invested, must bring returns. Additionally, the proposition of a procedure allows the operations strategies to be constantly assessed, which is primary of importance in the current dynamic context. The proposed procedure could contribute to an agile decision-making process to support emergent strategies contributing to the organization being aligned within the new demand of the competitive environment.

The availability of reliable data is an important assumption for this research, as the framework requires an updated database to represent the competitive environment. When the 4th round of the HPM data becomes outdated, other data must be considered. Another limitation is that, for being context-driven, each company has a particular result, not allowing the comparison between various cases, as each company has its own frontier model. As a third limitation, we indicate that the performance frontier is estimated based on the responses gathered from a perceptive Likert scale. Therefore, the reliability of the data depends on the participants' awareness of the analyzed business.

Future opportunities surround the implementation of the proposed procedural model in more cases. Additionally, the development of an automated process to gather the data and identify the performance frontier can be positive to allow the framework implementation more frequently. Besides automation of the data collection process, open data sources can also contribute to generating big data allowing the identification of the sector behavior and the development of a database for improvement actions through data mining techniques.

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Appendix A
Operations Strategy Questionnaire

Step 1: Collect Data
Collect operations strategy performance data

Please, considers the competitive criteria definition.

According to the Nine-point Importance Scale, Indicate the index that fit better with the importance of the performance objectives
(you must have only one index to each performance objective)

Operations Strategy Performance Criteria		´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

According to the Nine-point Performance Scale, Indicate the index that fit better with the importance of the performance objectives
(you must have only one index to each performance objective)

Operations Strategy Performance Criteria		´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]	´[People in Charge]
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

Appendix B
Competitive criteria Questionnaire

Step 1: Collect Data Collect input/output performance data									
	Question	1	2	3	4	5	People in Charge	136%	
Fator/Variavel original	Question	Options					People in Charge	Weight	
Manufacturing costs, including operating expense	Question	1	2	3	4	5	People in Charge	100%	0,00
Manufacturing Costs	How do your plant's products compare to its leading competitors, on Product selling price?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	17,45%	
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Unit cost of manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	18,93%	
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Labor cost ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	42,47%	
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	21,15%	
Manufacturing costs - recently launched products	Question	1	2	3	4	5	People in Charge	100%	0,00
Manufacturing costs - recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas? Unit manufacturing cost	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	49,56%	
Manufacturing costs - recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors (Unit cost of manufacturing)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	50,44%	
Dependability performance	Question	1	2	3	4	5	People in Charge	100%	0,00
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: The promises that our plant makes to its customers are reliable.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	35,56%	
Dependability performance	How does your plant compare with its competitors in its industry, on a global basis, on On-time delivery performance?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	29,74%	
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for punctual delivery	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	34,69%	
Costumer vision about company flexibility	Question	1	2	3	4	5	Respondent	100%	0,00
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers select us because we deliver flexibly for their needs	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	32,56%	
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	31,85%	
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: We are selected by our customers because of our reputation for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	35,59%	
Production system capacity of changing production mix and volume in the vision of the plant manager	Question	1	2	3	4	5	Respondent	100%	0,00
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change product mixt ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	49,43%	
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change volume?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	50,57%	
Product customization	Question	1	2	3	4	5	Respondent	100%	0,00
Product customization	Indicate the extent to which you agree or disagree with The statement: We are highly capable of large scale product customization.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	35,16%	
Product customization	Indicate the extent to which you agree or disagree with The statement: We can easily add significant product variety without increasing cost.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	27,87%	
Product customization	Indicate the extent to which you agree or disagree with The statement: We can customize products while maintaining high volume.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	36,96%	
Speed performance	Question	1	2	3	4	5	Respondent	100%	0,00
Speed performance	How do your plant's products compare to its leading competitors, on Fast delivery?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	24,82%	
Speed performance	How do your plant's products compare to its leading competitors, on Speed of new product introduction into the plant (development lead time)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	23,75%	
Speed performance	How do your plant's products compare to its leading competitors, on Agile manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	25,36%	
Speed performance	How do your plant's products compare to its leading competitors, on Cycle time (from raw materials to delivery)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	26,06%	
Quality performance compared to competitors	Question	1	2	3	4	5	Respondent	100%	0,00
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Overall product quality perceived by customers?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	17,83%	
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Conformance to established standards?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	17,59%	
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Primary product performance characteristics?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	16,99%	
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Secondary options or features; characteristics that supplement the basic functioning of the product?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	15,62%	
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Aesthetics; how the product looks, feels, sounds, tastes or smells?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	15,77%	
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Serviceability; ease of repair?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	16,20%	
Quality performance compared to competitors in recently launched products	Question	1	2	3	4	5	Respondent	100%	0,00
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Conformance quality?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	29,27%	
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Performance (functionality)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	36,02%	
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Features?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	34,71%	

Reliability	Question	1	2	3	4	5	Respondent	100%	0,00
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Durability; amount of use before the product deteriorates or needs to be replaced?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	50,16%	
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Reliability of the product; probability of failure in a specified time?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management	49,84%	
Reliability	Question	1	2	3	4	5	Respondent	100%	0,00
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Durability (life expectancy)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	50,33%	
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Reliability (time between failures)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	49,67%	
Capacity of environmental practices positively influence other company's results'	Question	1	2	3	4	5	Respondent	100%	0,00
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Being environmentally conscious can lead to substantial cost advantages for our plant.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	16,23%	
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	16,85%	
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can enter lucrative new markets by adopting environmental strategies.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	17,63%	
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can increase market share by making our current products more environmentally friendly.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	17,34%	
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	14,48%	
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Better environmental performance can differentiate our plant from our competitors.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management	17,47%	
Overall environmental performance	Question	1	2	3	4	5	Respondent	100%	0,00
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Environmental performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs	35,77%	
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Regulatory performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs	34,27%	
Overall environmental performance	How does your plant compare to others in your global industry, in Overall environmental performance?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs	29,96%	
Process technology innovativeness	Question	1	2	3	4	5	Respondent	100%	0,00
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We quickly adopt new technologies by applying what we learn from our customers.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM	14,29%	
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We often fail to achieve the potential of new process technology.	Strongly agree	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Strongly disagree	Process Engineering	14,29%	
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: As new technologies emerge, we modify our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	14,29%	
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: There are no substitutes for our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	14,29%	
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our plant stays on the leading edge of new technology in our industry.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	14,29%	
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our current production technology is protected by patents.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	14,29%	
Process technology innovativeness	Which term best describes the plant's posture toward new processes?	Never adopts new processes	Usually among the last to adopt new processes	Adopts new processes when it becomes more or less the general rule	Among the first to adopt new process, but not the leader	Leader in new processes	Process Engineering	14,29%	
Equipment technology innovativeness	Question	1	2	3	4	5	Respondent	100%	0,00
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We frequently modify equipment to meet our specific needs.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	25,00%	
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We produce a substantial amount of our equipment in-house.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	25,00%	
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: In order to improve equipment performance, we sometimes redesign equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	25,00%	
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We actively develop proprietary equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering	25,00%	
Product innovativeness	Question	1	2	3	4	5	Respondent	100%	0,00
Product innovativeness	How does your plant compare with its competitors in its industry, on a global basis, on Product innovativeness?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management	50,00%	
Product innovativeness	Which term best describes the plant's posture toward new products?	Never adopts new products	Among the last to adopt new products	Adopts new products when it becomes more or less the general rule	Among the first to adopt new products, but not the leader	Leader in new products	Product Development	50,00%	
Throughput: the rate at which the plant generates money through sales	Question	1	2	3	4	5	Respondent	100%	0,00
Financial Performance	How does your plant compare with its competitors in its industry, on a global basis, on Throughput: the rate at which the plant generates money through sales?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Plant Management	100,00%	
Market Share and customer satisfaction on recently launched products	Question	1	2	3	4	5	Respondent	100%	0,00
Market Share and customer satisfaction on recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	36,21%	
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	38,48%	
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Customer satisfaction?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development	25,32%	
Customer satisfaction	Question	1	2	3	4	5	Respondent	100%	0,00
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our plant satisfies or exceeds the requirements and expectations of our customers.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management	25,18%	
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers are pleased with the products and services we provide for them.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management	26,36%	
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers have been well satisfied with the quality of our products, over the past three years.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management	25,15%	
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers seem happy with our responsiveness to their problems.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management	23,30%	

Table 1. Competitive environment data

Category	Factor or not observed variable	N	Mean	Median	Std Deviation
Input variables					
Costs	COS_F1: Manufacturing costs, including operating expense	77	3.22	3.09	0.70
	COS_F2: Costumer vision about company costs	77	3.06	3.00	0.72
Dependability	DEP_F1: Dependability performance	77	4.06	4.05	0.65
Environmental factors	ENV_F1: Capacity of environmental practices positively influence other company's results	77	3.41	3.39	0.79
	ENV_F2: Overall environmental performance	77	4.11	4.04	0.58
Flexibility	FLE_F1: Costumer vision about company flexibility	77	3.89	3.85	0.63
	FLE_F2: Production system capacity of changing production mix and volume	77	3.82	3.99	0.71
	FLE_F3: Product customization	77	3.47	3.55	0.78
Innovativeness	INO_F1: Process technology innovativeness	77	3.24	3.21	0.51
	INO_F2: Equipment technology innovativeness	77	3.55	3.70	0.69
	INO_F3: Product innovativeness	77	3.86	3.80	0.66
Quality	QUA_F1: Quality performance compared to competitors	77	3.76	3.79	0.51
	QUA_F2: Quality performance compared to competitors in recently launched products	77	3.89	3.83	0.53
Reliability	RE_F1: Reliability performance compared to competitors in recently launched products	77	3.80	3.75	0.61
	RE_F2: Reliability performance compared to competitors – quality management vision'	77	3.83	3.82	0.66
Speed	SPE_F1: Speed performance	77	3.65	3.47	0.65
Output variables					
Client	CLI_F1: Market Share and customer satisfaction on recently launched products	77	3.61	3.56	0.72
	CLI_F2: Customer satisfaction	77	3.94	3.92	0.63
Financial	FIN_F1: Throughput: the rate at which the plant generates money through sales	77	3.60	3.55	0.86

