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LUANA BONOME MESSAGE COSTA

LEAN & SIX SIGMA INITIATIVES IN THE FOOD INDUSTRY

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ABSTRACT

Food industry is an important sector that generates significant economic benefits. However, it is an industry that faces many challenges, due to the demanding market that requires a wide range of products, with short delivery times, frequent deliveries, and with price reductions. In view of this scenario, Continuous Improvement (CI) initiatives could assist this sector to deal with its challenges and to survive in the global market. Two widely used and stand as the best CI initiatives are Lean and Six Sigma, that can be integrated in a hybrid approach, Lean Six Sigma, joining their strengths. To understand the relevance of adoption of these initiatives in the food industry context, this research firstly performed a systematic literature review, which found a low amount of papers published, late adoption of the initiatives in the sector, and their low use, indicating the sector lacks familiarity with the subject. In spite of that, some implementation cases showed the sector can benefit with their implementation. Several improvements in food industry's performance can be obtained with their adoption, most of them related to cost reduction. Moreover, it was found that the main barriers to their use are strongly related to sector characteristics and managerial factors. Therefore, a survey was performed to better evaluate the potential for food industry to adopt Lean Six Sigma practices. First, a new multi-item measurement scales reflecting the multidimensional construct, Lean Six Sigma, in the food industry sector, was developed. A two-stage approach was used to ensure validity and reliability of the measurement items and scales. The scales were developed based on an initial set of 13 Lean and Six Sigma constructs and 73 items. They were purified and refined through four rounds of an item-sorting exercise and a prestest conducted using a questionnaire sent via web to fifty respondents (American Food and Beverage sector) from the SurveyMonkey Audience. Then, a large sample of 229 Brazilian and American food industries was used in order to confirm reliability and validity of Lean Six Sigma multi-item scales. The result was 11 constructs and 45 items to measure the adoption of Lean Six Sigma practices in the food sector. Then, a survey was conducted with 145 factories from Brazil and the United States. The findings showed a fragmented use of Lean Six Sigma practices; low adoption of practices related to pull, statistical process control and six sigma role structure; the effect of sector's characteristics to a certain extent in the degree of adoption of Lean Six Sigma practices; and the positive effect of their adoption in the food industry's performance, moderated by their level of experience. So, there is a great potential for the sector to adopt Lean Six Sigma practices; there are opportunities to increase the level of adoption of some practices low explored; expand the level of experience and the maturity of the sector in this field, and consequently, obtain better results with their adoption.

Keywords: Lean manufacturing. Six Sigma. Lean Six Sigma. Food industry. Systematic Literature Review. Survey. Structural Equation Modeling. PLS.

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1 INTRODUCTION

This chapter contextualizes the subject studied; specifying the goals and the importance of the study, as well as it briefly describes the research method used.

1.1 Contextualization and Motivation

The food industry is a highly relevant and important sector for the world economy (ABIA, 2019; CED, 2017; FOODDRINKEUROPE, 2019). Recent reports have shown the economic role of the sector both in developing and developed countries (see ABIA, 2019; CED, 2017; FOODDRINKEUROPE, 2019). In Brazil, the sector registered a growth of 2.08% in revenues in 2018 and was the largest employer in the manufacturing industry (ABIA, 2019). In Europe, it is a major contributor to economy, ahead of other manufacturing sectors, such as the automotive industry and was also the leading employer in 2018 (FOODDRINKEUROPE, 2019). In USA, it accounting for about 5% of gross domestic product and 10 percent of total US employment in 2017 (CED, 2017).

The sector is a massive business and if a factory performs well it will grow (DUDBRIDGE, 2011). It has to satisfy stringent regulations to ensure food safety (DORA et al., 2013a; LIM; ANTONY; ALBLIWI, 2014). Its consumer is very sensitive to issues in the supply chain, i.e. if a food product is unavailable in a store, the consumer may well look elsewhere and the store will have lost business (DUDBRIDGE, 2011). The sector also has to deal with powerful retailers, who demand a wide range of products, short delivery times, frequent deliveries and regular price reductions (JAIN; LYONS, 2009). These pressures lead companies to look for new ways to improve their performance and increase their profits, to stay competitive in the market.

Moreover, the food industry has characteristics that deserve some attention and could be obstacles to improvement initiatives. Some of them are long changeover times, due to compulsory cleaning requirements between batches of different products using the same machinery (DORA; GELLYNCK, 2015a), volatility of product demand and limited shelf-life (VAN KAMPEN; VAN DONK, 2014), complex place to work considering the number of different raw materials and processes that are needed to manufacture the massive variety of foods available in retail (DUDBRIDGE, 2011), be conservative and slow to change (HUNG; SUNG, 2011), low research intensity (BIGLIARDI; GALATI, 2013), among others.

According to Dudbridge (2011) to business in the food sector performs well, costs have to be controlled and minimized, and performance has to be at a high level and consistent. Wastes reduction and lead time shortening could be significant actions, as they have great importance for food industry, especially because the perishable nature of food products (MAHALIK; NAMBIAR, 2010). Reduction of wastes and losses are also relevant and could be an interesting starting point to reduce costs and increase profitability (AKKERMAN; DONK, 2008) and also to meet the global increase of food demand (HALLORAN et al., 2014). Furthermore, the proper operation of the sector is crucial for providing safe, affordable and timely food to the population (IVERT et al., 2015).

In order to better accomplish these improvements, some continuous improvement initiatives could be useful, since they facilitate reaching various organizational manufacturing priorities and goals, such as quality, productivity, cost, delivery, safety and morale (SINGH; SINGH, 2015), being a constant activity that must be done over time (SANCHEZ; BLANCO, 2014).

Among various continuous improvement methodologies, Six Sigma and Lean stand as the best, widely used by various industries and currently referred to as state of the art (ALBLIWI; ANTONY; LIM, 2015; ALHURAISH; ROBLEDO; KOBI, 2017; SALAH; RAHIM; CARRETERO, 2010). They have experienced success in a wide ranging spectrum of industries (PEPPER; SPEDDING, 2010) and their hybrid approach (Lean Six Sigma) can capitalize their strengths (ARNHEITER; MALEYEFF, 2005).

Lean strategies play an important role in eliminating waste and non-value-added activities across the organization; while Six Sigma, through the use of statistical tools and techniques, has the potential to take an organization to an improved level of process performance and capability (KUMAR et al., 2006). Lean Six Sigma uses tools from both approaches with the view to get the best of them, increasing speed and accuracy (LAUREANI; ANTONY, 2017).

Therefore, to evaluate the potential for Food Industry to adopt Lean, Six Sigma and Lean Six Sigma initiatives (L&SSi), first a systematic literature review was conducted. Two research questions were proposed to consolidate the existing knowledge, bring more information, analyze relevant aspects of their implementation, and direct future studies about the field:

RQ1: How is L&SSi evolving within the food industry?

RQ2: How is L&SSi implemented in the food industry?

The systematic literature review found the late adoption of the initiatives in the sector, a few number of studies about the subject, most of them concentrated in Europe and Asia, which have led to the speculation of L&SSi effectiveness in this industry. Hence, to better investigate the adoption of these initiatives in the sector, a survey research is performed to answer the following question:

RQ3: What is the degree of adoption of Lean Six Sigma practices in the food industry?

A set of constructs and items from the well-known instruments of Shah and Ward (2007) and Zu, Fredendall and Douglas (2008) were purified and pretested to assess reliability and validity. Then, a large sample was used to validate and develop a multi-item measurement to reflect Lean Six Sigma concept.

Furthermore, some food industry characteristics seem to affect the adoption of L&SSi practices in the sector, such as seasonality of products and raw materials, quality assurance requirements, long changeover time, perishable products, among others (see ABDULMALEK; RAJGOPAL; NEEDY, 2006; DORA et al., 2014; DORA; GELLYNCK, 2015b; DORA; KUMAR; GELLYNCK, 2015; HUNG; SUNG, 2011; JAIN; LYONS, 2009; JIMÉNEZ et al., 2011; UPADHYE; DESHMUKH; GARG, 2010; VLACHOS, 2015). In order to investigate that, the following question emerged:

RQ4: What is the impact of Food Industry characteristics on the adoption of Lean Six Sigma practices?

Additionally, the study intends to investigate the impact of Lean Six Sigma adoption on food industry's performance, since these initiatives have benefited different sectors (DROHOMERETSKI et al., 2014; MARODIN; SAURIN, 2013; SHAFER; MOELLER, 2012; SHAH; WARD, 2007), so the following question emerged:

RQ5: What is the impact of Lean Six Sigma adoption on food industry's performance?

1.2 Objective

The main objective of this study is to evaluate the potential for food industry to adopt Lean Six Sigma practices. To reach this objective some specific objectives should be achieved. Table 1.1 shows these objectives and how (research method) they are addressed in this study.

Table 1.1 - Specific objectives

Objectives	Chapter of the thesis	How
Specific objective 1 Consolidate the existing knowledge about the adoption of L&SSi in the food industry and analyze relevant aspects of their implementation	3. Lean, Six Sigma and Lean Six Sigma in the food industry: a systematic literature review	Systematic Literature Review
Specific objective 2 Develop new multi-item measurement scales reflecting the multidimensional construct, Lean Six Sigma, in the food industry sector.	4. Lean Six Sigma in the food industry: Construct development and measurement validation	Survey
Specific objective 3 Verify the degree of adoption of Lean Six Sigma practices in the food industry. Specific objective 4 Evaluate the impact of food industry characteristics on the adoption of Lean Six Sigma practices. Specific objective 5 Analyze the impact of adoption of Lean Six Sigma practices on food industry's performance.	5. The effect of Lean Six Sigma practices on food industry performance: implications of sector's experience and typical characteristics	Survey

Source: Proposed by the author.

1.3 Research method release

The research method is a way of doing science, taking care of procedures, tools and paths taken (DEMO, 1985). In the research process, the choice of the method is one of the fundamental decisions to conduct a research (NAKANO, 2010).

The research method selection is directly related to the problem to be studied; their choice will depend of several factors related to research, such as the natural phenomena, the research object, the financial resources, the human team and other elements (LAKATOS; MARCONI, 1995). In the present work two research methods are used, a systematic literature review and a survey research.

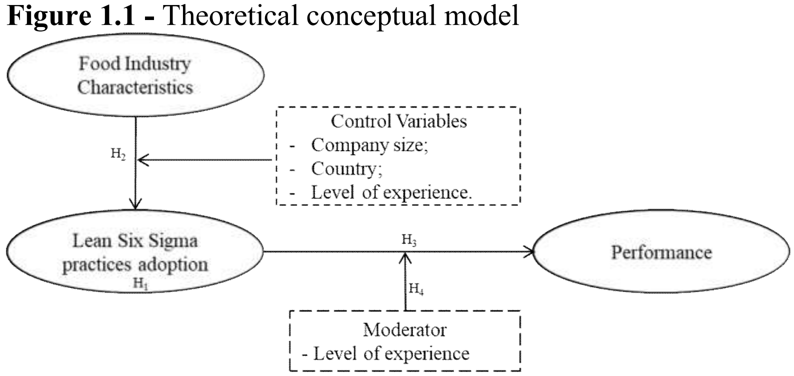
The literature review is a summary of a subject field that supports the identification of specific research questions. They are important in supporting the identification of a research topic, question or hypothesis; identifying the literature to which the research will make a contribution, and contextualizing the research within that literature; building an understanding of theoretical concepts and terminology; facilitating the building of a bibliography or list of the sources that have been consulted; suggesting research methods that might be useful; and in analyzing and interpreting results (ROWLEY; STACK, 2004).

A systematic review is a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthesizes data, and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what we do and do not know (DENYER; TRANFIELD, 2009).

The results obtained through the systematic literature review and also through the theoretical background were used to develop a theoretical conceptual model, illustrated in Figure 1.1 that will be evaluated through a survey research.

In this study, we use Contingency Theory (see SOUSA; VOSS, 2008) to support the first two hypotheses, the fragmented adoption of Lean Six Sigma practices in the food industry and the effect of food industry inherent characteristics on this adoption (H1. Food industry has a narrow view of Lean Six Sigma concept, implementing Lean Six Sigma practices in a fragmented way; H2. Food industry characteristics impact the degree of adoption of Lean Six Sigma practices.). The study is also grounded on Practice Based View (see BROMILEY; RAU, 2016) to support hypothesis 3 and 4, the effect of adoption of Lean Six Sigma practices in the food industry's performance and the moderator effect of level of experience in this performance (H3. The adoption of Lean Six Sigma practices positively impacts food industry performance; H4. The positive effect of Lean Six Sigma practices on food industry performance is moderated by level of experience, such that the positive effect is greater when level of experience is higher.).

Figure 1.1 - Theoretical conceptual model



Source: Proposed by the author.

The survey research is used when the available knowledge on a research issue is very limited, then the concepts are not well defined, measures are not available, lessons from previous empirical research may not be available, associations between concepts and explanations of these associations may be unknown, and so on (FORZA, 2009).

To Malhotra and Grover (1998) a survey research has three specific characteristics:

- Involves collection of information by asking people for information in some structured format, which could be performed using mail questionnaire, telephone interview, or face-to-face interview, depending on the quality and cost tradeoffs involved. The individuals surveyed could be representatives of themselves, their project, their expertise, or their organization, depending on the unit of analysis;
- It is usually a quantitative method that requires standardized information in order to define or describe variables, or to study relationships between variables;
- The information is gathered via a sample, which is a fraction of the population, with the need to be able to generalize findings from the sample to the population.