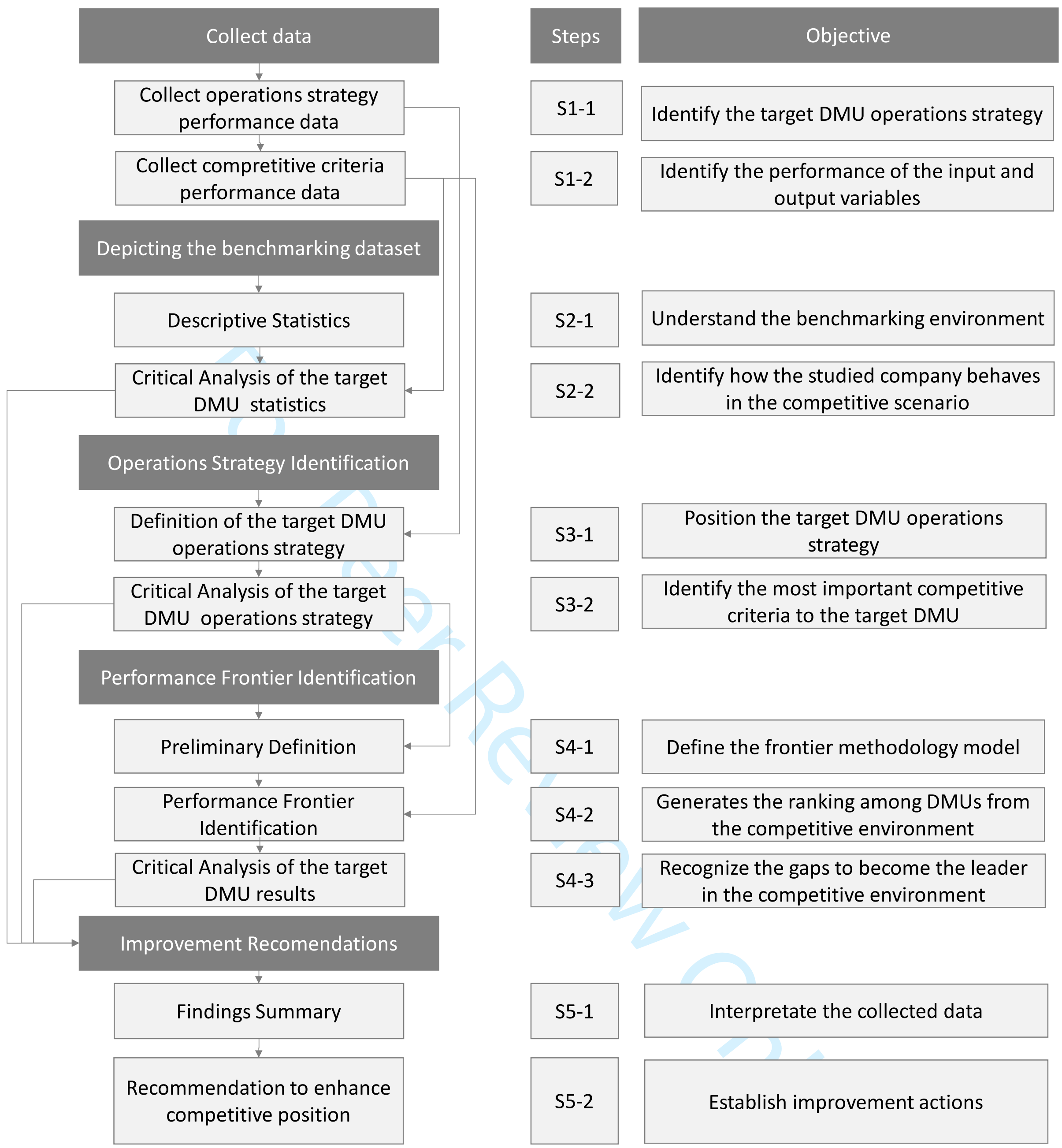

Collect data
Steps
Objective
Collect operations strategy performance data
S1-1
Identify the target DMU operations strategy
Collect competitive criteria performance data
S1-2
Identify the performance of the input and output variables
Depicting the benchmarking dataset
Descriptive Statistics
S2-1
Understand the benchmarking environment
Critical Analysis of the target DMU statistics
S2-2
Identify how the studied company behaves in the competitive scenario
Operations Strategy Identification
Definition of the target DMU operations strategy
S3-1
Position the target DMU operations strategy
Critical Analysis of the target DMU operations strategy
S3-2
Identify the most important competitive criteria to the target DMU
Performance Frontier Identification
Preliminary Definition
S4-1
Define the frontier methodology model
Performance Frontier Identification
S4-2
Generates the ranking among DMUs from the competitive environment
Critical Analysis of the target DMU results
S4-3
Recognize the gaps to become the leader in the competitive environment
Improvement Recomendations
Findings Summary
S5-1
Interpretate the collected data
Recommendation to enhance competitive position
S5-2
Establish improvement actions

Table 2. Operations strategy questionnaire scale

Importance Scale	Performance Scale
Order-winning objectives	*Better than competitors*
1. Provide a crucial advantage with customers - they are the main thrust of competitiveness;	1. Consistently considerably better than our nearest competitor;
2. Provide an important advantage with most customers - they are always considered by customers;	2. Consistently clearly better than our nearest competitor;
3. Provide a useful advantage with most customers - they are usually considered by customers;	3. Marginally better than our nearest competitor;
Qualifying objectives	*The same as competitors*
4. Need to be at least up to good industry standard;	4. Often marginally better than most competitors;
5. Need to be around the median industry standard;	5. About the same as most competitors;
6. Need to be within close range of the rest of the industry;	6. Often within striking distance of the main competitors;
Less important objectives	*Worse than competitors*
7. Do not usually come into customers' consideration, but could become more important in the future;	7. Usually marginally worse than most competitors;
8. Very rarely come into customers' considerations;	8. Usually worse than most competitors;
9. Never come into consideration by customers and are never likely to do so.	9. Consistently worse than most competitors?

Source: Slack et al., 2018

Table 3. Example of S2-S result

Factor or not observed variable	Sector Average	Target DMU	Gap	% Gap	Status
COS_F1: Manufacturing costs, including operating expense	3.29	2.98	-0.31	-10%	worse than the sector average
COS_F2: Manufacturing costs - recently launched products	2.99	2.00	-0.99	-50%*	worse than the sector average
DEP_F1: Dependability performance	4.06	5.00	0.94	19%	better than the sector average
ENV_F1: Capacity of environmental practices positively influence other company's results	3.41	3.47	0.07	2%	better than the sector average
ENV_F2: Overall environmental performance	4.11	4.66	0.54	12%	better than the sector average
FLE_F1: Costumer vision about company flexibility	3.89	5.00	1.11	22%	better than the sector average
FLE_F2: Production system capacity of changing production mix and volume	3.82	3.51	-0.32	-9%	worse than the sector average
FLE_F3: Product customization	3.47	4.26	0.79	18%	better than the sector average
INO_F1: Process technology innovativeness	3.24	3.86	0.61	16%	better than the sector average
INO_F2: Equipment technology innovativeness	3.55	3.25	-0.30	-9%	worse than the sector average
INO_F3: Product innovativeness	3.86	3.00	-0.86	-29%*	worse than the sector average
QUA_F1: Quality performance compared to competitors	3.76	4.33	0.57	13%	better than the sector average
QUA_F2: Quality performance compared to competitors in recently launched products	3.89	3.71	-0.19	-5%	worse than the sector average
RE_F1: Reliability performance compared to competitors in recently launched products	3.80	4.50	0.71	16%	better than the sector average
RE_F2: Reliability performance compared to competitors – quality management vision'	3.83	3.50	-0.33	-9%	worse than the sector average
SPE_F1: Speed performance	3.65	2.99	-0.66	-22%*	worse than the sector average
CLI_F1: Market Share and customer satisfaction on recently launched products	3.61	5.00	1.39	28%	better than the sector average
CLI_F2: Customer satisfaction	3.94	4.00	0.06	2%	better than the sector average
FIN_F1: Throughput: the rate at which the plant generates money through sales	3.60	3.00	-0.60	-20%*	worse than the sector average