The survey research is appropriate when: (a) the central questions of interest about the phenomena are "what?", "how?" and "why?"; (b) control of the independents and dependents variables is not possible or not desirable; (c) the phenomena of interest must be studied in their natural setting; (d) the phenomena of interest occurs in the current time or the recent past (PINSONNEAULT; KRAEMER, 1993).

In this study the survey method was chosen mainly for (a), (c) and (d) reasons, once the study aims to answering "what questions" (a) such as "What is the degree of adoption of Lean Six Sigma practices in food industry?", "What is the impact of Food Industry characteristics on the adoption of Lean Six Sigma practices?", among others, in (c) Brazilian and American food industry context, using (d) current industries data.

The survey research can also be classified according to their purpose and their number of moments (FREITAS et al., 2000). Related to their purpose, a survey is classified in exploration, description or explanation (PINSONNEAULT; KRAEMER, 1993):

- Exploration research: has the purpose of becoming more familiar with a topic or identifies preliminary concepts about it. It is used to determine which concepts should be measured and how to measure them best. It is also used to discover and raise new possibilities and dimensions of the interest population;

- Description research: has the purpose of discovering what situations, events, attitudes or opinions are occurring in a population. Describe a distribution of some population phenomena or among subgroups of a population, or make comparisons among the distributions. The hypothesis is not causal, but simply that common perceptions of the facts are or are not odds with reality;
- Explanation research: has the purpose of testing a theory and casual relations, explains how and why the variables are related, and asks why the relationships exist. For example, if the relationship is positive or negative, or if the variable A influence the variable B.

In this study, the survey method is classified as exploration, because aims at becoming more familiar with a topic: the potential for Food Industry to adopt Lean Six Sigma initiatives; and it is also explanation, because aims at investigating the relationship between variables (e.g. the relationship between food industry characteristics and degree of adoption of Lean Six Sigma practices).

The survey classification can also be related to its number of moments or points in time at which the data is collected (SAMPIERI; COLLADO; LUCIO, 1991):

- Longitudinal: the data are collected along the time in periods or points specifics, to analyze the evolution of certain variables and relationships;
- Transversal: collect the data in a single moment to describe and analyze one or more variables in a given time.

In this study the survey research method is classified as transversal, once intends to analyze the variables in a given time.

The use of each method and their steps of execution are described in specific sections of this thesis (3. Lean, Six Sigma and Lean Six Sigma in the food industry: a systematic literature review, 4. Lean Six Sigma in the food industry: construct development and measurement validation, 5. The effect of Lean Six Sigma practices on food industry performance: implications of sector's experience and inherent characteristics).

1.4 Thesis Structure

The present thesis is divided into 7 chapters. The chapters 3, 4 and 5 of this thesis are structured in paper format, so some information appears more than once in the entire thesis. I apologize about that.

Chapter 1 is the introduction. It contextualizes the subject studied; specifying the goals and the importance of the study, as well as it briefly describes the research method used. Chapter 2 is a brief conceptual background about food industry and continuous improvement initiatives studied in this work: Lean, Six Sigma and Lean Six Sigma. Chapter 3 presents a systematic literature review of Lean, Six Sigma and Lean Six Sigma (L&SSi) in the food industry. It is performed in order to increase the knowledge about the subject, understand how L&SSi is evolving within the food industry and, how L&SSi is implemented in the sector to guide research in the area and future implementations. In Chapter 4 is developed and validated a multi-item measurement scale to reflect Lean Six Sigma multidimensional construct. Chapter 5 presents a survey performed in order to verify the degree of adoption of Lean Six Sigma practices in the food industry, the impact of food industry characteristics in Lean Six Sigma adoption, and the impact of Lean Six Sigma adoption in the performance of food industry moderated by companies' experience. Chapter 6 is the conclusion of this research. Chapter 7 presents the bibliographic references used.

2 CONCEPTUAL BACKGROUND

This chapter is a brief conceptual background about food industry and continuous improvement initiatives studied in this work: Lean, Six Sigma and Lean Six Sigma.

2.1 Food Industry

The Food Industry is a process industry, i.e. it handles non-discrete materials that cannot be disassembled and then reassembled (PANWAR et al., 2015). Industries in the food manufacturing transform livestock and agricultural products into products for intermediate or final consumption.

The food industries, for a long time, have a common policy of producing in large batches to keep production costs low and limit the number of set-ups (VAN DONK, 2001). However, the market has changed, it is globalized, and the consumers are more demanding. Retailers and food industries now source their products from all over the world, transforming the food industry towards an interconnected system with a large variety of complex relationships (TRIENEKENS; ZUURBIER, 2008).

Some of the market requirements, such as short lead time and small batches, opposes to the typically production characteristics found in process industries, as in the food industry (batch processes, flow production, sequence dependent cleaning times) (VAN WEZEL; VAN DONK; GAALMAN, 2006), and need special attention.

The sector also has specific characteristics that differentiates it from other type of industries and can interfere in the improvement process performed in the sector. Van Donk (2001) and Dora et al. (2014) show some of these characteristics, grouped into three main aspects: product, production and plant, as illustrated in Table 2.1.

Table 2.1 - Food industry characteristics

Product
- Perishability of raw material, semi-manufactured products, and end products;
- Variability in quality of raw materials and supply;
- Volume and/or weights are used, in contrast to discrete manufacturing.
Production
- Manual and/or minimal automatic operations;
- High variation of composition, recipes, products and processing techniques;
- Variable yield and processing duration;
- Divergent product structure, especially in the packaging stage;
- Short throughput time for batches.
Plant
- Long set-up times between different products;
- Plants are batch processing and have two to six production lines;
- Processing and packaging are separated because of food quality assurance;
- Processing equipment has sequence-dependent cleaning time;
- Small and single-site factories with 30 to 100 employees.

Source: Adapted from Van Donk (2001) and Dora et al. (2014).

The characteristics of food industries, such as perishable products and raw materials, shared resources, divergent product structure, among others imply two limitations: capacity constraints and time constraints (AKKERMAN; VAN DONK; GAALMAN, 2007). The capacity constraints are related to the often-limited number of storage tanks, which normally have to be shared by a multitude of products. These constraints become even more relevant if the number of products is greater than the number of tanks, or if not, all products can be stored in every tank. The second limitation is the time constraints, associated to the perishability of the intermediate food product. Usually, the unpackaged intermediate products are more perishable than packaged products, which make the storage time constraint in the intermediate stage of the production process more important than in other stages (raw material and final products).

Moreover, the primarily focus of the sector is quality assurance to satisfy regulatory requirements and improve food quality safety (DORA et al., 2013a; LIM; ANTONY; ALBLIWI, 2014). The importance of quality has significantly grown in the food sector because of increasing consumers' expectations, governmental regulations and expanding competition in the market (DORA et al., 2013a).

Food poisoning or microbiological outbreaks have been the biggest concern for food producers, governments and consumers (LIM; ANTONY; ALBLIWI, 2014). Attention should be paid in machines' installation, cleanability and maintenance, since they are in contact with food and have control over food quality (DUKE-ROHNER, 2007). Training on hygienic engineering of all concerned, suppliers and users, is critical (DUKE-ROHNER, 2007).

Food Safety Management System (FSMS) such as Good manufacturing practices (GMP), Hazard Analysis and Critical Control Points (HACCP), British Retail Consortium (BRC) and International Organization for Standardization (ISO) enable the application and verification of control measures intended to assure the quality and safety of food (DORA et al., 2013a; TRIENEKENS; ZUURBIER, 2008; TUTU; ANFU, 2019).

Good Manufacturing Practices are a set of principles and rules to be adopted by the food industry in order to ensure the sanitary quality of their products (TUTU; ANFU, 2019). HACCP is a systematic approach to analyze hazards (biological, chemical or physical; identify critical control points (these are points in a food's production at which the potential hazard can be controlled or eliminated.); establish preventive measures with critical limits for each control point; establish procedures to monitor the critical control points; establish corrective actions to be taken when monitoring shows that a critical limit has not been met; establish procedures to verify that the system is working properly; and establish effective recordkeeping to document the HACCP system (TRIENEKENS; ZUURBIER, 2008).

The BRC Global Standards began when the British Retail Consortium (BRC), in response to industry needs, developed the BRC Food Technical Standard, first published in 1998 (BRC, 2019). BRC system reinforces the fundamental HACCP system (CHAONIRUTHISAI; PUNNAKITIKASHEM; RAJCHAMAHA, 2018). It focuses on: encouraging development of product safety culture; expanding the requirements for environmental monitoring to reflect the increasing importance of this technique; encouraging sites to further develop systems for security and food defense; adding clarity to the requirements for high-risk, high-care and ambient high-care production risk zones; providing greater clarity for sites manufacturing pet food; and ensuring global applicability and benchmarking to the Global Food Safety Initiative (GFSI) (BRC, 2019).

ISO standards are international standards in order to achieve uniformity and to prevent technical barriers to trade throughout the world (TRIENEKENS; ZUURBIER, 2008). ISO 22000 sets out the requirements for a food safety management system and can be certified (ISO, 2019). It maps out what an organization needs to do to demonstrate its ability to control food safety hazards in order to ensure that food is safe (ISO, 2019).

While Food Safety Management System satisfies regulatory requirements and improves food quality safety, continuous improvement initiatives (e.g. Lean and Six Sigma) help companies to improve current business processes (DORA et al., 2013a).

2.2 The continuous improvement initiatives: Lean, Six Sigma and Lean Six Sigma

Continuous improvement initiatives are important tools to support the improvement of companies. Some of them come and go, however improving the bottom line never goes out of style (SNEE, 2010). Already in 1990s impressive results have been reported with their use in a growing number of firms (CAFFYN, 1999).

Nowadays, the importance of continuous improvement in business environment can be associated with three major phenomena: changes in the business environment, the emergence of new management systems, and the importance of quality management itself (SANCHEZ; BLANCO, 2014).

It involves all organizational participants working together to make improvements without necessarily making huge capital investments, and also can be defined as a culture of sustained improvement with the aim of waste elimination in all organizational systems and processes (SINGH; SINGH, 2015). It is considered the most effective way to increase productivity and maintain competitiveness for any manufacturing system (LI, 2013), and it is widely practiced by manufacturing firms to improve quality, reduce lead times, reduce price and improve delivery reliability (SINGH; SINGH, 2012).

Lean manufacturing, Six Sigma and, more recently, Lean Six Sigma are referred as operations management models that contribute to the continuous improvement of company processes (DROHOMERETSKI et al., 2014) in manufacturing and service sectors, as well as in the public sector (ALBLIWI; ANTONY; LIM, 2015; LEE; CHOI, 2006).

The term “Lean” was first used in 1988 by Krafcik (KRAFCIK, 1988), and subsequently, by Womack, Jones, and Roos in the ‘Machine’ book in 1990 (WOMACK; JONES; ROOS, 1990) to contrast Toyota with the Western ‘mass production’ system (HOLWEG, 2007).

This system emerged from the need faced by Japanese industry in the period after World War II, in which the market required the production of small quantities of many varieties under low demand conditions, but it had not attracted the attention of Japanese industry until the first petroleum crisis in 1973 (OHNO, 1997). This crisis renewed the interest in researching the future of the automotive industry, the starting point of the International Motor Vehicle Program at MIT (HOLWEG, 2007).

The Lean thinking is based on five principles highlighted by Womack and Jones (1996):

- Specify Value from the customer perspective;

- Identify the Value Stream to each product or service to eliminate wastes;
- Implement Continuous Flow;
- Introduce Pull Systems where the flow is not possible;
- Pursue Perfection.

The organization structure is transformed from traditional, characterized as top-down with project-driven improvement, led by middle managers, into one where continuous improvement is conducted throughout the company by those teams close to the work processes (FULLERTON et al., 2014).

It is an improvement initiative designed to increase productivity by eliminating waste. These wastes can be classified in seven different types: transportation, inventory, motion, waiting, over-processing, over-production, and defects (OHNO, 1997). The elimination of two of them, inventory and defects, have been the focus of many articles, according to the recent literature review of Jasti and Kodali (2015), since both influence the cost of product directly.

The implementation of Lean manufacturing can be influenced by many factors, such as management support and/or commitment (MARODIN; SAURIN, 2013), lack of direction, lack of planning and lack of adequate project sequencing (BHASIN; BURCHER, 2006), internal resistance (SHAMAH, 2013), tools selection (ANVARI et al., 2014; ANVARI; ZULKIFLI; ARGHISH, 2014). Moreover, according to Panwar et al. (2015) initiatives such as Lean need to be carefully adapted to be implemented in a new environment, considering the process, supply chain, market characteristics and other contingency factors.

In the process industry some Lean tools are largely applicable than others. These tools do not depend on the process characteristics such as 5S, Total Productive Maintenance (TPM), quality management programs, Value Stream Mapping (VSM), work standardization, and team-based problem-solving. On the other hand, Lean techniques such as stopping the line, cellular manufacturing and focused factory are examples of tools that either require customization or could not be used in process industry (PANWAR et al., 2015).

Six Sigma is an improvement concept developed at Motorola nearly the mid-1980s. At the time, Motorola was one of many United States and European corporations that were facing the threat of Japanese competition and also had problems with the awful quality of their products. Like many companies at the time, Motorola did not have one “quality” program, it had several. However, in 1987, a new approach came out of Motorola’s Communications Sector, the innovative improvement concept called “Six Sigma” (PANDE;

NEUMAN; CAVANAGH, 2000). Using Six Sigma, Motorola became known as a quality and a profit leader (PYZDEK; KELLER, 2010).

Sigma, σ, is a letter in the Greek alphabet used by statisticians to measure the variability in any process (PYZDEK; KELLER, 2010). The sigma level measures the company's performance of their business processes. It is believed that most organizations operate at Three Sigma, which translates to 66,000 errors per million (MEHRJERDI, 2011). The Six Sigma suggests a goal of 3.4 defects per million opportunities (DPMO) (LINDERMAN et al., 2003).

Six Sigma can have several definitions; in a recent literature review, four interpretations were identified. The first stream defines Six Sigma as a set of statistical tools; the second as an operational philosophy of management; the third as a business culture; and the fourth as an analysis methodology that uses scientific methods. The streams are not mutually exclusive but, instead, overlapping (TJAHJONO et al., 2010).

One key to the success of the Six Sigma program is the step-by-step approach or roadmap, using define, measure, analyze, improve and control (DMAIC) methodology (ANTONY; BANUELAS, 2002). According to Pyzdek and Keller (2010) the five DMAIC phases are defined as follows:

- Define (D) the goals of the improvement activity;
- Measure (M) the existing system;
- Analyze (A) the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal;
- Improve (I) the system;
- Control (C) the new system.

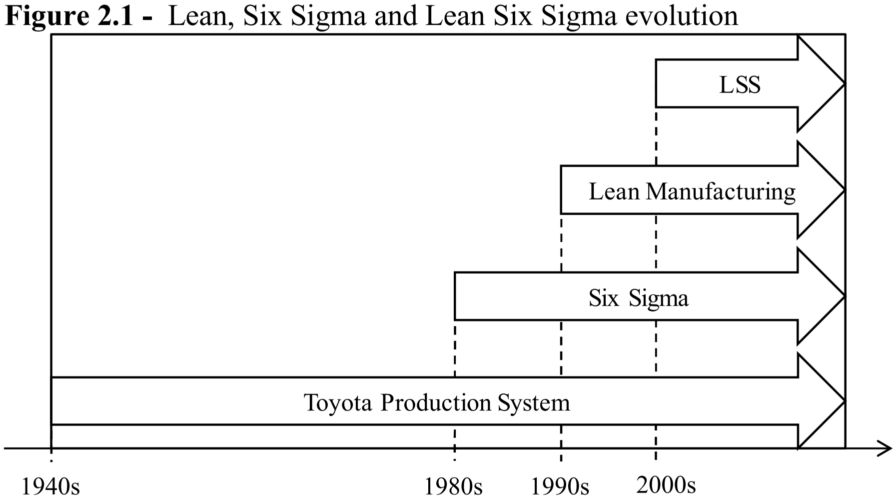
Under DMAIC methodology a large range of tools can be used in Six Sigma implementation. Some of them are statistical process control, process capability analysis, process charts, SIPOC (Supplier Input Process Output Customer), measurement system analysis, Pareto, histogram, control charts, design of experiments (DOE), robust design, quality function deployment (QFD), failure mode and effects analysis (FMEA), analysis of variance (ANOVA), regression analysis, analysis of mean and variances, hypothesis testing, process mapping and standardization, among others (MEHRJERDI, 2011; MOOSA; SAJID, 2010).

As people master the tools and techniques of Six Sigma and carry out more and more projects, they stand to gain experience in scientific problem solving. Also project-by-project success influences the business performance (ARUMUGAM; ANTONY; LINDERMAN, 2014).

The integration of Lean and Six Sigma and the raise of the term Lean Six Sigma (LSS) occurred around 2000s, with the aim of maximize shareholder value, by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital, achieved by merging tools and principles from both approaches (GEORGE, 2002; LAUREANI; ANTONY, 2011).

Figure 2.1 illustrates the historical evolution of these continuous improvement initiatives based on Womack, Jones, and Roos (1990), Ohno (1997), Pande, Neuman and Cavanagh (2000) and George (2002).

Figure 2.1 - Lean, Six Sigma and Lean Six Sigma evolution



Source: Proposed by the author.

Finding the optimal combination of the initiatives is important. This combination provides an overarching improvement philosophy that incorporates powerful data-driven tools to solve problems and create rapid transformational improvement at lower cost (SHAHIN; ALINAVAZ, 2008).

The choice of the tools and techniques related with Lean Six Sigma initiatives allows the organizations to deal with a range of different problems. The tools used in the initiatives were not all invented in these methodologies, but they were used in a structured approach to form each methodology. Certain tools might be more suitable than others depending on the nature of problem or opportunity faced (SALAH; RAHIM; CARRETERO, 2010).

Lean, Six Sigma and Lean Six Sigma can be compared in relation of some important aspects (see AKBULUT-BAILEY; MOTWANI; SMEDLEY, 2012; BHUIYAN; BAGHEL; WILSON, 2006; PACHECO et al., 2015). Table 2.2 illustrates some of their similarities and differences.

Table 2.2 - Comparison of Lean, Six Sigma and Lean Six Sigma aspects

Aspects	Lean	Six Sigma	Lean Six Sigma
Objective	Provide high value to the customer by reducing waste.	Product and process improvement; minimization of variation.	Reduce variation; speed up production; reduce waste.
Principles	Use the best practices and process to improve efficiency, reduce costs and speed up the process.	Keep the number of defects below 3.4 per million opportunities.	Use the best practices of Six Sigma and Lean; increase market share of organizations.
View of waste	Non-value adding activities.	Variation.	Non-value adding activities; variation.
Focus	On the flow.	On the problem.	Simultaneous focus on eliminating problems and improving production flow.
Methodology/ Applicability structure	Identify value; Map the value stream; Implement flow; Introduce pull; Search for perfection.	Define; Measure; Analyze; Improve; Control.	Tools used in Six Sigma and Lean.
Tools and Techniques	Value stream mapping, work cell design, 5S, mistake proofing, set-up reduction, takt time, visual controls, among others.	Statistical process control charts (histograms, normal distribution graphs, flowcharts etc.) and quality management tools (activity network diagrams, affinity diagrams etc.).	Tools used in Six Sigma and Lean.
Deficiencies	Not based on statistical or analysis systems; restrict focus on losses.	Do not consider interdependencies within the system; process improvements are achieved independently; creates employee elite.	Lack of a structured methodology to use the Lean and Six Sigma approaches in converging and complementary way.
KPI	Value provided to the customer.	Number of defects; customer satisfaction.	Customer satisfaction; market share.

Source: Adapted from Akbulut-Bailey, Motwani, and Smedley (2012), Bhuiyan, Baghel, and Wilson (2006), Pacheco et al. (2015).

Antony (2011) also highlights some differences between the methodologies. Six Sigma application requires more intense training and more investment compared to Lean methodology; Lean is fundamentally used to tackle process inefficiency issues whereas Six Sigma is primarily used to tackle process effectiveness issues; Six Sigma will eliminate defects in processes, but it will not address the question of how to optimize process flow, in contrast, Lean principles are not very helpful in achieving high capability and high stability processes.

Lean and Six Sigma also differ in the role of the management. In Lean, a bottom up approach, management plays a supportive and facilitating role in engaging shop-floor workers to form cross-functional self-directed work teams and apply Lean tools. In Six Sigma, management plays a more active role often selecting improvement projects based on financial and strategic goals, and championing and monitoring the improvement projects (SHAH; CHANDRASEKARAN; LINDERMAN, 2008).

To choose the appropriate initiative and tools, not only the nature of the problem needs to be considered, but also the improvement to be pursued and the root causes. In the cases when shifting the process average or reducing process variation is appropriate for the problem, Six Sigma will dominate, and in cases when improving process flow or reducing process complexity is appropriate, Lean tools may dominate (SNEE, 2010).

The application of these initiatives can be performed in different ways. Salah, Rahim, and Carretero (2010) suggest six possible models: (1) Lean as an encompassing methodology that uses Six Sigma as a tool within it; (2) Six Sigma as an encompassing methodology that forces some Lean tools into the DMAIC structure; (3) Six Sigma and Lean used separately from each other (to tackle different problems), according to the classification of the project; (4) apply both in parallel (as when applied to the same problem, but separately); (5) apply one after another in series (as when applied to the same problem); (6) and apply both simultaneously. To leverage the synergy between the initiatives, the authors affirm that is important that Six Sigma and Lean are used simultaneously, so they should not be used in parallel.

In the food industry, the adoption of Lean, Six Sigma and Lean Six Sigma is analyzed in Chapter 3 through a systematic literature review.

3 LEAN, SIX SIGMA AND LEAN SIX SIGMA IN THE FOOD INDUSTRY: A SYSTEMATIC LITERATURE REVIEW

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4 LEAN SIX SIGMA IN THE FOOD INDUSTRY: CONSTRUCT DEVELOPMENT AND MEASUREMENT VALIDATION

In this chapter a multi-item measurement scale was developed and validated to reflect Lean Six Sigma multidimensional construct.

4.1 Introduction

Lean Six Sigma (LSS) is the combination of Lean manufacturing and Six Sigma, which are two Continuous Improvement (CI) Initiatives that organizations adopt to improve their performance and competitiveness. Lean is an improvement initiative designed to do more with less while providing customers exactly what they want (WOMACK; JONES; ROOS, 1990). Six Sigma is an improvement initiative that uses a large range of tools in a series of steps named DMAIC (define, measure, analyze, improve and control). Six Sigma seeks to find and eliminate causes of mistakes or defects in business processes by focusing on outputs that are of critical importance to customers (ANTONY; BANUELAS, 2002; MEHRJERDI, 2011; MOOSA; SAJID, 2010; SNEE, 2000).

The term "Lean" was first used by Krafcik in 1988 (KRAFCIK, 1988) to describe the Toyota Production System, and subsequently, by Womack, Jones, and Roos (1990) in a study that contrasted Toyota to the Western 'mass production' system (HOLWEG, 2007). Six Sigma was developed at Motorola by an engineer Bill Smith during the mid-1980s (SNEE, 2000, 2010). The term "Six Sigma" refers to a statistically derived performance target of operating with only 3.4 defects for every million activities or "opportunities" (PANDE; NEUMAN; CAVANAGH, 2000). Sigma, σ, is a letter in the Greek alphabet (PYZDEK; KELLER, 2010) by statisticians to measure the variability in any process. The name Six Sigma suggests a goal of 3.4 defects per million opportunities (DPMO) and 99.99966% process yield that requires a very aggressive improvement efforts (LINDERMAN et al., 2003). The "per million opportunities" aspect of the Six Sigma metric is critical because it allows you to compare the capability of widely different processes (PANDE; NEUMAN; CAVANAGH, 2000).

The integration of both, Lean and Six Sigma into LSS occurred around 2000s. The goal was to maximize shareholder value, by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital by merging the tools and principles of both approaches (GEORGE, 2002; LAUREANI; ANTONY, 2011). It is an initiative that relies on a collaborative team effort to improve performance (RAJAK; NIRAJ; KUMAR, 2016). From a business perspective, LSS allows companies to drastically identify the customer desires, eliminate all non-value-added activities and reduce the variability within the production process (YADAV; DESAI, 2016).

Lean and Six Sigma are multi-dimensional initiatives that encompass different set of practices, which complement and mutually support each other. Their adoption can be measured by multi-item scales. There are some studies in the literature that present instruments to measure Lean (see AGUS; HAJINOOR, 2012; CHAVEZ et al., 2014; NAWANIR; TEONG; OTHMAN, 2013; SHAH; WARD, 2007) and to measure Six Sigma (see CHOI et al., 2012; LEE; CHOI, 2006; SCHROEDER et al., 2008; ZU; FREDENDALL; DOUGLAS, 2008). The adoption of the hybrid initiative, LSS, can be measured by the integrating these existing measures (CORBETT, 2011). However, these modified multi-item scales should undergo a new and rigorous process of reliability and validity testing to ensure they measure LSS (FORZA, 2002).

This study developed the new multi-item measurement scales to measure LSS, in the food industry sector. Since no universal set of practices is applicable in all organizational contexts (GINSBERG; VENKATRAMAN, 1985; SOUSA; VOSS, 2008), the resulting validity and reliability analysis is appropriate only for the food industry without further testing. This is however an important contribution given the food industry's considering the importance of this sector to the world economy (AMORIM et al., 2016; BIGLIARDI; GALATI, 2013; HAQ; BODDU, 2017; MOHEZAR; NOR, 2014). The industry also has quite unique characteristics and quality assurance requirements to deliver safe and competitive products to powerful retailers and demanding customers (COSTA et al., 2018; DORA et al., 2014). Creating valid, reliable scales is also important due to the scarcity of studies of Lean, Six Sigma & Lean Six Sigma Initiatives (L&SSi) in this industry and the potential of L&SSi to improve the food industry's performance (COSTA et al., 2018).

4.2 Lean Six Sigma concept

Despite their different origins, Lean and Six Sigma initiatives, share some commonalities, such as an emphasis on a culture of continuous improvement, customer satisfaction, comprehensive employee involvement, and searching for the root causes (LAUREANI; ANTONY, 2017). They have been applied by many organizations to improve their business processes (AQLAN; AL-FANDI, 2018). The hybrid approach allows the organizations to deal with a range of different problems using tools and techniques from both initiatives.