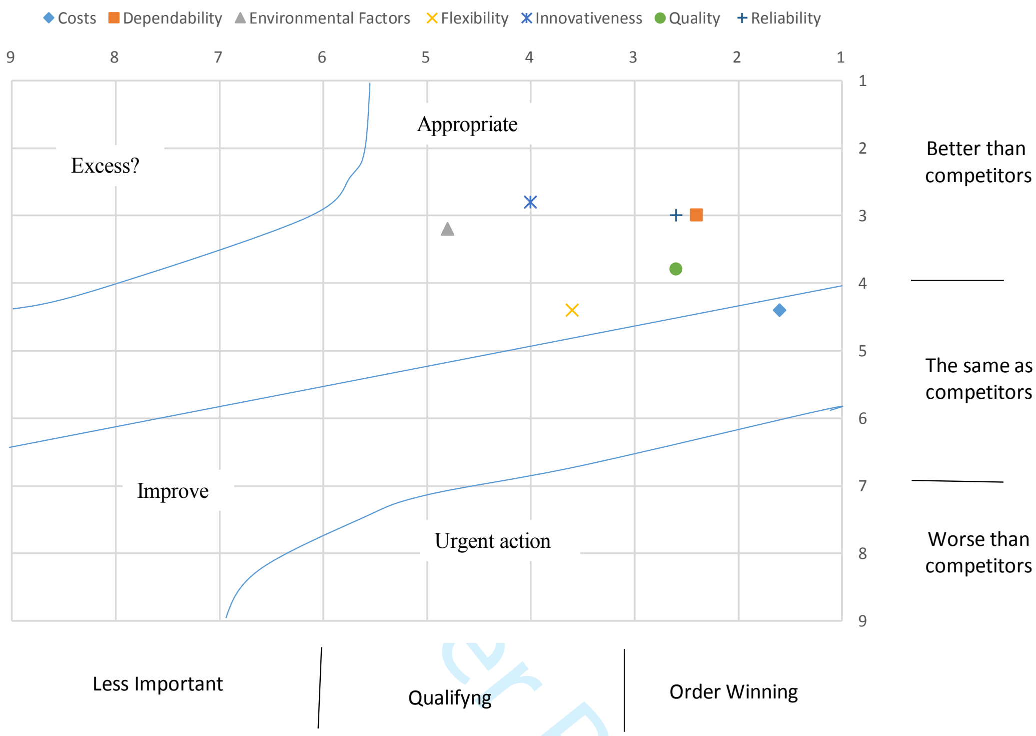
* critical results, worse than the established guideline

Table 4. Example of S3-1 and S3-2 result

Competitive Criteria	Average Importance	Standard Deviation	Classification	Average Performance	Standard Deviation	Classification
Costs	1.6	0.89	Oder-winning	4.4	2.41*	The same as competitors
Dependability	2.4	1.52*	Oder-winning	3.0	1.22	Better than competitors
Environmental Factors	4.8	1.30	Qualifying	3.2	1.64*	Better than competitors
Flexibility	3.6	1.82*	Oder-winning	4.4	1.82*	The same as competitors
Innovativeness	4.0	1.87*	Qualifying	2.8	1.30	Better than competitors
Quality	2.6	1.14	Oder-winning	3.8	1.10	Better than competitors
Reliability	2.6	0.89	Oder-winning	3.0	1.22	Better than competitors
Speed	3.2	1.10	Oder-winning	4.0	2.12*	The same as competitors

* worse than the target


Costs
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
Dependability
Environmental Factors
Flexibility
Innovativeness
Quality
Reliability
Speed
Importance
Performance


Costs
Dependability
Environmental Factors
Flexibility
Innovativeness
Quality
Reliability
9
8
7
6
5
4
3
2
1
Appropriate
Excess?
Improve
Urgent action
Better than competitors
The same as competitors
Worse than competitors
Less Important
Qualifyng
Order Winning

Step 4: Frontier Identification Preliminary Definition Worksheet					
DMU selection					
Frontier analysis method choice					
Data Envelopment Analysis with variable return to scale and output orientation					
Definition of the input and outputs variables					
Select the variables that you are interested in benchmarking. The order winning criterias should be selected.					
Input Variables Selection			Input Variables Selection		
Quality			Flexibility		
	QUA_F1	Quality performance compared to competitors		FLE_F1	Costumer vision about company flexibility
	QUA_F2	Quality performance compared to competitors in recently launched products		FLE_F2	Production system capacity of changing production mix and volume in the vision of the plant manager
				FLE_F3	Product customization
Costs			Reliability		
	COS_F1	Manufacturing costs, including operating expense		RE_F1	Reliability performance compared to competitors in recently launched products
	COS_F2	Costumer vision about company costs		RE_F2	Reliability performance compared to competitors – quality management vision'
Dependability			Speed		
	DEP_F1	Dependability performance		SPE_F1	Speed performance
Innovativeness					
	INO_F1	Process technology innovativeness	Output Variables Selection		
	INO_F2	Equipment technology innovativeness	Financial perpective Results		
	INO_F3	Product innovativeness		F1_FIN	Throughput: the rate at which the plant generates money through sales
Environmental Factors			Client perspective Results		
	ENV_F1	Capacity of environmental practices positively influence other company's results'		CLI_F1	Market Share and customer satisfaction on recently launched products
	ENV_F2	Overall environmental performance		CLI_F2	Customer satisfaction
Definition of the miminum required sample size					
Input the number of selected input and outout variables, to see the minimum requires sample size to allow the DEA.					
	Number of inputs variables (ki)		ki*ko	0	According to Golany and Roll (1989)
	Number of outputs variables (ko)		(ki+ko)*3	0	According to Banker et. al (1989)
The recommended sample size is:					
0	DMUs data				

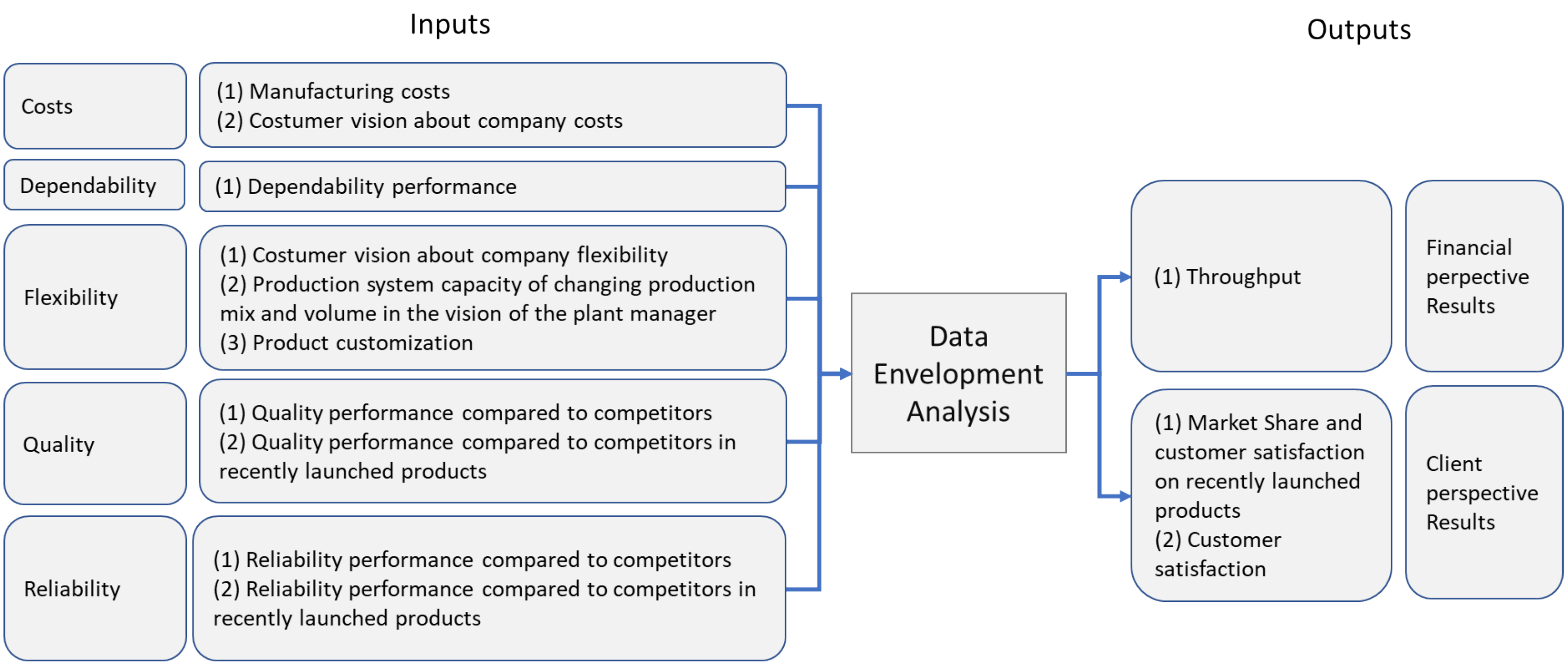

Inputs
Costs
(1) Manufacturing costs
(2) Costumer vision about company costs
Dependability
(1) Dependability performance
Flexibility
(1) Costumer vision about company flexibility
(2) Production system capacity of changing production mix and volume in the vision of the plant manager
(3) Product customization
Quality
(1) Quality performance compared to competitors
(2) Quality performance compared to competitors in recently launched products
Reliability
(1) Reliability performance compared to competitors
(2) Reliability performance compared to competitors in recently launched products
Data Envelopment Analysis
Outputs
(1) Throughput
Financial perpective Results
(1) Market Share and customer satisfaction on recently launched products
(2) Customer satisfaction
Client perspective Results