Lean is directly descended from and is frequently used as a proxy for Toyota Production System, which itself evolved from Taiichi Ohno's experiments and initiatives over three decades at Toyota Motor Company (SHAH; WARD, 2007). The Toyota Production System emerged from the need faced by Japanese industry in the period after World War II, in which the market required the production of small quantities of many product varieties under low demand conditions, but it had not attracted the attention of Japanese industry until the first petroleum crisis in 1973 (OHNO, 1997). This crisis also renewed the interest in researching the future of the automotive industry, which was the starting point of the International Motor Vehicle Program at MIT (HOLWEG, 2007).

Lean emphasizes excellence through the elimination of waste and a focus on continuous improvement (FULLERTON et al., 2014). Lean focuses on enhancing value (or perceived value) to customers by adding product or service features and/or removing wasteful activities (HINES; HOLWEG; RICH, 2004). Lean practices enable the production of a larger variety of products at a lower cost and higher quality while using fewer resources compared to traditional mass production practices (MARODIN et al., 2018). It is one of the most common initiatives in Operations Management that firms adopt to boost their competitiveness (ABREU-LEDÓN et al., 2018). Womack and Jones (1996) argued that Lean is based on five principles. that involve the specification of value from the customer perspective; identification of the value stream to each product or service to eliminate wastes; implementation of continuous flow; introduction of pull systems where the flow is not possible; and finally the pursuit of perfection (WOMACK; JONES, 1996).

While, Six Sigma is an initiative created by Motorola to make drastic improvements in their quality levels to face Japanese competition in the mid-1980s (LINDERMAN et al., 2003; SHAFER; MOELLER, 2012). Early successes in Motorola and other high profile companies such as Allied Signal (now Honeywell), and General Electric helped to both popularize and legitimize the approach (SWINK; JACOBS, 2012). Six Sigma evolved into a comprehensive and flexible system for achieving, sustaining and maximizing business success, uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes (PANDE; NEUMAN; CAVANAGH, 2000). To accomplish this, Six Sigma typically involves the creation of a hierarchical structure to provide dispersed and specialized training efforts, and allows for cross-functional project execution (SWINK; JACOBS, 2012). A variety of both part-time and full-time improvement specialists is involved to achieve its goals, including Full-time Black Belts, who lead improvement projects and typically receive 4 weeks of training; Master Black Belts, who receive even more training, and generally serve as instructors and internal consultants; Green Belts, who are part-time improvement specialists that receive less training since they provide supporting roles on the improvement projects; and Project Champions who identify strategically important projects for the improvement teams and provide resources, typically receive an orientation to Six Sigma rather than detailed training (LINDERMAN et al., 2003). So, Six Sigma adoptions usually involve large resource expenditures, however, provide significant returns in both general and specific performance metrics employed at multiple levels of the organization (JACOBS; SWINK; LINDERMAN, 2015; SCHROEDER et al., 2008).

The tools used in Six Sigma adoption are applied within a structured method known as DMAIC (Define-Measure-Analyze-Improve-Control), which is described as follows (PYZDEK; KELLER, 2010):

- Define the goals of the improvement activity.
- Measure the existing system.
- Analyze the system to identify ways to eliminate the gap between the current performance of the system or process and the desired goal.
- Improve the system.
- Control the new system.

LSS unified the strengths of both initiatives, integrating human and process aspects of process improvement (SNEE, 2010). It can be represented by the integration of Lean and Six Sigma measurement models identified from the past literature, since existing and preferably validated scales should be adopted or adapted wherever possible (MALHOTRA; GROVER, 1998).

In this study the scales proposed by Shah and Ward (2007) to represent Lean concept and the scales proposed by Zu, Fredendall and Douglas (2008) to represent Six Sigma were selected to be integrated and validated as measures of Lean Six Sigma in the food industry. These instruments were validated with a sample of 280 and 226 companies respectively and are more comprehensive than others found in the literature (e.g. AGUS;

HAJINOOR, 2012; CHAVEZ et al., 2014; CHOI et al., 2012; LEE; CHOI, 2006; NAWANIR; TEONG; OTHMAN, 2013; SCHROEDER et al., 2008).

Shah and Ward (2007) defined Lean as an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability. They identified 10 constructs in their study to map onto the Lean conceptual definition. Three of them measure supplier involvement, one measures customer involvement, and the remaining six address issues internal to the firm (see Figure 4.1). To measure each of them the authors proposed 48 items.

Figure 4.1 - Lean manufacturing constructs

Supplier related	- Supplier feedback: provide regular feedback to suppliers about their performance; - JIT delivery by suppliers: ensures that suppliers deliver the right quantity at the right time in the right place; - Supplier development: develop suppliers so they can be more involved in the production process of the focal firm.
Customer related	- Customer involvement: focus on a firm's customers and their needs.
Internally related	- Pull: facilitate JIT production including kanban cards which serves as a signal to start or stop production; - Continuous flow: establish mechanisms that enable and ease the continuous flow of products; - Set up time reduction: reduce process downtime between product changeovers; - Total productive/preventive maintenance: address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability; - Statistical process control: ensure each process will supply defect free units to subsequent process; - Employee involvement: employees' role in problem solving, and their cross functional character.

Source: Shah and Ward (2007).

Zu, Fredendall, and Douglas (2008) describe Six Sigma through three dimensions (see Figure 4.2) that augment the traditional Quality Management practices and provide new paths to quality improvement. These three Six Sigma dimensions suggests that the deployment of Six Sigma entails establishing a Six Sigma role structure within the organization's human resource management system, instituting the structured improvement procedure as a formal paradigm of conducting improvement projects, and emphasizing using quantitative objective metrics in quality improvement. They are firstly represented by 25 items.

Figure 4.2 - Six Sigma constructs

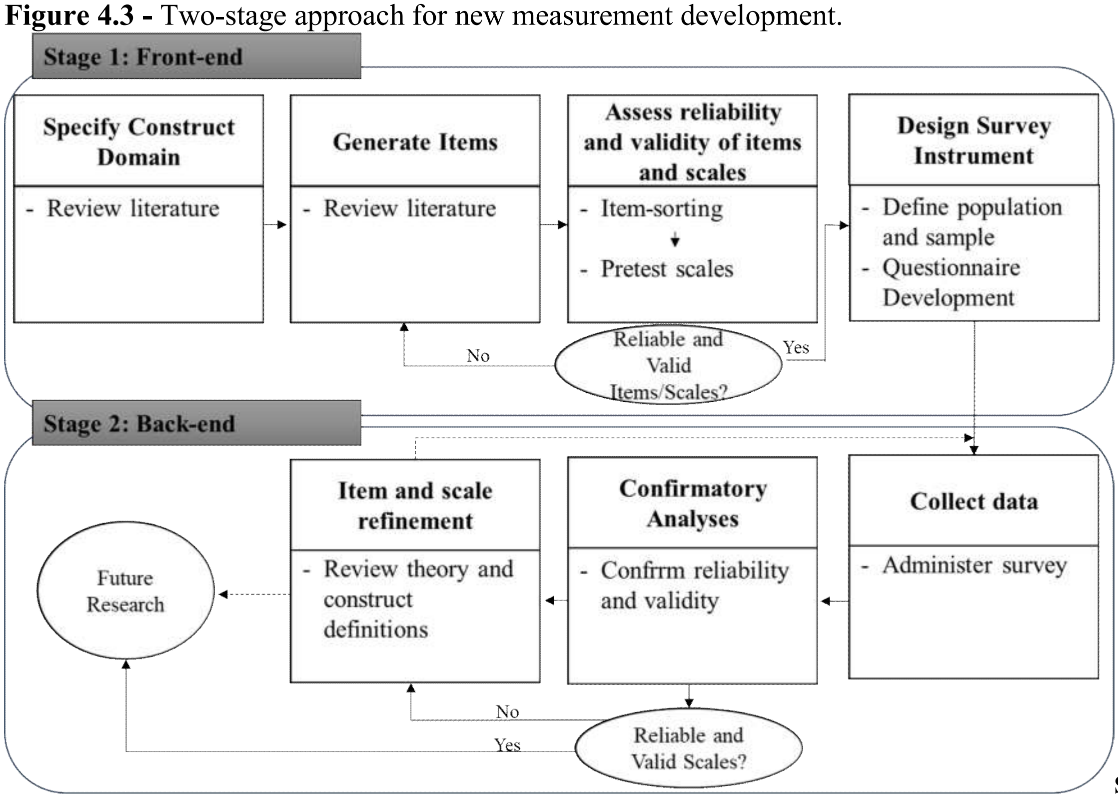
Six Sigma role structure	-	The organization uses a group of improvement specialists who are developed through Six Sigma training and certification programs. The improvement specialists are classified with different ranks based on their expertise. The specialists are assigned with specific leadership roles and responsibilities in improvement teams.
Six Sigma structured improvement procedure	-	There is an emphasis on following a standardized procedure in planning and conducting improvement projects or design projects. Teams apply the appropriate Quality Management tools and techniques as prescribed in each step of the structured procedure.
Six Sigma focus on metrics	-	Quantitative metrics are used to measure process performance and product quality performance, and set project goals. Business-level performance measures and customer expectations are integrated with process-level performance measures.

Source: Zu, Fredendall, and Douglas (2008).

4.3 Development and validation of Lean Six Sigma measurement items and scales

These prior scales were adapted for the food industry using a two-stage approach adapted from Churchill (1979) and Menor and Roth (2007), illustrated in Figure 4.3.

Figure 4.3 - Two-stage approach for new measurement development.



Source: Adaptation of Churchill (1979) and Menor and Roth (2007)

The first step for developing better measures involves specifying the domain of the construct, i.e. delineate what is included in the concept definition and what is excluded, and the second step is to generate items which capture the domain as specified (CHURCHILL, 1979).

The first two steps (Specify Construct Domain and Generate Items) were developed based on the initial set of Lean and Six Sigma constructs proposed by Shah and Ward (2007) and Zu, Fredendall and Douglas (2008). These constructs were: supplier feedback, JIT delivered by supplier, supplier development, pull, continuous flow, set up time reduction, total productive/preventive maintenance, statistical process control, employee involvement, customer involvement, Six Sigma role structure, Six Sigma structure improvement procedure, Six Sigma focus on metrics as presented in Figure 4.1 and Figure 4.2. A total of 73 items were used (see Appendix A).

In step 3, these 13 constructs and their items were purified and refined to establish their reliability and validity as a measurement instrument for LSS. There were four rounds of an item-sorting exercise. This was an iterative process in which respondents identified the construct the items were measuring based on the construct definitions provided (MENOR; ROTH, 2007). In the first three rounds, convenience samples of 28, 19 and 16 operations management students with previous knowledge on Lean and Six Sigma initiatives were the judges. In the fourth round 20 judges with knowledge, experience and/or motivation (professionals from operations management and food industry field) were employed. Each judge received the constructs definition and a randomized list of a set of items sent using the Qualtrics platform. For each item, the judges selected the construct that each item represented given the definitions.

Each round was analyzed using 3 interrater reliability estimators (Interjudge Agreement Percentage, Cohen's k and Perreault and Leigh's I_r). The interjudge agreement percentage is the ratio of pairwise agreements in item classifications made between judges to the total number of pairwise judgments possible in each round. It was used as a baseline in conjunction with the other measures of reliability (MENOR; ROTH, 2007). Cohen's k is a conservative estimator proposed by Cohen (1960). A Cohen's k greater than 0.65 indicates an adequate interjudge agreement, meaning that the agreement is due to more than chance (MOORE; BENBASAT, 1991). The last estimator, the Perreault and Leigh's I_r, was proposed by Perreault and Leigh (1989). If it is lower than 0.8, or 0.7 in more exploratory work, corrective adjustments can be made early in the research process (PERREAULT; LEIGH, 1989).

The substantive validity of the measurement items was analyzed to check how well the measurement item is reflective of, or theoretically linked to, the construct of interest

(ANDERSON; GERBING, 1991), using two estimators: the proportion of substantive validity and coefficient of substantive validity. The proportion of substantive validity, i.e. the proportion of judges from a sample who assign an item to its intended construct, ranges from 0 to 1.0, with larger values indicating greater substantive validity; and the coefficient of substantive validity that measure the extent to which respondents assign an item to its posited construct rather than to any other construct, ranges from -1.0 to 1.0, with more positive values indicating greater substantive validity (ANDERSON; GERBING, 1991).

The overall placement ratio (OPR) measures the number of items correctly placed in a construct. According to Moore and Benbasat (1991) the constructs which have a high degree (more than 75%) of "correct" placement of items within them can be considered to have a high degree of construct validity, with a high potential for good reliability scores. So, their values were used to support the decisions about which items and constructs to review for revision or deletion.

After each round the above estimators were used to improve the multi-item scale to measure LSS. In the first round the low value of the interrater reliability and validity estimators (Table 4.1 and Table 4.2) indicated the necessity for reviewing and refining the measurement items and/or construct definitions.