Table 5. Example of S4-2 results

Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency	Ranking	DMU Code	Supper-Efficiency
1	1304	2.999	27	1719	1.000	53	1310	0.678
2	922	2.513	28	1716	1.000	54	101	0.673
3	1924	2.331	29	1809	0.996	55	606	0.669
4	1909	2.021	30	315	0.986	56	411	0.661
5	502	1.999	31	407	0.966	57	1328	0.649
6	1724	1.674	32	814	0.943	58	920	0.645
7	327	1.576	33	1709	0.942	59	1401	0.634
8	1904	1.559	34	320	0.923	60	0403	0.617
9	703	1.551	35	714	0.918	61	1902	0.616
10	1920	1.437	36	702	0.890	62	910	0.611
11	1905	1.424	37	808	0.885	63	921	0.604
12	330	1.370	38	816	0.884	64	1211	0.600
13	1215	1.370	39	803	0.878	65	1704	0.598
14	1801	1.256	40	914	0.867	66	807	0.585
15	504	1.186	41	409	0.828	67	1216	0.580
16	822	1.178	42	1723	0.821	68	415	0.578
17	Target DMU	1.161	43	406	0.800	69	904	0.572
18	503	1.145	44	918	0.799	70	1207	0.567
19	107	1.067	45	905	0.788	71	1201	0.554
20	902	1.059	46	428	0.777	72	926	0.507
21	1910	1.054	47	1220	0.776	73	1413	0.494
22	106	1.040	48	805	0.724	74	810	0.472
23	1718	1.014	49	903	0.713	75	412	0.467
24	501	1.007	50	813	0.696	76	421	0.464
25	1914	1.000	51	1204	0.696	77	1327	0.456
26	901	1.000	52	1308	0.688	78	704	0.444

	1304	922	1924	Target Company
COS_F1	4,6	1,7	4,8	3,0
COS_F2	3,5	5,0	4,5	2,0
DEP_F1	5,0	3,7	4,3	5,0
FLE_F1	3,3	4,0	4,7	5,0
FLE_F2	5,0	2,2	5,0	3,5
FLE_F3	2,3	4,0	4,7	4,3
SPE_F1	5,0	3,1	5,0	3,0
QUA_F1	4,3	4,2	4,7	4,3
QUA_F2	5,0	5,0	4,7	3,7
RE_F1	5,0	5,0	4,0	4,5
RE_F2	4,0	4,0	5,0	3,5
F1_FIN	5,0	3,0	5,0	3,0
CLI_F1	5,0	5,0	4,6	3,1
CLI_F2	3,7	3,7	4,5	4,0

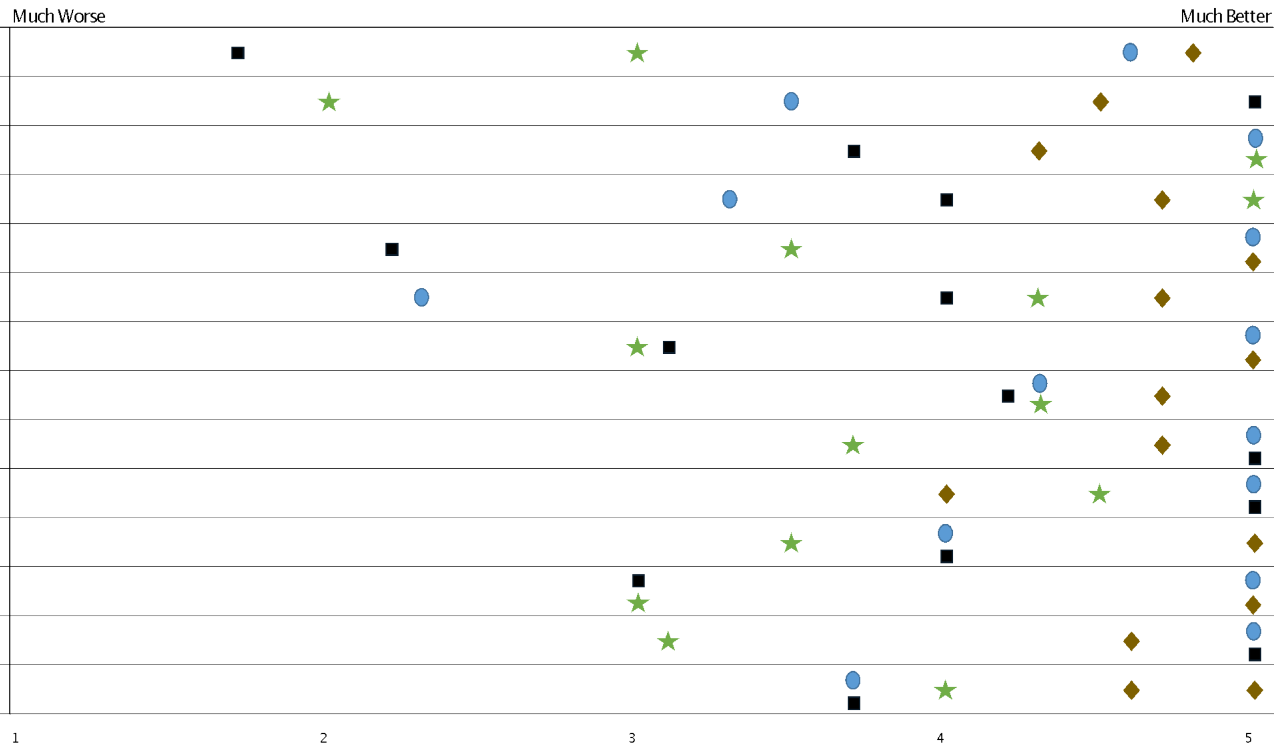


Table 6. Example of S4-3 results (shortage analysis)

Code	Variable	Target Company	Suggested Level	Shortage	Shortage %
Inputs					
COS_F1	Manufacturing costs, including operating expense	2.98	4.79	1.81	60.90%*
COS_F2	Manufacturing costs - recently launched products	2.00	5.00	3.00	150.00%*
DEP_F1	Dependability performance	5.00	5.00	0.00	0.00%
FLE_F1	Costumer vision about company flexibility	5.00	5.00	0.00	0.00%
FLE_F2	Production system capacity of changing production mix and volume in the vision of the plant manager	3.51	5.00	1.49	42.63%
FLE_F3	Product customization	4.26	4.72	0.46	10.81%
SPE_F1	Speed performance	2.99	5.00	2.01	67.07%*
QUA_F1	Quality performance compared to competitors	4.33	4.67	0.34	7.89%
QUA_F2	Quality performance compared to competitors in recently launched products	3.71	5.00	1.29	34.87%
RE_F1	Reliability performance compared to competitors in recently launched products	4.50	5.00	0.50	11.06%
RE_F2	Reliability performance compared to competitors	3.50	5.00	1.50	42.72%
Output					
F1_FIN	Throughput: the rate at which the plant generates money through sales	3.00	5.00	2.00	66.67%*
CLI_F1	Market Share and customer satisfaction on recently launched products	3.08	5.00	1.92	62.52%*
CLI_F2	Customer satisfaction	4.00	5.00	1.00	25.01%

* critical results, worse than the established guideline

Table 7. Guideline to define improvement opportunities

Step	Evaluated Item	Aimed behavior
Depicting the benchmarking dataset – Step 2	- The difference between the target company and the sector average index	Gaps smaller than 20%
Operations strategy Identification – Step 3	- Gaps between importance and performance - Position in the matrix	Befalls in the appropriate zone
	- Answer consistency in the responses to evaluate the importance of the competitive criteria	Standard deviation smaller than 1.5
	- Answer consistency in the responses to evaluate the performance of the competitive criteria	Standard deviation smaller than 1.5
Performance Frontier Identification – Step 4	- Supper-efficiency index	No aimed position, but the bigger, the best.
Improvement recommendations – Step 5	- The difference between the target company and the best index among the five best positioned (to input and output variables)	Gaps smaller than 50%

Table 8. example of S5-1

Competitive Criteria	Findings	Description
Participant Consensus (shared understanding)		
Input variables (dependability, flexibility, and innovativeness)	lack of shared understanding (importance scale)	The respondents demonstrated distinct perceptions regarding the importance attached by customers on the competitive criteria. This behavior occurred mainly for 'dependability', 'flexibility' and 'innovativeness', which presented a standard deviation among answers bigger than 1.5.
Input variables (Costs, environmental factors, flexibility, and speed)	lack of shared understanding (performance scale)	Looking at the performance scale of the competitive criteria (see Table 5), it is possible to recognize a smaller shared vision. Four criteria presented a standard deviation bigger than 1.5 (costs, environmental factors, flexibility, and speed).
Performance in key competitive criteria		
Costs	Urgent call for improvement	Cost is important to customers (classification of 1.60 – provide an important advantage with most customers) but the company performance is not along with this importance (classification about 4.40 – About the same as most competitors).
		Cost is in the 'improve zone' since this criterion is order-winning and has its performance at the same level as competitors.
		Target DMU performs more than 20% worse than the sector average to COS_F2: Manufacturing costs - recently launched products flexibility
		The biggest gap between and suggested performance is for COS_F2 (Manufacturing costs - recently launched products), to this variable, the target is 150% behind of DMU 1924 (the best performing DMU) and is behind all of the references DMUs. COS_F1 (Manufacturing costs, including operating expenses) also presented an important difference of 60.9%.
Speed	Call for improvement	Target DMU performs more than 20% worse than the sector average to SPE_F1: Speed performance
		SPE_F1 (Speed performance) is the second variable with a bigger gap, 67% behind the best DMU.
Innovativeness		Target DMU performs more than 20% worse than the sector average to INO_F3: Product innovativeness
Flexibility	Good result Customer vision about company flexibility	Target DMU performs more than 20% better than the sector average to FLE_F1: Costumer vision about company flexibility
		Target DMU is one of the DMUs with the best evaluation for FLE_F1: Costumer vision about company flexibility
Client output variable	Call for improvement	Looking at the output variables, two important calls for improvement is found: - FIN_F1: Throughput: the rate at which the plant generates money through sales (gap of 66.7%) - CLI_F1: Market Share and customer satisfaction on recently launched products (gap of 62.5%)
		Target DMU performs more than 20% worse than the sector average to the financial output.

Table 9. Example of S5-2

Improvement Recommendation	Competitive Criteria	Findings
Participant Consensus (shared understanding)		
Provide a deeper understanding of customer requirements, by the Strengthen the discussion of customers reports (eg. market share and customer satisfaction)	Input variables (dependability, flexibility, and innovativeness)	lack of shared understanding (importance scale)
Internal alignment of company initiatives	Input variables (costs, innovativeness, environmental factors, and speed)	lack of shared understanding (performance scale)
Performance in key competitive criteria		
Determinate strategies to improve performance in the criteria that are considered important to clients	Costs	Urgent call for improvement
	Speed	Call for improvement
Sustain the good result in the Order Winning criteria	Dependability	Good result
Sustain the good result in the qualifying criteria to remain in the industry standard	Flexibility	Good result Customer vision about company flexibility
Determinate strategies to improve financial results and market share on recently launched products	Financial output variable	Call for improvement
	Market Share and customer satisfaction on recently launched products	
Sustain the result in Customer satisfaction	Customer satisfaction	Good result

A procedure for assessing and improving operations strategy

Appendix B– HPM variables selection (original questions)

Questions regarding costs competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
POSTNX01	How do your plant's products compare to its leading competitors, on each of the following?	Product selling price	Five points Likert scale	Plant Management
GLOBLX01	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Unit cost of manufacturing	Five points Likert scale	Plant Management
GLOBLX23	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Labor cost	Five points Likert scale	Plant Management
COSTCN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers can rely on us for low cost products.	Five points Likert scale	Downstream SCM
SUCCSX08	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas?	Unit manufacturing cost	Five points Likert scale	Product Development
NPDPFX11	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Unit cost of manufacturing	Five points Likert scale	Product Development
GLOBLX27	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation	Five points Likert scale	Plant Management
TOCOUTN02	Please rate your plant's performance in each of the following areas, compared to the industry average.	Operating expense	Five points Likert scale	Accounting
DISTIX12	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Labor cost	Five points Likert scale	Plant Management

Questions regarding dependability competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
CREDCN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	The promises that our plant makes to its customers are reliable.	Five points Likert scale	Downstream SCM
GLOBLX03	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	On-time delivery performance	Five points Likert scale	Plant Management
GLOBLX11	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	On time new product launch	Five points Likert scale	Plant Management
LINKCN02	To what extent do you agree with the following statements?	We always deliver on time to our customers.	Five points Likert scale	Production Control
ONTIMN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers can rely on us for punctual delivery.	Five points Likert scale	Downstream SCM
ONTIMN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We are selected by our customers because of our reputation for on-time delivery.	Five points Likert scale	Downstream SCM

Questions regarding environmental factors competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
OUTCMX01	How have each of the following outcomes changed for your plant, as a result of undertaking environmental initiatives?	Environmental performance	Five points Likert scale	Environmental Affairs
OUTCMX02	How have each of the following outcomes changed for your plant, as a result of undertaking environmental initiatives?	Regulatory performance	Five points Likert scale	Environmental Affairs
EPERFX01	How have each of the following outcomes changed for your plant, as a result of undertaking environmental initiatives?	Overall environmental performance	Five points Likert scale	Environmental Affairs
CPADVN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Being environmentally conscious can lead to substantial cost advantages for our plant.	Five points Likert scale	Plant Management
CPADVN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Five points Likert scale	Plant Management
CPADVN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our plant can enter lucrative new markets by adopting environmental strategies.	Five points Likert scale	Plant Management
CPADVN05	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our plant can increase market share by making our current products more environmentally friendly.	Five points Likert scale	Plant Management
CPADVN06	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Five points Likert scale	Plant Management
CPADVN07	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Better environmental performance can differentiate our plant from our competitors.	Five points Likert scale	Plant Management
CPADVN08	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Being environmentally conscious can set us apart from the competition.	Five points Likert scale	Plant Management

Questions regarding flexibility competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
FLEXCN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers select us because we deliver flexibility for their needs.	Five points Likert scale	Downstream SCM
FLEXCN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers can rely on us for flexibility.	Five points Likert scale	Downstream SCM
FLEXCN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We are selected by our customers because of our reputation for flexibility.	Five points Likert scale	Downstream SCM
GLOBLX05	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Flexibility to change product mix	Five points Likert scale	Plant Management

Questions regarding flexibility competitive priority (Continuation)

Code	Question	Respondent Option	Type of question	source questionnaire
GLOBLX06	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Flexibility to change volume	Five points Likert scale	Plant Management
MCUSTN05	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We can add product variety without sacrificing quality.	Five points Likert scale	Process Engineering
DESCHGN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our production system is designed to accommodate changes in production mix.	Five points Likert scale	Process Engineering
LINKCN03	To what extent do you agree with the following statements?	We can adapt our production schedule to sudden production stoppages by our customers.	Five points Likert scale	Production Control
RELFLXN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Flexibility in response to requests for changes is a characteristic of our relationship with our key suppliers.	Five points Likert scale	Upstream SCM
NPDPFX12	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Our ability to customize the product	Five points Likert scale	Product Development
MCUSTN08	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We can quickly adjust the product design based on customers.	Five points Likert scale	Process Engineering
DESCHGN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our production system is designed to accommodate changes in demand volume.	Five points Likert scale	Process Engineering
MCUSTN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our setup costs, changing from one product to another, are very low.	Five points Likert scale	Process Engineering
MCUSTN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We are highly capable of large-scale product customization.	Five points Likert scale	Process Engineering
MCUSTN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We can easily add significant product variety without increasing cost.	Five points Likert scale	Process Engineering
MCUSTN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We can customize products while maintaining high volume.	Five points Likert scale	Process Engineering
RECNFGN06	To what extent is your plant developing each of the following capabilities?	Customization: ability to adapt production systems and machines to meet new requirements	Five points Likert scale	Process Engineering
RECNFGN04	To what extent is your plant developing each of the following capabilities?	Convertability: ability to quickly transform the functionality of existing equipment to suit new	Five points Likert scale	Process Engineering

Questions regarding innovativeness competitive priority

Code	Question	Respondent Option	Type of question	Source questionnaire
GLOBLX12	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Product innovativeness	Five points Likert scale	Plant Management
ANTICN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our plant stays on the leading edge of new technology in our industry.	Five points Likert scale	Process Engineering
DESTCHN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our current production technology is protected by patents.	Five points Likert scale	Process Engineering
EQUIPN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We actively develop proprietary equipment.	Five points Likert scale	Process Engineering
PROCSX05	Which term best describes the plant's posture toward new processes?	Leader in new processes, Among the first to adopt new, adopts new processes when it, Usually among the last to adopt new or Never adopts new processes	Five points Likert scale	Process Engineering
PRDCTX04	Which term best describes the plant's posture toward new products?	Leader in new products, Among the first to adopt new products, but not the leader, adopts new products when it becomes more or less the general rule, Usually among the last to adopt new products or Never adopts new products	Five points Likert scale	Product Development
KNOWLN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We quickly adopt new technologies by applying what we learn from our customers.	Five points Likert scale	Downstream SCM
PROCSR01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We often fail to achieve the potential of new process technology.	Five points Likert scale	Process Engineering
DESTCHN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	As new technologies emerge, we modify our production technology.	Five points Likert scale	Process Engineering
EQUIPN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We frequently modify equipment to meet our specific needs.	Five points Likert scale	Process Engineering
YPREVN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	In order to improve equipment performance, we sometimes redesign equipment.	Five points Likert scale	Process Engineering
EQUIPN06	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We produce a substantial amount of our equipment in-house.	Five points Likert scale	Process Engineering
DESTCHN05	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	There are no substitutes for our production technology.	Five points Likert scale	Process Engineering

Questions regarding quality competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
QUALCN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers can rely on us for quality products.	Five points Likert scale	Downstream SCM
QUALCN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We are selected by our customers because of our reputation for quality.	Five points Likert scale	Downstream SCM
POSTNX04	How do your plant's products compare to its leading competitors, on each of the following?	Product quality	Five points Likert scale	Plant Management
GLOBLX02	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Conformance to product specifications	Five points Likert scale	Plant Management
GLOBLX10	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Product capability and performance	Five points Likert scale	Plant Management

Questions regarding quality competitive priority (continuation)