Table 4.1 - Comparison of interrater reliability and validity estimators

Reliability and Validity Estimators	First Round	Second Round	Third Round	Fourth Round
Interjudge agreement percentage	28%-42%	40%-63%	21%-75%	65%-79%
Cohen's k	0.21-0.40	0.37-0.62	0.14-0.74	0.64-0.78
Perreault and Leigh's, Ir	0.46-0.61	0.37-0.78	0.39-0.85	0.79-0.88
Proportion of substantive validity (p_{sa})	0.47	0.64	0.69	0.82
Coefficient of substantive validity (c_{sv})	0.17	0.37	0.47	0.68
Overall Placement Ratio (OPR)	49%	63%	67%	83%

Table 4.2 - Overall Placement Ratios to each construct

Constructs		First Round	Second Round	Third Round	Fourth Round
Supplier feedback →	**Supplier relationship**	32%	84%	88%	95%
JIT delivery by suppliers Supplier development	**Supplier development**	30% 24%	47%	65%	58%
	Customer development	62%	96%	83%	95%
	Pull	86%	68%	88%	95%
	Continuous flow	54%	53%	56%	74%
	Set up time reduction	56%	79%	81%	100%
	Total productive/ preventive maintenance	57%	95%	63%	89%
	Statistical process control	35%	53%	63%	84%
	Employee involvement	68%	84%	81%	84%
	Six Sigma role structure	52%	52%	45%	74%
	Six Sigma structured improvement procedure	44%	58%	75%	74%
	Six Sigma focus on metrics	43%	37%	46%	74%
Average		**49%**	**63%**	**67%**	**83%**

Following the first round, the three suppliers related constructs were refined. Their OPR was low indicating that the judges had difficulty in distinguishing between items. The "supplier feedback" construct was renamed "supplier relationship" and its definition was changed to "The organization actively seeks close contact with suppliers including performance feedback and visits.". This definition was based on examination of its items, which suggested they were focused more on building relationships than directly providing feedback. The construct "JIT delivery by suppliers" was combined with "Supplier development" and the construct definition was revised to reflect the new set of items. Small refinements in the other constructs' definitions were also made, to make them more understandable. For example, the reverse coded items were changed, since some judges commented about the difficult of classifying them. Some items were also reworded to make them easier to understand. Five troublesome items (low validity estimators and/or no consensus between judges and/or eliminated during item purification in their original scale) were deleted.

After the second and third rounds items with unsatisfactory estimators were reworded, the troublesome items were carefully analyzed and some of them were eliminated. After the forth-round the reliability and validity estimators were considered acceptable. The average of Perreault and Leigh's I_r was greater than 0.8; and the validity estimators (the proportion of substantive ranges and the coefficient of substantive validity) were greater than 0.8 and 0.64, respectively. So, 46 items and 12 constructs were retained to measure the adoption of LSS in the food industry.

A pretest was conducted using a questionnaire containing the 46 items retained in the item-sorting exercise to confirm the reliability and validity of the scales before sending to a large sample. The web questionnaire was sent to fifty respondents obtained from the SurveyMonkey Audience. Respondents were from the American Food and Beverage sector, which is similar to the target population of the final study. Six of the 50 pretest study respondents were excluded because they had unengaged responses (i.e. the same answer to all items and/or all questions answered within a short duration). The remaining answers were 44 questionnaires analyzed to confirm reliability and validity for each scale (see Table 4.3).

The composite reliability (CR) was calculated to check whether the measurement items sufficiently represent their respective constructs. A CR value greater than 0.70 indicates good reliability (HAIR et al., 2009). Convergent validity, the degree to which items share a common concept (DOBRZYKOWSKI; MCFADDEN; VONDEREMBSE, 2016) was assessed by the magnitude and sign of the standardized factor loadings of the measurement items and average variance extracted (AVE). AVE measures the amount of variance that is captured by the construct in relation to amount of variance due to measurement error and should be greater than 0.5 to indicate convergent validity (FORNELL; LARCKER, 1981).

Table 4.3 shows the reliability, convergent validity and the descriptive statistics before and after refinement computed using the software SPSS Version 21 and SmartPLS 3. All constructs have satisfactory AVE and Composite Reliability values. Except for five items, all items had statistical significance (at $p < 0.05$) and standardized loadings (λ) values above the common threshold of 0.70, indicating positive correspondence between constructs and their indicators (HAIR et al., 2014) and they were further examined.

Item number two of Customer Involvement had a standardized path loading of 0.44 and was deleted from the scale. Its removal increased the CR and AVE. Item number three of Supplier Relationship was also removed, since it can be represented by the first item of its scale and the scale's CR and AVE values then increased. To keep at least four measurement items in the construct scale, an additional item ("we give our suppliers feedback on quality and delivery performance"), previously removed in the q-sorting step was included. Structural equation modeling prefers at least four items for each construct (HAIR et al., 2009). Item four of Supplier Development and item one of Employee involvement were also retained to maintain at least four items in their respective constructs.

An additional item was added to four constructs: to pull construct ("we use Kanban, squares, or containers of signals for production control"); to the set up time construct ("we have short production cycle times to quickly respond to customer requests"); to the SPC construct ("we use fishbone type diagrams to identify causes of quality problems"); and to the six sigma structured improvement procedure ("all improvement projects are reviewed regularly during the process"). The LSS measurement scales for the food industry consisted of 49 items reflecting 12 constructs dimensions after the pretest.

Table 4.3 - Validity and reliability estimators and descriptive statistics of Pretest

Lean Six Sigma scales and measurement items	Original			After Refinement					
	AVE	CR	λ	AVE	CR	λ	t value	Mean	Std. Dev.
Supplier Relationship	*0.61*	*0.86*		*0.69*	*0.87*				
We frequently are in close contact with our suppliers			0.90			0.93	50.82	4.8	1.81
Our suppliers frequently visit our plants			0.78			0.78	9.03	3.5	1.93
We frequently visit our supplier's plants *			0.70						
We strive to establish long-term relationship with our suppliers			0.72			0.78	11.00	5.3	1.71
Supplier Development	*0.64*	*0.87*		*0.64*	*0.87*				
Suppliers are directly involved in the new product development process			0.88			0.88	27.93	4.1	2.03
We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis			0.85			0.85	20.05	4.5	1.93
We work with our key suppliers so they are contractually committed to annual cost reductions			0.80			0.80	12.61	4.7	1.84
Our key suppliers manage our inventory			0.63			0.63	4.98	3.3	1.95
Customer involvement	*0.54*	*0.87*		*0.61*	*0.89*				
We frequently are in close contact with our customers			0.67			0.67	3.45	5.5	1.59
Our customers frequently visit our plants *			0.44						
Our customers give us feedback on quality and delivery performance			0.79			0.79	7.55	5.6	1.85
Our customers are directly involved in current and future product offerings			0.79			0.79	8.20	4.8	1.89
Our customers frequently share current and future demand information with marketing department			0.83			0.83	18.60	4.8	1.90
We regularly conduct customer satisfaction surveys			0.81			0.81	15.64	5.2	1.99
Pull	*0.65*	*0.85*		*0.65*	*0.85*				
Production is 'pulled' by the shipment of finished goods			0.75			0.75	5.13	4.5	2.03
Production at stations is 'pulled' by the current demand of the next station			0.79			0.79	9.63	4.2	1.90
We use a "pull" production system			0.86			0.86	21.12	4.2	2.08
Continuous flow	*0.71*	*0.91*		*0.71*	*0.91*				
Products are classified into groups with similar processing requirements			0.88			0.88	25.99	4.5	1.92
Products are classified into groups with similar routing requirements			0.82			0.82	8.93	4.8	1.97
Equipment is grouped to produce a continuous flow of families of products			0.76			0.76	5.91	4.4	1.91
Families of products determine our factory layout			0.90			0.90	27.06	4.8	2.01
Set up time reduction	*0.69*	*0.87*		*0.69*	*0.87*				
Our employees practice setups to reduce the time required			0.79			0.79	11.61	4.4	2.06
We are working to lower setup times in our plant			0.81			0.81	8.65	4.1	1.86
We have low set up times of equipment in our plant			0.90			0.90	26.64	4.3	1.95
Statistical Process Control	*0.61*	*0.83*		*0.61*	*0.83*				
Large amount of process/equipment on the shop floor is currently under Statistical Process Control			0.77			0.77	10.62	3.7	2.00
We extensively use statistical techniques to reduce process variance			0.83			0.83	8.71	4.0	1.83
Charts showing defect rates are used as tools on the shop-floor			0.75			0.75	8.13	3.6	2.12

* eliminated during item refinement.

Table 4.3 - Validity and reliability estimators and descriptive statistics of Pretest (continued)

Lean Six Sigma scales and measurement items	Original			After refinement					
	AVE	CR	λ	AVE	CR	λ	t value	Mean	Std. Dev.
Employee involvement	*0.60*	*0.85*		*0.60*	*0.85*				
Shop-floor employees are key to problem solving teams			0.67			0.67	4.00	5.3	1.74
Shop-floor employees drive suggestion program			0.71			0.71	6.73	4.6	1.77
Shop-floor employees lead product / process improvement efforts			0.82			0.82	13.84	4.5	1.69
Shop-floor employees undergo cross functional training			0.87			0.87	19.57	4.8	1.87
Total productive/preventive maintenance	*0.64*	*0.87*		*0.64*	*0.87*				
We dedicate a portion of everyday to planned equipment maintenance related activities			0.72			0.72	8.48	4.5	2.05
We maintain all our equipment regularly			0.81			0.81	10.79	5.1	2.17
We maintain excellent records of all equipment maintenance related activities			0.81			0.81	10.65	5.0	1.96
We post equipment maintenance records on shop floor for active sharing with everyone			0.84			0.84	12.60	4.3	2.10
Six Sigma role structure	*0.64*	*0.87*		*0.64*	*0.87*				
We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs			0.71			0.71	5.99	3.2	1.97
In our plant, members of improvement teams have their roles and responsibilities specifically identified			0.74			0.74	7.88	4.7	1.98
The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience			0.90			0.90	37.88	3.9	2.05
Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities			0.82			0.82	14.08	4.2	2.02
Six Sigma structured improvement procedure	*0.76*	*0.90*		*0.76*	*0.90*				
In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC—Define, Measure, Analyze, Improve and Control)			0.89			0.89	18.11	4.0	2.29
We use a structured approach to manage quality improvement activities			0.84			0.84	13.53	4.7	1.99
We have a formal planning process to decide the major quality improvement projects			0.88			0.88	22.35	4.5	2.18
Six Sigma focus on metrics	*0.70*	*0.90*		*0.70*	*0.90*				
Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance			0.85			0.85	19.69	4.1	2.03
Metrics are used to link quality performance to strategic goals			0.86			0.86	17.47	3.9	2.00
Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant			0.84			0.84	18.36	4.7	1.90
Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance			0.78			0.78	8.05	4.1	2.03

* eliminated during item refinement.

The sampling frame for the survey consisted of 1849 food industries selected from Brazilian and American Food Industry Associations websites. An invitation to take part in the survey was sent via LinkedIn to a manufacturing or quality manager/supervisor of companies in the Food Industry Association. Managers agreeing to participate received an email link to the survey questionnaire on the Qualtrics platform. The data collection was conducted from September through November of 2018. The response scale for each item was the respondent's level of agreement with each item using a seven-point Likert scale range from (1) strongly disagrees to (7) strongly agree.

The survey instrument's introduction highlighted the relevance of the survey and the effort expected of respondents (FROHLICH, 2002). It also described the study and the information requested by the Institutional Review Board (IRB2017-423). We offered a donation (APPENDIX B) to a charity upon completion of the survey as recommended by Azadegan et al. (2013). Moreover, three reminders to complete the survey were sent. A total of 357 companies (19% response rate) answered the questionnaire. After removing unengaged and outliers' answers, 229 responses remained.

The respondents mainly work at manufacturing department (48%), followed by quality (28%) and continuous improvement (7%). Nine percent work at other departments and 8% did not answer their department. Most of them (44%) are manager/coordinator, 30% are Supervisor/Lead, 9% are director, and 5% are President/CEO. The remaining 12% responded other (6%) or did not answer (7%). Twenty nine percent works in the company for more than 1 year and less than 4, 26% work above 10 years, 20% between 4 and 7 years, 14% less than 1 year, and 11% between 7 and 10 years.

Response bias was investigated by comparing early respondents (responded following the first contact) to late respondents (answered on the following contacts) (ARMSTRONG; OVERTON, 1977); no statistically significant differences were detected. In addition, common method bias (CMB) was evaluated using Harmon's single-factor test, which is run by loading all the items of the dimensions into a principal component analysis and forcing them into one latent factor (PODSAKOFF et al., 2003). One factor accounted for 41.1% of the variance explained, which was not the majority of the total variance, suggesting that CMB is not a major concern in this study (PODSAKOFF et al., 2003) .

Two food industry characteristics highlighted in previous studies (DORA et al., 2013a; see DORA; KUMAR; GELLYNCK, 2015; JAIN; LYONS, 2009; MANZOURI et al., 2013) were also investigated, since the degree of adoption of some operations management practices can be distinct across different contexts (SOUSA; VOSS, 2008). The first characteristic is the effect on the changeover time of cleaning. This effect is due to the sector's focus on quality assurance to satisfy regulatory requirements and improve food quality safety (DORA et al., 2013b; LIM; ANTONY; ALBLIWI, 2014) that leads to compulsory and frequent cleaning (DORA; KUMAR; GELLYNCK, 2015; JAIN; LYONS, 2009). Respondents reported that cleaning time's effect on changeover time was high (47%); low (30%) and medium (27%). The second is related to the heterogeneity of the sector that affects the type of operation. Some food companies produce large batches to avoid frequent changeovers, however, other food industries are characterized as continuous (MANZOURI et al., 2013; PANWAR et al., 2015). The process types reported by respondents were continuous (43%), batch (37%), and hybrid (21%). These results confirm the heterogeneity of the companies within the sector.