Code	Question	Respondent Option	Type of question	source questionnaire
NPDPFX05	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Conformance quality	Five points Likert scale	Product Development
DIMENX08	How does the quality of your plant's products compare to its competitors' products?	Overall product quality perceived by customers	Five points Likert scale	Quality Management
SATISR06	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	In general, our plant's level of quality performance over the past three years has been low, relative to industry norms.	Five points Likert scale	Quality Management
SATISN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Customer standards are always met by our plant.	Five points Likert scale	Quality Management
DIMENX04	How does the quality of your plant's products compare to its competitors' products?	Conformance to established standards	Five points Likert scale	Quality Management
SUCCSX03	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas?	Technical performance relative to specification	Five points Likert scale	Product Development
NPDPFX01	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Performance (functionality)	Five points Likert scale	Product Development
DIMENX01	How does the quality of your plant's products compare to its competitors' products?	Primary product performance characteristics	Five points Likert scale	Quality Management
DIMENX02	How does the quality of your plant's products compare to its competitors' products?	Secondary options or features; characteristics that supplement the basic functioning of the product	Five points Likert scale	Quality Management
NPDPFX02	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Features	Five points Likert scale	Product Development
NPDPFX06	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Aesthetic appeal of this product	Five points Likert scale	Product Development
DIMENX07	How does the quality of your plant's products compare to its competitors' products?	Aesthetics; how the product looks, feels, sounds, tastes or smells	Five points Likert scale	Quality Management
NPDPFX08	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Ease of servicing this product	Five points Likert scale	Product Development
DIMENX06	How does the quality of your plant's products compare to its competitors' products?	Serviceability; ease of repair	Five points Likert scale	Quality Management

Questions regarding reliability competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
NPDPFX03	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Durability (life expectancy)	Five points Likert scale	Product Development
DIMENX05	How does the quality of your plant's products compare to its competitors' products?	Durability; the amount of use before the product deteriorates or needs to be replaced	Five points Likert scale	Quality Management
DIMENX03	How does the quality of your plant's products compare to its competitors' products?	Reliability of the product; the probability of failure in a specified time	Five points Likert scale	Quality Management
NPDPFX04	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Reliability (time between failures)	Five points Likert scale	Product Development

Questions regarding speed competitive priority

Code	Question	Respondent Option	Type of question	source questionnaire
SPEEDN04	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We are selected by our customers because of our reputation for fast delivery.	Five points Likert scale	Downstream SCM
SPEEDN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Fast delivery is the most important criterion used by our customers in selecting us as a supplier.	Five points Likert scale	Downstream SCM
GLOBLX04	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Fast delivery	Five points Likert scale	Plant Management
NPDPFX13	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Our ability to rapidly deliver	Five points Likert scale	Product Development
GLOBLX09	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Speed of new product introduction into the plant (development lead time)	Five points Likert scale	Plant Management
DISTIX11	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Agile manufacturing	Five points Likert scale	Bigger, Better
GLOBLX08	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Cycle time (from raw materials to delivery)	Five points Likert scale	Bigger, Better

Questions regarding firm outputs (Financial results)

Code	Question	Respondent Option	Type of question	source questionnaire
GLOBLX25	How does your plant compare with its competitors in its industry, on a global basis, on each of the following?	Throughput: the rate at which the plant generates money through sales	Five points Likert scale	Plant Management

Questions regarding firm outputs (clients results)

Code	Question	Respondent Option	Type of question	source questionnaire
POSTNX05	How do your plant's products compare to its leading competitors, on each of the following?	Brand image	Five points Likert scale	Plant Management
NPDPFX10	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Market share	Five points Likert scale	Product Development
SUCCSX02	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas?	Market share	Five points Likert scale	Product Development
SATISN03	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	We have a large number of repeat customers.	Five points Likert scale	Quality Management
SATISN07	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our plant satisfies or exceeds the requirements and expectations of our customers.	Five points Likert scale	Quality Management
SATISN01	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers are pleased with the products and services we provide for them.	Five points Likert scale	Quality Management
SATISN05	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers have been well satisfied with the quality of our products, over the past three years.	Five points Likert scale	Quality Management
SATISN02	Please indicate the extent to which you agree or disagree with each of the following statements about your plant.	Our customers seem happy with our responsiveness to their problems.	Five points Likert scale	Quality Management
SUCCSX01	How successful have products that were recently launched by your plant been, in terms of their goals in of each of the following areas?	Customer satisfaction	Five points Likert scale	Product Development
NPDPFX07	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors?	Customers' perception of this product	Five points Likert scale	Product Development

Appendix C– Descriptive statistics of the original variables (from HPM)

Descriptive statistics of costs original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
POSTN X01	Product selling price	Five points likert scale	Bigger, better	117	1.5	5.0	3.54	0.89
GLOBL X01	Unit cost of manufacturing	Five points likert scale	Bigger, better	117	1.5	5.0	3.52	0.91
GLOBL X23	Labor cost	Five points likert scale	Bigger, better	117	1.0	5.0	3.30	1.10
COSTC N03	Our customers can rely on us for low cost products.	Five points likert scale	Bigger, better	117	1.5	5.0	3.47	0.84
SUCCS X08	Unit manufacturing cost	Five points likert scale	Bigger, better	117	1.0	5.0	3.13	0.80
NPDPF X11	Unit cost of manufacturing	Five points likert scale	Bigger, better	117	1.0	5.0	3.09	0.85
GLOBL X27	Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation	Five points likert scale	Bigger, better	117	1.5	5.0	3.31	0.84
TOCOU TN02	Operating expense	Five points likert scale	Bigger, better	117	2.0	5.0	3.31	0.82
DISTIX1 2	Labor cost	Five points likert scale	Bigger, better	117	1.0	5.0	3.10	0.91

Descriptive statistics of dependability original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
CREDC N01	The promises that our plant makes to its customers are reliable.	Bigger, Better	Bigger, better	241	1.5	5.0	4.08	0.81
GLOBL X03	On time delivery performance	Five points likert scale	Bigger, better	241	1.0	5.0	3.90	0.82
GLOBL X11	On time new product launch	Five points likert scale	Bigger, better	241	1.0	5.0	3.54	0.91
LINKCN 02	We always deliver on time to our customers.	Five points likert scale	Bigger, better	241	1.0	5.0	3.93	0.85
ONTIM N03	Our customers can rely on us for punctual delivery.	Five points likert scale	Bigger, better	241	1.5	5.0	4.12	0.82
ONTIM N04	We are selected by our customers because of our reputation for on-time delivery.	Five points likert scale	Bigger, better	241	1.0	5.0	3.75	0.82

Descriptive statistics of environmental factors original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
OUTCM X01	Environmental performance	Five points likert scale	Bigger, better	249	2.0	5.0	4.14	0.67
OUTCM X02	Regulatory performance	Five points likert scale	Bigger, better	249	2.0	5.0	4.27	0.72
EPERF X01	Overall environmental performance	Five points likert scale	Bigger, better	249	2.0	5.0	3.75	0.77
CPADV N01	Being environmentally conscious can lead to substantial cost advantages for our plant.	Five points likert scale	Bigger, better	249	1.0	5.0	3.56	0.95
CPADV N02	Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Five points likert scale	Bigger, better	249	1.0	5.0	3.42	0.94
CPADV N04	Our plant can enter lucrative new markets by adopting environmental strategies.	Five points likert scale	Bigger, better	249	1.0	5.0	3.32	1.01
CPADV N05	Our plant can increase market share by making our current products more environmentally friendly.	Five points likert scale	Bigger, better	249	1.0	5.0	3.44	0.97
CPADV N06	Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Five points likert scale	Bigger, better	249	1.0	5.0	3.70	0.88
CPADV N07	Better environmental performance can differentiate our plant from our competitors.	Five points likert scale	Bigger, better	249	1.0	5.0	3.65	0.96
CPADV N08	Being environmentally conscious can set us apart from the competition.	Five points likert scale	Bigger, better	249	1.0	5.0	3.57	1.00

Descriptive statistics of flexibility original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
FLEXCN02	Our customers select us because we deliver flexibly for their needs.	Five points likert scale	Bigger, better	212	1.0	5.0	3.90	0.80
FLEXCN03	Our customers can rely on us for flexibility.	Five points likert scale	Bigger, better	212	1.0	5.0	4.03	0.70
FLEXCN04	We are selected by our customers because of our reputation for flexibility.	Five points likert scale	Bigger, better	212	1.0	5.0	3.85	0.82
GLOBLX05	Flexibility to change product mix	Five points likert scale	Bigger, better	212	1.0	5.0	3.81	0.81
GLOBLX06	Flexibility to change volume	Five points likert scale	Bigger, better	212	1.0	5.0	3.80	0.83
MCUSTN05	We can add product variety without sacrificing quality.	Five points likert scale	Bigger, better	212	1.0	5.0	3.90	0.84
DESCHGN03	Our production system is designed to accommodate changes in production mix.	Five points likert scale	Bigger, better	212	1.0	5.0	3.90	0.78
LINKCN03	We can adapt our production schedule to sudden production stoppages by our customers.	Five points likert scale	Bigger, better	212	1.0	5.0	3.84	0.81
RELFLXN02	Flexibility in response to requests for changes is a characteristic of our relationship with our key suppliers.	Five points likert scale	Bigger, better	212	2.0	5.0	4.04	0.67
NPDPFX12	Our ability to customize the product	Five points likert scale	Bigger, better	212	1.0	5.0	3.78	0.86
MCUSTN08	We can quickly adjust the product design based on customers.	Five points likert scale	Bigger, better	212	1.0	5.0	3.92	0.89
DESCHGN02	Our production system is designed to accommodate changes in demand volume.	Five points likert scale	Bigger, better	212	1.0	5.0	3.74	0.85
MCUSTN03	Our setup costs, changing from one product to another, are very low.	Five points likert scale	Bigger, better	212	1.0	5.0	3.25	0.98
MCUSTN01	We are highly capable of large scale product customization.	Five points likert scale	Bigger, better	212	1.0	5.0	3.62	0.99
MCUSTN02	We can easily add significant product variety without increasing cost.	Five points likert scale	Bigger, better	212	1.0	5.0	3.33	0.96
MCUSTN04	We can customize products while maintaining high volume.	Five points likert scale	Bigger, better	212	1.0	5.0	3.64	0.95
RECNFGN06	Customization: ability to adapt production systems and machines to meet new requirements	Five points likert scale	Bigger, better	212	1.0	5.0	3.60	0.79
RECNFGN04	Convertability: ability to quickly transform the functionality of existing equipment to suit new	Five points likert scale	Bigger, better	212	1.0	5.0	3.24	0.89

Descriptive statistics of innovativeness original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
KNOWL N04	We quickly adopt new technologies by applying what we learn from our customers.	Five points likert scale	Bigger, better	202	1.0	5.0	3.63	0.89
PROCS R01	We often fail to achieve the potential of new process technology.	Five points likert scale	Bigger, better	202	1.0	5.0	2.74	1.01
DESTC HN02	As new technologies emerge, we modify our production technology.	Five points likertscale	Bigger, better	202	1.0	5.0	3.83	0.75
DESTC HN05	There are no substitutes for our production technology.	Five points likertscale	Bigger, better	202	1.0	5.0	2.69	1.02
ANTICN 03	Our plant stays on the leading edge of new technology in our industry.	Five points likert scale	Bigger, better	202	1.0	5.0	3.61	0.91
DESTC HN03	Our current production technology is protected by patents.	Five points likert scale	Bigger, better	202	1.0	5.0	3.90	0.82
PROCS X05	Leader in new processes, Among the first to adopt new, adopts new processes when it, Usually among the last to adopt new or Never adopts new processes	Five points likert scale	Bigger, better	202	1.0	5.0	2.58	0.74
EQUIPN 04	We frequently modify equipment to meet our specific needs.	Five points likertscale	Bigger, better	202	1.0	5.0	3.74	0.94
YPREV N02	In order to improve equipment performance, we sometimes redesign equipment.	Five points likertscale	Bigger, better	202	1.0	5.0	3.80	0.88
EQUIPN 06	We produce a substantial amount of our equipment in-house.	Five points likertscale	Bigger, better	202	1.0	5.0	2.87	1.12
EQUIPN 01	We actively develop proprietary equipment.	Five points likert scale	Bigger, better	202	1.0	5.0	3.41	1.04
GLOBL X12	Product innovativeness	Five points likert scale	Bigger, better	202	1.0	5.0	3.70	0.88
PRDCT X04	Leader in new products, Among the first to adopt new products, but not the leader, adopts new products when it becomes more or less the general rule, Usually among the last to adopt new products or Never adopts new products	Five points likert scale	Bigger, better	202	1.0	5.0	2.22	0.81

Descriptive statistics of Quality original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
QUALCN03	Our customers can rely on us for quality products.	5 points likert scale	Bigger, better	210	2.0	5.0	4.36	0.66
QUALCN04	We are selected by our customers because of our reputation for quality.	Five points likert scale	Bigger, better	210	1.0	5.0	4.20	0.80
POSTNX04	Product quality	Five points likert scale	Bigger, better	210	1.0	5.0	3.80	0.79
GLOBLX02	Conformance to product specifications	Five points likert scale	Bigger, better	210	1.0	5.0	3.92	0.74
GLOBLX10	Product capability and performance	Five points likert scale	Bigger, better	210	1.0	5.0	3.84	0.73
NPDPFX05	Conformance quality	Five points likert scale	Bigger, better	210	1.5	5.0	3.82	0.75
DIMENX08	Overall product quality perceived by customers	Five points likert scale	Bigger, better	210	1.0	5.0	3.83	0.73
SATISR06	In general, our plant's level of quality performance over the past three years has been low, relative to industry norms.	Five points likert scale	Bigger, better	210	1.0	5.0	2.41	1.15
SATISN04	Customer standards are always met by our plant.	Five points likert scale	Bigger, better	210	1.5	5.0	3.88	0.81
DIMENX04	Conformance to established standards	Five points likert scale	Bigger, better	210	2.5	5.0	3.85	0.73
SUCCSX03	Technical performance relative to specification	Five points likert scale	Bigger, better	210	1.5	5.0	3.75	0.70
NPDPFX01	Performance (functionality)	Five points likert scale	Bigger, better	210	2.0	5.0	3.79	0.68
DIMENX01	Primary product performance characteristics	Five points likert scale	Bigger, better	210	2.5	5.0	3.86	0.69
DIMENX02	Secondary options or features; characteristics that supplement the basic functioning of the product	Five points likert scale	Bigger, better	210	2.0	5.0	3.76	0.66
NPDPFX02	Features	Five points likert scale	Bigger, better	210	2.0	5.0	3.77	0.68
NPDPFX06	Aesthetic appeal of this product	Five points likert scale	Bigger, better	210	2.0	5.0	3.58	0.80
DIMENX07	Aesthetics; how the product looks, feels, sounds, tastes or smells	Five points likert scale	Bigger, better	210	2.0	5.0	3.60	0.77
NPDPFX08	Ease of servicing this product	Five points likert scale	Bigger, better	210	1.5	5.0	3.58	0.74
DIMENX06	Serviceability; ease of repair	Five points likert scale	Bigger, better	210	2.0	5.0	3.54	0.73

Descriptive statistics of Reliability original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
NPDPFX03	Durability (life expectancy)	Five points likert scale	Bigger, better	261	1.0	5.0	3.76	0.75
DIMENX05	Durability; amount of use before the product deteriorates or needs to be replaced	Five points likert scale	Bigger, better	261	2.0	5.0	3.87	0.76
DIMENX03	Reliability of the product; probability of failure in a specified time	Five points likert scale	Bigger, better	261	2.0	5.0	3.86	0.72
NPDPFX04	Reliability (time between failures)	Five points likert scale	Bigger, better	261	2.0	5.0	3.78	0.81

Descriptive statistics of Speed original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
SPEED N04	We are selected by our customers because of our reputation for fast delivery.	Five points likert scale	Bigger, better	181	1.0	5.0	3.47	0.92
SPEED N01	Fast delivery is the most important criterion used by our customers in selecting us as a supplier.	Five points likert scale	Bigger, better	181	1.0	5.0	3.46	0.92
GLOBL X04	Fast delivery	Five points likert scale	Bigger, better	181	1.0	5.0	3.84	0.84
NPDPF X13	Our ability to rapidly deliver	Five points likert scale	Bigger, better	181	2.0	5.0	3.55	0.81
GLOBL X09	Speed of new product introduction into the plant (development lead time)	Five points likert scale	Bigger, better	181	1.5	5.0	3.56	0.91
DISTIX11	Agile manufacturing	Five points likertscale	Bigger, better	181	1.0	5.0	3.75	0.92
GLOBL X08	Cycle time (from raw materials to delivery)	Five points likertscale	Bigger, better	181	1.0	5.0	3.70	0.87

Descriptive statistics of client results original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
POSTN X05	Brand image	Five points likert scale	Bigger, better	241	1.0	5.0	3.82	0.91
NPDPF X10	Market share	Five points likert scale	Bigger, better	241	1.0	5.0	3.47	0.90
SUCCS X02	Market share	Five points likert scale	Bigger, better	241	1.0	5.0	3.48	0.87
SATISN 03	We have a large number of repeat customers.	Five points likert scale	Bigger, better	241	2.0	5.0	4.40	0.67
SATISN 07	Our plant satisfies or exceeds the requirements and expectations of our customers.	Five points likert scale	Bigger, better	241	2.0	5.0	3.84	0.75
SATISN 01	Our customers are pleased with the products and services we provide for them.	Five points likert scale	Bigger, better	241	2.0	5.0	3.96	0.70
SATISN 05	Our customers have been well satisfied with the quality of our products, over the past three years.	Five points likert scale	Bigger, better	241	1.0	5.0	3.83	0.79
SATISN 02	Our customers seem happy with our responsiveness to their problems.	Five points likert scale	Bigger, better	241	1.5	5.0	3.92	0.76
SUCCS X01	Customer satisfaction	Five points likert scale	Bigger, better	241	2.0	5.0	3.78	0.68
NPDPF X07	Customers' perception of this product	Five points likert scale	Bigger, better	241	2.0	5.0	3.75	0.74

Descriptive statistics of financial results original variables

Code	Respondent Option	Type of question	Analysis procedure	N	Minimum	Maximum	Average	Std. Deviation
GLOBL X25	Throughput: the rate at which the plant generates money through sales	Five points likert scale	Bigger, better	271	1.0	5.0	3.53	0.83