Confirmatory Factor Analysis was used to assess the reliability and convergent and discriminant validity of the 49 items about LSS. All the composite reliability values exceeded the suggested 0.70 standard and all average variance extracted values exceeded 0.50. We also assessed the significance of item factor loading to establish convergent validity. All items showed high statistical significance (at $p < 0.05$) related to their corresponding construct (see Table 4.4). However, a few items had standardized loadings values below 0.70 (HAIR et al., 2014) and two of these were in the supplier development construct.

The two supplier constructs (supplier relationship and supplier development) were re-analyzed. The items with lowest factor loadings were removed and the combined construct was renamed Supplier Involvement and its definition was changed to "The organization builds close relationship with supplier and develops then to be more involved in production and deliver process". Its CR and AVE estimators were equal to or greater than the original scales, suggesting the positive effect of integrating them (see Table 4.4).

Additionally, one customer involvement item ("we frequently are in close contact with our customers") had a standardized loading below 0.70 and was removed, since it can be represented by the other items and its reliability and validity estimators, CR and AVE, increased after removal. The Flow and Setup constructs were also analyzed further to determine how they were affected by any Food Industry Characteristics, because they contained items with low standardized loading.

A Kruskal-Wallis test was accomplished to examine the impact of cleaning time on Set-up dimension. The result showed difference between item 3 ("We have low set up times of equipment in our plant") to companies that cleaning time highly and moderately affects changeover time compared with companies lowly affected (significance $p < 0.05$). Another Kruskal-Wallis test was performed to evaluate the effect of type of operation. The result showed difference between item 3 ("Equipment is grouped to produce a continuous flow of families of products") of Flow dimension to companies characterized as batch compared to continuous (significance $p < 0.05$). This result indicates that food industry characteristics may impact the implementation of some LSS practices and scales development should consider the sector of application.

Table 4.4 - Validity and reliability estimators and descriptive statistics of Large Sample

Lean Six Sigma Constructs	Items	Original				After Refinement					
		λ	T value	AVE	CR	λ	T value	AVE	CR	Mean	Std. Dev.
Supplier Involvement (SUPPINV)	Suppliers are directly involved in the new product development process*	0.69	13.43	0.54	0.82			0.60	0.87		
	We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis	0.82	11.49			0.76	16.06			4.31	1.74
	We work with our key suppliers so they are contractually committed to annual cost reductions	0.82	13.85			0.79	15.78			4.50	1.69
	Our key suppliers manage our inventory*	0.58	8.96	0.59	0.85						
	We frequently are in close contact with our suppliers	0.83	8.88			0.78	12.64			5.19	1.41
	Our suppliers frequently visit our plants*	0.72	15.15								
	We give our suppliers feedback on quality and delivery performance	0.78	14.58			0.76	14.82			5.04	1.55
	We strive to establish long-term relationship with our suppliers	0.74	6.70			0.71	9.09			5.32	1.32
Customer Involvement (CUSTINV)	We frequently are in close contact with our customers*	0.65	6.58	0.53	0.85			0.58	0.85		
	Our customers give us feedback on quality and delivery performance	0.76	9.26			0.75	8.33			5.28	1.33
	Our customers are directly involved in current and future product offerings	0.74	10.26			0.74	10.26			4.67	1.54
	Our customers frequently share current and future demand information with marketing department	0.74	11.84			0.76	10.97			4.10	1.63
	We regularly conduct customer satisfaction surveys	0.75	15.93			0.79	15.56			4.10	1.76
Pull (PULL)	Production is "pulled" by the shipment of finished goods	0.74	8.05	0.61	0.86	0.74	8.15	0.61	0.86	4.57	1.77
	Production at stations is "pulled" by the current demand of the next station	0.76	10.10			0.76	10.21			4.43	1.71
	We use a "pull" production system (a method of production control in which downstream activities signal their needs to upstream activities)	0.86	15.66			0.85	14.12			4.09	1.77
	We use a Kanban, squares, or containers of signals for production control	0.74	13.25			0.74	13.41			3.23	1.92
Continuous Flow (FLOW)	Products are classified into groups with similar processing requirements	0.79	10.61	0.54	0.82	0.79		0.54	0.82	5.21	1.39
	Products are classified into groups with similar routing requirements	0.77	9.11			0.77				4.90	1.44
	Equipment is grouped to produce a continuous flow of families of products	0.70	10.27			0.70				5.32	1.35
	Families of products determine our factory layout	0.67	7.05			0.67				5.10	1.60
Set up time reduction (SETUP)	Our employees practice setups to reduce the time required	0.85	19.34	0.51	0.80	0.85	19.48	0.51	0.80	4.54	1.67
	We are working to lower setup times in our plant	0.82	17.21			0.82	17.61			5.12	1.66
	We have low set up times of equipment in our plant	0.63	7.31			0.63	7.51			4.31	1.54
	We have short production cycle times to quickly respond to customer requests	0.47	5.48			0.47	5.44			4.55	1.55

* eliminated during item refinement.

Table 4.4 - Validity and reliability estimators and descriptive statistics of Large Sample (continued)

Lean Six Sigma Constructs	Items	Original				After Refinement					
		λ	T value	AVE	CR	λ	T value	AVE	CR	Mean	Std. Dev.
Statistical Process Control (SPC)	Large amount of process/equipment on the shop floor is currently under Statistical Process Control	0.87	25.21	0.68	0.9	0.87	23.76	0.68	0.9	3.83	1.84
	We extensively use statistical techniques to reduce process variance	0.83	23.01			0.83	22.81			4.01	1.76
	Charts showing defect rates are used as tools on the shop-floor	0.82	17.01			0.82	16.99			4.09	1.91
	We use fishbone type diagrams to identify causes of quality problems	0.78	22.47			0.78	23.20			4.63	1.89
Employee involvement (EMPINV)	Shop-floor employees are key to problem solving teams	0.79	16.41	0.68	0.89	0.79	16.68	0.68	0.89	5.15	1.72
	Shop-floor employees drive suggestion programs	0.83	22.28			0.83	21.77			4.00	1.83
	Shop-floor employees lead product / process improvement efforts	0.86	23.66			0.86	24.74			4.10	1.72
	Shop-floor employees undergo cross functional training	0.80	18.32			0.80	17.73			5.00	1.70
Total productive/preventive maintenance (TPM)	We dedicate a portion of everyday to planned equipment maintenance related activities	0.84	0.84	0.66	0.89	0.84	18.51	0.66	0.89	4.29	1.62
	We maintain all our equipment regularly	0.80	0.80			0.80	11.97			5.17	1.52
	We maintain excellent records of all equipment maintenance related activities	0.84	0.84			0.84	20.12			4.67	1.61
	We post equipment maintenance records on shop floor for active sharing with everyone	0.77	0.77			0.77	17.61			3.82	1.84
Six Sigma Role Structure (SSROLE)	We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs	0.90	0.90	0.71	0.91	0.90	33.70	0.71	0.91	3.43	1.95
	In our plant, members of improvement teams have their roles and responsibilities specifically identified	0.72	0.72			0.72	17.16			4.87	1.64
	The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience	0.84	0.84			0.84	18.78			3.59	1.92
	Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities	0.89	0.89			0.89	30.50			3.86	1.87
Six Sigma structured improvement procedure (SSIMP)	In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC-Define, Measure, Analyze, Improve and Control)	0.88	30.60	0.77	0.93	0.88	31.46	0.77	0.93	4.17	2.00
	We use a structured approach to manage quality improvement activities	0.86	32.69			0.86	36.12			4.76	1.59
	We have a formal planning process to decide the major quality improvement projects	0.90	36.19			0.90	37.83			4.52	1.76
	All improvement projects are reviewed regularly during the process	0.86	29.32			0.86	26.98			4.41	1.74
Six Sigma focus on metrics (SSMET)	Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance	0.89	30.15	0.69	0.90	0.89	31.28	0.69	0.90	5.02	1.60
	Metrics are used to link quality performance to strategic goals	0.88	33.80			0.88	32.17			4.98	1.58
	Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant	0.77	15.59			0.77	15.08			5.19	1.58
	Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance	0.79	15.72			0.79	14.83			4.38	1.85

The discriminant validity of each construct is an evaluation of the measurement items relationship to their respective construct compared to their relationship across other constructs (ANDERSON; GERBING, 1988). The square root of the AVE of each construct was compared to its correlation with the other constructs (FORNELL; LARCKER, 1981). The AVE of all constructs was larger than their correlation with other constructs except for the SPC and SSIMP AVE and their respective correlation (see Table 4.5).

Table 4.5 - Discriminant validity**:** Square root of AVE on diagonal

Constructs	CUSTINV	EMPINV	FLOW	PULL	SETUP	SPC	SSIMP	SSMET	SSROLE	SUPPINV	TPM
CUSTINV	**0.760**										
EMPINV	0.584	**0.822**									
FLOW	0.515	0.495	**0.734**								
PULL	0.429	0.577	0.424	**0.778**							
SETUP	0.531	0.686	0.547	0.570	**0.711**						
SPC	0.581	0.766	0.564	0.570	0.699	0.825					
SSIMP	0.594	0.804	0.568	0.569	0.709	0.834	**0.876**				
SSMET	0.625	0.725	0.565	0.491	0.657	0.769	0.803	**0.834**			
SSROLE	0.527	0.800	0.471	0.559	0.684	0.750	0.813	0.707	**0.841**		
SUPPINV	0.675	0.597	0.587	0.526	0.619	0.608	0.631	0.565	0.541	**0.762**	
TPM	0.502	0.705	0.498	0.491	0.676	0.724	0.715	0.626	0.699	0.590	**0.813**

The discriminant validity of the constructs is also evaluated by assessing if the items have higher loadings on their originating constructs than on other constructs (HAIR et al., 2014). As illustrated in Table 4.6, the cross loadings indicated good discriminant validity. Based on these analyses, the construct discriminant validity was considered satisfactory, so no further scale refinement was performed.

Table 4.6 - Cross loadings

Constructs	Manifest Variables	CUSTINV	EMPINV	FLOW	PULL	SETUP	SPC	SSIMP	SSMET	SSROLE	SUPPINV	TPM
CUSTINV	Our customers give us feedback on quality and delivery performance	0.750*	0.395	0.409	0.317	0.405	0.354	0.436	0.443	0.339	0.551	0.318
	Our customers are directly involved in current and future product offerings	0.739*	0.399	0.391	0.266	0.362	0.351	0.356	0.394	0.347	0.420	0.363
	Our customers frequently share current and future demand information with marketing department	0.764*	0.455	0.372	0.350	0.402	0.424	0.455	0.484	0.388	0.492	0.379
	We regularly conduct customer satisfaction surveys	0.788*	0.510	0.397	0.359	0.439	0.598	0.536	0.558	0.503	0.574	0.453
EMPINV	Shop-floor employees are key to problem solving teams	0.464	0.795*	0.402	0.378	0.526	0.563	0.605	0.592	0.608	0.424	0.502
	Shop-floor employees drive suggestion programs	0.485	0.827*	0.384	0.462	0.527	0.649	0.654	0.604	0.667	0.506	0.560
	Shop-floor employees lead product / process improvement efforts	0.472	0.860*	0.365	0.600	0.618	0.655	0.693	0.592	0.671	0.506	0.612
	Shop-floor employees undergo cross functional training	0.498	0.804*	0.476	0.445	0.580	0.646	0.686	0.597	0.680	0.521	0.637
FLOW	Products are classified into groups with similar processing requirements	0.379	0.366	0.790*	0.331	0.442	0.481	0.476	0.491	0.363	0.444	0.403
	Products are classified into groups with similar routing requirements	0.402	0.373	0.766*	0.220	0.377	0.413	0.428	0.428	0.332	0.450	0.299
	Equipment is grouped to produce a continuous flow of families of products	0.379	0.397	0.701*	0.375	0.442	0.419	0.422	0.433	0.406	0.410	0.426
	Families of products determine our factory layout	0.351	0.307	0.671*	0.315	0.327	0.323	0.324	0.276	0.262	0.421	0.322
PULL	Production is "pulled" by the shipment of finished goods	0.268	0.361	0.235	0.745*	0.400	0.363	0.348	0.263	0.335	0.357	0.347
	Production at stations is "pulled" by the current demand of the next station	0.290	0.399	0.403	0.764*	0.413	0.435	0.382	0.353	0.385	0.417	0.334
	We use a "pull" production system (a method of production control in which downstream activities signal their needs to upstream activities)	0.387	0.467	0.339	0.855*	0.503	0.437	0.461	0.398	0.434	0.465	0.399
	We use a Kanban, squares, or containers of signals for production control	0.367	0.536	0.329	0.743*	0.446	0.514	0.543	0.476	0.548	0.390	0.430
SETUP	Our employees practice setups to reduce the time required	0.407	0.621	0.447	0.555	0.851*	0.613	0.623	0.565	0.637	0.510	0.578
	We are working to lower setup times in our plant	0.450	0.620	0.431	0.444	0.825*	0.596	0.624	0.595	0.582	0.522	0.563
	We have low set up times of equipment in our plant	0.381	0.347	0.378	0.240	0.629*	0.410	0.390	0.352	0.357	0.436	0.428
	We have short production cycle times to quickly respond to customer requests	0.259	0.247	0.291	0.339	0.472*	0.291	0.289	0.272	0.273	0.243	0.299
SPC	Large amount of process/equipment on the shop floor is currently under Statistical Process Control	0.505	0.619	0.503	0.513	0.645	0.871*	0.676	0.601	0.624	0.545	0.629
	We extensively use statistical techniques to reduce process variance	0.542	0.655	0.481	0.505	0.623	0.828*	0.707	0.623	0.635	0.564	0.654
	Charts showing defect rates are used as tools on the shop-floor	0.426	0.611	0.392	0.448	0.502	0.818*	0.667	0.652	0.586	0.428	0.542
	We use fishbone type diagrams to identify causes of quality problems	0.439	0.641	0.481	0.413	0.529	0.782*	0.699	0.664	0.629	0.462	0.557
SSIMP	In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC-Define, Measure, Analyze, Improve and Control)	0.492	0.695	0.456	0.503	0.560	0.731	0.876*	0.707	0.768	0.524	0.612
	We use a structured approach to manage quality improvement activities	0.551	0.718	0.514	0.450	0.641	0.711	0.864*	0.715	0.675	0.592	0.614
	We have a formal planning process to decide the major quality improvement projects	0.549	0.715	0.510	0.518	0.655	0.750	0.902*	0.724	0.714	0.551	0.624
	All improvement projects are reviewed regularly during the process	0.489	0.691	0.512	0.524	0.630	0.729	0.862*	0.667	0.693	0.544	0.658

* higher loading in the original constructs.