Appendix D – Procedural Framework Questionnaires

Operations strategy questionnaire

Step 1: Operations Strategy Identification Collect operations strategy performance data		
Focused product line:		
Focused client vision:		
Please, considers the competitive criteria definition as follows		
Competitive Priority	**Definition**	
Costs	Offer products at lower costs than competitors or be cost-efficient. Costs are about the ability to optimize the utilization of manufacturing resources.	Slack and Lewis (2018), Lotfi and Saghiri (2018), Sansone et al. (2017).
Dependability	Fulfill the promises of deadline delivery. Besides on-time delivery, it also Includes delivery date estimation and communication.	Slack and Lewis (2018), Yusuf et al. (2014).
Environmental Factors	Items of the production process and product that interfere in the protection of the environment	Vivares-Vergara et al. (2016); Díaz-Garrido et al. (2011).
Flexibility	Have the capacity to adapt the operation whenever necessary and quickly enough, either by changes in demand or by needs of the production process. Cope with ever-changing market demands.	Slack and Lewis (2018), Slack and Brandon-Jones (2018), Asadi et al. (2017), Dey et al. (2019).
Innovativeness	Capacity to engaging in innovation, which in its turn is related to the introduction of a new process, products, and ideas in the organization	Hult et al. (2004), Laosirihongthong et al. (2014).
Quality	Offer products according to the design specifications.	Slack and Lewis (2018), Bernroider et al. (2014), Chen and Tan (2013).
Reliability	Quality of being trustworthy or of performing consistently well. Reliability is approached as a criterion detached from quality from some authors.	Slack et al. (1997). Narkhede (2017).
Speed	Deliver to the customer faster than competitors	Slack and Lewis (2018), Vázquez-Bustelo et al. (2007)

Importance Scale

According to the Nine-point Importance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Order-winning objectives	1. Provide a crucial advantage with customers - they are the main thrust of competitiveness;
	2. Provide an important advantage with most customers - they are always considered by customers;
	3. Provide a useful advantage with most customers - they are usually considered by customers;
Qualifying objectives	4. Need to be at least up to good industry standard;
	5. Need to be around the median industry standard;
	6. Need to be within close range of the rest of the industry;
Less important objectives	7. Do not usually come into customers' consideration, but could become more important in the future;
	8. Very rarely come into customers' considerations;
	9. Never come into consideration by customers and are never likely to do so.

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

According to the Nine-point Performance Scale, Indicate the index that fit better with the importance of the performance objectives (you must have only one index to each performance objective)

Better than competitors	1. Consistently considerably better than our nearest competitor;
	2. Consistently clearly better than our nearest competitor;
	3. Marginally better than our nearest competitor;
The same as competitors	4. Often marginally better than most competitors;
	5. About the same as most competitors;
	6. Often within striking distance of the main competitors;
Worse than competitors	7. Usually marginally worse than most competitors;
	8. Usually worse than most competitors;
	9. Consistently worse than most competitors?

Operations Strategy Performance Criteria		Quality	Process	Product	SCM	Environmental	Plant Management				
1)	Costs										
2)	Dependability										
3)	Environmental Factors										
4)	Flexibility										
5)	Innovativeness										
6)	Quality										
7)	Reliability										
8)	Speed										

Competitive strategy questionnaire

Step 3: Frontier Identification Collect input/output performance data							
Fator/Variavel original	Question	1	2	3	4	5	People in Charge
	Question	Options					People in Charge
Manufacturing costs, including operating expense	Question	1	2	3	4	5	People in Charge
Manufacturing Costs	How do your plant's products compare to its leading competitors, on Product selling price?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Unit cost of manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Labor cost ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing Costs	How does your plant compare with its competitors in its industry, on a global basis, on Operating expense: funds spent to generate turnover, including direct labor, indirect labor, rent, utility expenses and depreciation?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Manufacturing costs - recently launched products	Question	1	2	3	4	5	People in Charge
Manufacturing costs - recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in of each of the following areas? Unit manufacturing cost	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Manufacturing costs - recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors (Unit cost of manufacturing)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Dependability performance	Question	1	2	3	4	5	People in Charge
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: The promises that our plant makes to its customers are reliable.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Dependability performance	How does your plant compare with its competitors in its industry, on a global basis, on On-time delivery performance?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Dependability performance	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for punctual delivery	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Question	1	2	3	4	5	Respondent
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers select us because we deliver flexibly for their needs	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: Our customers can rely on us for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Costumer vision about company flexibility	Indicate the extent to which you agree or disagree with each of the statement: We are selected by our customers because of our reputation for flexibility.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Production system capacity of changing production mix and volume in the vision of the plant manager	Question	1	2	3	4	5	Respondent
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change product mixt ?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Production system capacity of changing production mix and volume in the vision of the plant manager	How does your plant compare with its competitors in its industry, on a global basis, on Flexibility to change volume?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product customization	Question	1	2	3	4	5	Respondent
Product customization	Indicate the extent to which you agree or disagree with The statement: We are highly capable of large scale product customization.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can easily add significant product variety without increasing cost.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product customization	Indicate the extent to which you agree or disagree with The statement: We can customize products while maintaining high volume.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Speed performance	Question	1	2	3	4	5	Respondent
Speed performance	How do your plant's products compare to its leading competitors, on Fast delivery?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Speed of new product introduction into the plant (development lead time)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Agile manufacturing?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Speed performance	How do your plant's products compare to its leading competitors, on Cycle time (from raw materials to delivery)?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management

Quality performance compared to competitors	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Overall product quality perceived by customers?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Conformance to established standards?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Primary product performance characteristics?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Secondary options or features; characteristics that supplement the basic functioning of the product?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Aesthetics; how the product looks, feels, sounds, tastes or smells?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors	How does the quality of your plant's products compare to its competitors' products on Serviceability; ease of repair?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Quality performance compared to competitors in recently launched products	Question	1	2	3	4	5	Respondent
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Conformance quality?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Performance (functionality)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Quality performance compared to competitors in recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Features?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Durability; amount of use before the product deteriorates or needs to be replaced?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability performance compared to competitors in recently launched products	How does the quality of your plant's products compare to its competitors' products on Reliability of the product; probability of failure in a specified time?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Quality Management
Reliability	Question	1	2	3	4	5	Respondent
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Durability (life expectancy)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Reliability performance compared to competitors – quality management vision'	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Reliability (time between failures)?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Capacity of environmental practices positively influence other company's results'	Question	1	2	3	4	5	Respondent
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Being environmentally conscious can lead to substantial cost advantages for our plant.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can realize significant cost savings by experimenting with ways to improve the environmental quality	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can enter lucrative new markets by adopting environmental strategies.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Our plant can increase market share by making our current products more environmentally friendly.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Reducing the environmental impact of our plant's activities will lead to a quality improvement in our products and processes.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Capacity of environmental practices positively influence other company's results	Indicate the extent to which you agree or disagree with each of the statement: Better environmental performance can differentiate our plant from our competitors.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Plant Management
Overall environmental performance	Question	1	2	3	4	5	Respondent
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Environmental performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How have the following outcomes changed for your plant, as a result of undertaking environmental initiatives:Regulatory performance ?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs
Overall environmental performance	How does your plant compare to others in your global industry, in Overall environmental performance?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Environmental Affairs

Process technology innovativeness	Question	1	2	3	4	5	Respondent
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We quickly adopt new technologies by applying what we learn from our customers.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Downstream SCM
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We often fail to achieve the potential of new process technology.	Strongly agree	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Strongly disagree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: As new technologies emerge, we modify our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: There are no substitutes for our production technology.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our plant stays on the leading edge of new technology in our industry.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Indicate the extent to which you agree or disagree with the statement: Our current production technology is protected by patents.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Process technology innovativeness	Which term best describes the plant's posture toward new processes?	Never adopts new processes	Usually among the last to adopt new processes	Adopts new processes when it becomes more or less the general rule	Among the first to adopt new process, but not the leader	Leader in new processes	Process Engineering
Equipment technology innovativeness	Question	1	2	3	4	5	Respondent
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We frequently modify equipment to meet our specific needs.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We produce a substantial amount of our equipment in-house.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: In order to improve equipment performance, we sometimes redesign equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Equipment technology innovativeness	Indicate the extent to which you agree or disagree with the statement: We actively develop proprietary equipment.	Strongly disagree	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Process Engineering
Product innovativeness	Question	1	2	3	4	5	Respondent
Product innovativeness	How does your plant compare with its competitors in its industry, on a global basis, on Product innovativeness?	Much Worse	Somewhat worse	About the same	Somewhat better	Much better	Plant Management
Product innovativeness	Which term best describes the plant's posture toward new products?	Never adopts new products	Among the last to adopt new products	Adopts new products when it becomes more or less the general rule	Among the first to adopt new products, but not the leader	Leader in new products	Product Development
Throughput: the rate at which the plant generates money through sales	Question	1	2	3	4	5	Respondent
Financial Performance	How does your plant compare with its competitors in its industry, on a global basis, on Throughput: the rate at which the plant generates money through sales?	Much Worse	Somewhat Worse	About the Same	Somewhat Better	Much Better	Plant Management
Market Share and customer satisfaction on recently launched products	Question	1	2	3	4	5	Respondent
Market Share and customer satisfaction on recently launched products	How do products that were recently launched by your plant compare with similar products that are manufactured and sold by your competitors on Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Market share?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Market Share and customer satisfaction on recently launched products	How successful have products that were recently launched by your plant been, in terms their goals in Customer satisfaction?	Much worse	Somewhat worse	About the same	Somewhat better	Much better	Product Development
Customer satisfaction	Question	1	2	3	4	5	Respondent
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our plant satisfies or exceeds the requirements and expectations of our customers.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers are pleased with the products and services we provide for them.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers have been well satisfied with the quality of our products, over the past three years.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management
Customer satisfaction	indicate the extent to which you agree or disagree with the statement: Our customers seem happy with our responsiveness to their problems.	Strongly disagree	Disagree domewhat	Neither agree nor disagree	Agree somewhat	Strongly agree	Quality Management