Table 4.6 - Cross-loading analysis (continued)

Constructs	Manifest Variables	CUSTINV	EMPINV	FLOW	PULL	SETUP	SPC	SSIMP	SSMET	SSROLE	SUPPINV	TPM
SSMET	Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance	0.542	0.655	0.513	0.459	0.607	0.676	0.735	0.888*	0.633	0.458	0.561
	Metrics are used to link quality performance to strategic goals	0.604	0.699	0.503	0.439	0.581	0.714	0.765	0.881*	0.665	0.522	0.605
	Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant	0.468	0.544	0.467	0.396	0.474	0.539	0.582	0.767*	0.483	0.499	0.448
	Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance	0.455	0.496	0.393	0.333	0.518	0.621	0.569	0.792*	0.556	0.405	0.453
SSROLE	We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs	0.424	0.712	0.390	0.497	0.609	0.672	0.716	0.623	0.899*	0.443	0.588
	In our plant, members of improvement teams have their roles and responsibilities specifically identified	0.506	0.649	0.516	0.409	0.577	0.620	0.650	0.570	0.724*	0.533	0.596
	The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience	0.375	0.614	0.291	0.434	0.538	0.621	0.664	0.589	0.844*	0.389	0.534
	Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities	0.466	0.709	0.387	0.534	0.575	0.606	0.701	0.593	0.887*	0.456	0.631
SUPPINV	We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis	0.550	0.424	0.463	0.529	0.521	0.469	0.484	0.443	0.438*	0.762*	0.468
	We work with our key suppliers so they are contractually committed to annual cost reductions	0.576	0.484	0.463	0.428	0.519	0.530	0.523	0.491	0.467	0.794*	0.465
	We frequently are in close contact with our suppliers	0.517	0.459	0.469	0.384	0.448	0.412	0.417	0.348	0.389	0.781*	0.405
	We give our suppliers feedback on quality and delivery performance	0.491	0.509	0.405	0.335	0.464	0.490	0.561	0.506	0.433	0.763*	0.512
	We strive to establish long-term relationship with our suppliers	0.422	0.390	0.440	0.311	0.391	0.398	0.399	0.339	0.315	0.709*	0.386
TPM	We dedicate a portion of everyday to planned equipment maintenance related activities	0.377	0.577	0.401	0.427	0.574	0.584	0.621	0.528	0.590	0.446	0.839*
	We maintain all our equipment regularly	0.374	0.458	0.357	0.292	0.458	0.504	0.468	0.443	0.454	0.442	0.803*
	We maintain excellent records of all equipment maintenance related activities	0.435	0.577	0.455	0.367	0.563	0.620	0.609	0.563	0.593	0.492	0.842*
	We post equipment maintenance records on shop floor for active sharing with everyone	0.439	0.658	0.396	0.487	0.585	0.628	0.604	0.490	0.613	0.532	0.766*

* higher loading in the original constructs.

The outcome of this two-stage approach to develop and validate a multi-item measurement scale is a proposed hierarchical factor structure to represent LSS concept (see Figure 4.4). It has 11 constructs with a total of 45 items (see Figure 4.5), each of which uses a seven-point Likert response scale anchored at (1) strongly disagree to (7) strongly agree. This scale can be used to assess which LSS practices are implemented and are most effective in the food industries settings. Those practices found to be more effective (i.e., with adequate fit) should be applied to a high degree (SOUSA; VOSS, 2008).

Figure 4.4 – Hierarchical factor structure

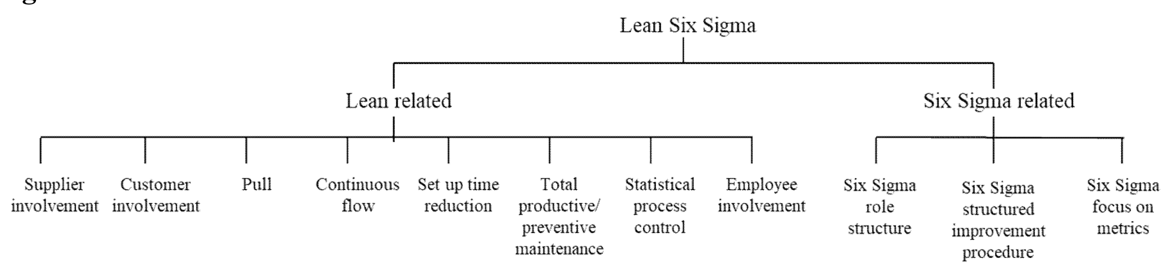


Figure 4.5 - Final LSS constructs and items

Construct Name	Construct Definition	Multi-item scales
Supplier involvement	The organization builds close relationship with supplier and develops then to be more involved in production and deliver process.	1. We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis. 2. We work with our key suppliers so they are contractually committed to annual cost reductions. 3. We frequently are in close contact with our suppliers. 4. We give our suppliers feedback on quality and delivery performance. 5. We strive to establish long-term relationship with our suppliers.
Customer involvement	The organization focuses on their customers and their needs.	6. Our customers give us feedback on quality and delivery performance. 7. Our customers are directly involved in current and future product offerings. 8. Our customers frequently share current and future demand information with marketing department. 9. We regularly conduct customer satisfaction surveys.
Pull	The organization facilitates just-in-time (JIT) production by using tools such as kanban to signal when to start or stop production.	10. Production is "pulled" by the shipment of finished goods. 11. Production at stations is "pulled" by the current demand of the next station. 12. We use a "pull" production system (a method of production control in which downstream activities signal their needs to upstream activities). 13. We use a Kanban, squares, or containers of signals for production control.

Figure 4.5 – Final LSS constructs and items (continued)

Construct Name	Construct Definition	Multi-item scales
Continuous flow	The organization establishes mechanisms that enable and ease the continuous flow of products.	14. Products are classified into groups with similar processing requirements. 15. Products are classified into groups with similar routing requirements. 16. Equipment is grouped to produce a continuous flow of families of products. 17. Families of products determine our factory layout.
Set up time reduction	The organization seeks to reduce process downtime between product changeovers.	18. Our employees practice setups to reduce the time required. 19. We are working to lower setup times in our plant. 20. We have low set up times of equipment in our plant. 21. We have short production cycle times to quickly respond to customer requests.
Total productive/ preventive maintenance	The organization addresses equipment downtime by using total productive maintenance to achieve a high level of equipment availability.	22. We dedicate a portion of everyday to planned equipment maintenance related activities. 23. We maintain all our equipment regularly. 24. We maintain excellent records of all equipment maintenance related activities. 25. We post equipment maintenance records on shop floor for active sharing with everyone.
Statistical process control	The organization ensures that each process will supply defect free units to subsequent process.	26. Large amount of process/equipment on the shop floor is currently under Statistical Process Control. 27. We extensively use statistical techniques to reduce process variance. 28. Charts showing defect rates are used as tools on the shop-floor. 29. We use fishbone type diagrams to identify causes of quality problems.
Employee involvement	The organization's employees have a role in problem solving and cross functional teams.	30. Shop-floor employees are key to problem solving teams. 31. Shop-floor employees drive suggestion programs. 32. Shop-floor employees lead product / process improvement efforts. 33. Shop-floor employees undergo cross functional training.
Six Sigma role structure	The organization uses improvement specialists who are developed through Six Sigma training and certification programs and who have specific leadership roles and responsibilities in improvement teams.	34. We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs. 35. In our plant, members of improvement teams have their roles and responsibilities specifically identified. 36. The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience. 37. Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities.
Six Sigma structured improvement procedure	The organization follows a standardized procedure in planning and conducting improvement projects or design projects and it uses appropriate Quality Management tools and techniques as prescribed in each step of the structured procedure.	38. In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC-Define, Measure, Analyze, Improve and Control). 39. We use a structured approach to manage quality improvement activities. 40. We have a formal planning process to decide the major quality improvement projects. 41. All improvement projects are reviewed regularly during the process.

Figure 4.5 – Final LSS constructs and items (continued)

Construct Name	Construct Definition	Multi-item scales
Six Sigma focus on metrics	The organization uses quantitative metrics to measure performance, and to set improvement goals.	42. Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance. 43. Metrics are used to link quality performance to strategic goals. 44. Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant. 45. Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance.

4.4 Conclusion

This research reports the development and validation of multi-item measurement scales for LSS concept. LSS is a hybrid initiative that identifies customer desires, eliminate wastes and reduce variability. This instrument uses 11 first order constructs - Supplier Involvement, Customer Involvement, Pull, Continuous flow, Set up time reduction, Statistical Process Control, Employee involvement, Total productive/preventive maintenance, Six Sigma role structure, Six Sigma structured improvement procedure, Six Sigma focus on metrics – to measure LSS implementation using a multi-item scale.

Although prior studies have developed scales to represent Lean and Six Sigma, no study was found that present a measurement instrument to the hybrid approach, LSS. This instrument was designed to help researcher identify which LSS practices are most effective in this industry. This study created an instrument to measure the adoption of LSS practices in the food industry. Some food industry characteristics, such as compulsory cleaning due to quality assurance requirements and heterogeneity in their type of operation, batch and continuous, seems to affect the appropriateness of some LSS practices and should be further examined in future studies as contingency factors.

For practitioners, the instrument developed contributes by offering the set of practices that are needed when food industries intend to adopt LSS in their settings. Companies who have already adopted LSS can use the instrument to assess and monitor their LSS implementation. This allows firms to track whether they are improving. The instrument can also be used as a tool to identify improvement opportunities allowing companies to enhance performance and competitiveness. Moreover, the research can be used as model for other sectors that operate under different contingency factors.

This study is subjected to limitations that can be served as topics for future research. One limitation of this study is that development of this instrument was through a focus on the food industry. However, it may potentially be valuable for other sectors that operate under different contingency factors. The instrument should be a valuable tool to sectors that operate under different contingency factors. This instrument needs further testing across food industry to ensure its validity in multiple contexts and the correlation of LSS adoption with food companies' performance.

5 THE EFFECT OF LEAN SIX SIGMA PRACTICES ON FOOD INDUSTRY PERFORMANCE: IMPLICATIONS OF SECTOR' S EXPERIENCE AND TYPICAL CHARACTERISTICS

In this chapter a survey is performed in order to verify the degree of adoption of Lean Six Sigma practices in the food industry, the impact of food industry characteristics in Lean Six Sigma adoption, and the impact of Lean Six Sigma adoption in the performance of food industry moderated by companies' experience.

5.1 Introduction

Companies are constantly looking for new ways of performing their activities to improve performance and remain competitive. Continuous Improvement (CI) initiatives can help organizations reach this goal by integrating their operations processes and enhance their ability to make cohesive and quick process changes (ANAND et al., 2009).

The Continuous Improvement concept is associated with different initiatives, among them Lean manufacturing, Six Sigma and, more recently, Lean Six Sigma (DROHOMERETSKI et al., 2014). Lean focuses on enhancing value (or perceived value) to customers by adding product or service features removing wasteful activities (HINES; HOLWEG; RICH, 2004). Six Sigma seeks to find and eliminate causes of mistakes or defects in business processes by focusing on outputs that are of critical importance to customers (SNEE, 2000). Lean Six Sigma has unified the strengths of both initiatives to increase organizations' performance through enhanced customer satisfaction and improved bottom line results ($) (SNEE, 2010).

Lean, Six Sigma and Lean Six Sigma initiatives (L&SSi) have been adopted by different industry and service sectors (AQLAN; AL-FANDI, 2018; D'ANDREAMATTEO et al., 2015; GRIMA et al., 2013; KUMAR; ANTONY; TIWARI, 2011; TJAHJONO et al., 2010). They have been used to effectively improve companies' performance (DROHOMERETSKI et al., 2014; NEGRÃO; GODINHO FILHO; MARODIN, 2016; TJAHJONO et al., 2010). However, in the food industry their adoption is still very low (DORA et al., 2014; LIM et al., 2015a), both in developed (SCOTT; WILCOCK; KANETKAR, 2009) and developing countries (MANZOURI et al., 2013; SANTOS; ANTONELLI, 2011).

In Canada, Scott et al. (2009) found that 44.8% of the survey respondents from the food industry did not use any continuous improvement initiatives. In Malaysia, more than 70% of the Halal food supply chain companies that participated in a survey study had not implemented Lean Supply Chain Management (MANZOURI et al., 2013). In Brazil, 75.68% of the food companies that took part in a survey did not implement Six Sigma (SANTOS; ANTONELLI, 2011). The low rates of L&SSi implementation in the food industry have led to speculation about its effectiveness in the food industry.

In the food industry the perception of “quality” is biased towards assurance, safety, health, and hygiene (DORA; GELLYNCK, 2015a). Food poisoning or microbiological outbreaks have been the industry’s, governments’ and consumer’s biggest concern (LIM; ANTONY; ALBLIWI, 2014). Industry efforts focus on ensuring quality and safety by using standard quality assurance systems such as Hazard Analysis and Critical Control Points (HACCP), British Retail Consortium (BRC) and International Organization for Standardization (ISO) (DORA et al., 2013b; TRIENEKENS; ZUURBIER, 2008; TUTU; ANFU, 2019).

The food industry’s heterogeneous product mix and its processes may also impact the adoption of L&SSi. For example, the shelf-life of food materials can be long, as the case of frozen or dried or canned materials, or shorter, as fresh vegetables or dairy products, meat or fruit (DUDBRIDGE, 2011). The food industry is a process industry, i.e. it handles non-discrete materials that cannot be disassembled and then reassembled (PANWAR et al., 2015). Some inherent characteristics of the food industry are seasonality and perishability of raw materials and products, long changeover due compulsory cleaning requirements (DORA; KUMAR; GELLYNCK, 2015; JAIN; LYONS, 2009; JIMÉNEZ et al., 2011) all of which may impact the adoption of Lean Six Sigma practices (COSTA et al., 2018).

Studies of L&SSi in this type of industry is relatively low (COSTA et al., 2018; PANWAR et al., 2018), so the effectiveness of these CI initiatives in the field are still not well known. There are some case studies of L&SSi implementations in the sector that indicate that their adoption is beneficial to food industries (e.g. DORA; KUMAR; GELLYNCK, 2015; LOPES; FREITAS, 2015; MOYA et al., 2016; MU et al., 2011; UPADHYE; DESHMUKH; GARG, 2010).

This study is grounded in Contingency theory, which suggests that a set of practices such as the Lean Six Sigma (LSS) practices will be more effective in certain environments than others (SOUSA; VOSS, 2008). It also draws on the Practice Based View, which argues that the benefits of a practice such as those in L&SSi may vary across firms and may depend on moderators (BROMILEY; RAU, 2016). A survey of 145 Food Industry firms was conducted and then analyzed using structural equation modeling to provide an empirical basis for testing the research framework comprised of four hypotheses, presented in section 5.2.

5.2 Theoretical background, literature review and development of hypothesis

This section develops the theoretical background for the study using the Contingency Theory and Practice Based View to develop the four research hypotheses.

5.2.1 *Contingency Theory*

Contingency Theory (CT) is a major theoretical lens used to view organizations (SOUSA; VOSS, 2008). It argues that no theory or method can be applied in all instances (LAWRENCE, LORSCH, 1967; THOMPSON, 1967). According to Sousa and Voss (2008) contingency theory can provide guidelines for the selection of the set of Operations Management (OM) practices that is most appropriate for a given organizational context (SOUSA; VOSS, 2008).

Researches have employed contingency in different fields. Tenhiälä (2011) tested the effect of complexity of process types in the applicability of different capacity planning methods. Taylor et al. (2013) applied it to explaining the circumstances under which proactive supply chain risk management evolves with past supplier insolvencies. Lucianetti et al. (2018) studied the influence of factors such as environmental uncertainty, decentralization, and organizational strategy on the adoption of advanced manufacturing tools and advanced managerial practices.

In this study, we use contingency theory to support the first two hypotheses, the fragmented adoption of Lean Six Sigma practices in the food industry and the effect of food industry inherent characteristics on this adoption.

5.2.1.1 The degree of adoption of Lean Six Sigma practices in the food industry and the effect of sector's inherent characteristics in these adoption

L&SSi have been widely adopted in multiple industry and service sectors (see COSTA; GODINHO FILHO, 2016; DROHOMERETSKI et al., 2014; FULLERTON et al., 2014; SHAFER; MOELLER, 2012; NETLAND, 2016; YADAV; DESAI, 2016) to improve companies' performance in the long range (ABREU-LEDÓN et al., 2018; CORBETT, 2011; NEGRÃO; GODINHO FILHO; MARODIN, 2016; SHAFER; MOELLER, 2012). But, there is limited understanding of L&SSi implementation in the food sector (COSTA et al., 2018). The first paper found in the literature was a Six Sigma study in 2004 of Knowles et al. (2004), it was implemented in a confectionery plant to reduce cost and to reduce process variation. In the follow year (2005), four papers were published concern the subject, all of them applying Lean manufacturing initiative. The publication of the hybrid initiative, LSS, was only found in 2013 (CHAKRABORTTY; BISWAS; AHMED, 2013), thirteen years after its emergence (GEORGE, 2002). The peak in the number of L&SSi papers was in 2015, with nine researches published in academic journals this year (COSTA et al., 2018).

This study focuses on 11 constructs regarding LSS as defined below:

- Supplier involvement (SUPPINV): the organization builds close relationship with supplier and develops them to be more involved in production and deliver process;
- Customer involvement (CUSTINV): the organization focuses on their customers and their needs;
- Pull (PULL): the organization facilitates just-in-time (JIT) production by using tools such as kanban to signal when to start or stop production:
- Continuous flow (FLOW): the organization establishes mechanisms that enable and ease the continuous flow of products;
- Set up time reduction (SETUP): the organization seeks to reduce process downtime between product changeovers;
- Total productive/preventive maintenance (TPM): the organization addresses equipment downtime by using total productive maintenance to achieve a high level of equipment availability;
- Statistical process control (SPC): the organization ensures that each process will supply defect free units to subsequent process;

- Employee involvement (EMPINV): the organization's employees have a role in problem solving and cross functional teams;
- Six Sigma role structure (SSROLE): the organization uses improvement specialists who are developed through Six Sigma training and certification programs and who have specific leadership roles and responsibilities in improvement teams;
- Six Sigma structured improvement procedure (SSIMP): the organization follows a standardized procedure in planning and conducting improvement projects or design projects and it uses appropriate Quality Management tools and techniques as prescribed in each step of the structured procedure;
- Six Sigma focus on metrics (SSMET): the organization uses quantitative metrics to measure performance, and to set improvement goals.

Contingency Theory suggests that food industry characteristics which are barriers to L&SSi implementation (see Costa et al., 2018) can be classified as contextual variables. These characteristics can influence the adoption of specific LSS practices, consequently, limiting the number of implementation of this continuous improvement initiative in the sector. The literature of L&SSi in the food industry and in the process industry are used to identify the main contextual variables that may impact the adoption of LSS practices in the sector. To further analyze the effect in the degree of adoption of these LSS practices across different food industry contexts, a set of contingency variables is selected, considering the recommendation of Sousa and Voss (2008).

Food industry firms are usually characterized by divergent product structures, where a relatively small number of (agricultural) raw materials (e.g. milk) are used to produce a large variety of end products (e.g. varieties of milk, yogurt and cream products) (AKKERMAN; DONK, 2009; POWELL et al., 2017). Differences in products can be associated with customer-specific products requests, either in packaging (form, size, print, labeling) or product recipe (AKKERMAN; VAN DER MEER; VAN DONK, 2010). This variety increases the number of process changeovers required for production.

Changeover is the time elapsed between the last piece in the run just completed and the first good piece from the process after the changeover (LEAN LEXICON, 2008). It is also affected by one of the main aspects that distinguishes the food industry from others sectors, their compulsory cleaning activity (DORA; GELLYNCK, 2015a; JAIN; LYONS, 2009; PANWAR et al., 2015). Cleaning must be performed to comply with quality assurance requirements to ensure safety products. When changing between recipes, piping is emptied, the equipment must be sterilized and the new product started. Also, when the sterilization process or one of the packaging lines reaches its maximum running time, the equipment has to be cleaned and again sterilized to ensure product quality (AKKERMAN; DONK, 2008). According to Dora et al. (2014) this strict cleaning environment found on food industry plants makes it difficult to implement the LSS practices that require set-up time reduction.

Another characteristic of the food industry is the large portion of raw materials obtained directly from agricultural activities which are subject to harvest cycles, making their availability seasonal (SATOLO et al., 2017). Additionally, these raw materials can be highly perishable (e.g. milk, fruit, vegetables, meat), so they can be stored only for a short period of time. To minimize raw materials losses and ensure product availability during the year, the product must be manufactured to stock (make to stock), affecting the adoption of practices related to JIT.

Food industry production is often batch or continuous production (AKKERMAN; VAN DONK, 2007). For example the beverage industry often uses continuous production. In a continuous environment tools such as the kanban pull systems are unrealistic but, equipment reliability and availability are critical, so practices such as TPM are very useful (ABDULMALEK; RAJGOPAL; NEEDY, 2006). The equipment used in the process also affects the adoption of pull practices. As equipment becomes more specialized equipment for the production of a specific product, there is less need for it to be used in other products and fast changeover practices are less applicable (ABDULMALEK; RAJGOPAL; NEEDY, 2006). Given what has been found, our first two hypotheses are stated as following:

H_1. Food industry implements Lean Six Sigma practices in a fragmented way.

H_2. Food industry characteristics impact the degree of adoption of Lean Six Sigma practices.

5.2.2 *Practice Based View*

Practice Based View (PBV) defines practices as an activity or set of activities that a variety of firms might execute (BROMILEY; RAU, 2014). The central argument of PBV is that some firms do not use all practices that could benefit them; so the use of practices can explain performance variation (BROMILEY; RAU, 2016). In contrast to the resource based view (RBV) the PBV examines imitable activities or practices, often in the public domain, amenable to transfer across firms (BROMILEY; RAU, 2014). Also in contrast to RBV, PBV's dependent variable is firm performance, not sustained competitive advantage (CARTER, 2017).

Recent studies were drawn on this theory. Treacy et al. (2019) used PBV to determine whether firms can enhance operational efficiency by adopting replicable management practices prescribed under the ISO 14001 standard. Silva, Pereira and Gold (2018) identified intra- and inter-organizational supply chain practices using PBV that helped focal companies in the cashew nut supply chain in Brazil respond to natural disasters. PBV was also used to evaluate the effect of operational, easily imitable types of environmental practices on environmental performance (BETTS; SUPER; NORTH, 2018). The PBV analysis assumes the benefits of a practice may vary across firms and may depend on a variety of moderators (BROMILEY; RAU, 2016).

In this study, practice based view is employed to test two hypothesis. These are: the adoption of Lean Six Sigma practices positively impacts food industry performance and, the positive effect of Lean Six Sigma practices on food industry performance is moderated by level of experience, such that the positive effect is greater when the level of experience is higher.

5.2.2.1 The effect of adoption of Lean Six Sigma practices in the Food industry's Performance

Some case studies showed that adopting L&SSi practices was beneficial to small and medium-sized food enterprises. These benefits included reduction of production costs and customer complaints, increases in profitability and productivity (DORA et al., 2014). Lean manufacturing reduced production lead time, eliminated losses, improved the use of physical space and machinery in a wine production company (JIMÉNEZ et al., 2011). Six Sigma implementation in a small food plant reduced the number of defective products and increased production efficiency in India (MAHESHWAR, 2012). LSS implemented in a confectionary plant reduced process variability, the number of defects and also achieved significantly improved financial performance (DORA; GELLYNCK, 2015b).

A recent, systematic literature review of L&SSi implementation in the food industry counted 31 different benefits in 28 cases of implementation (Costa et al., 2018). The most cited were productivity increases, cost reduction and inventory reduction. Benefits related to defect, time and value were also found. In accordance with these findings we hypothesize the following:

H_3. The adoption of Lean Six Sigma practices positively impacts food industry performance.

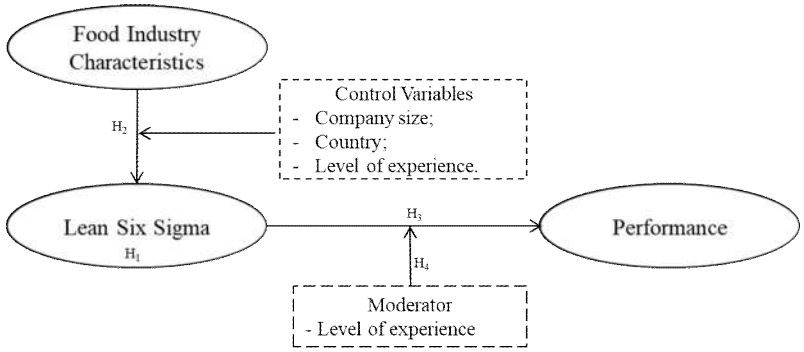
In general, the benefits of a practice may depend on moderators (BROMILEY; RAU, 2016). Experience plays a meaningful role in the implementation of continuous improvement initiatives (EASTON; ROSENZWEIG, 2012; JACOBS; SWINK; LINDERMAN, 2015; JAYARAM; AHIRE; DREYFUS, 2010; SWINK; JACOBS, 2012). Knowledge and experience provides a foundation for new knowledge absorption, by creating familiarity and reducing causal ambiguities (SWINK; JACOBS, 2012). Since Lean, Six Sigma and Lean Six Sigma initiatives are not well studied and were recently adopted (COSTA et al., 2018), the level of experience may significantly moderate the LSS adoption and firm performance in the food industry. So, we hypothesize the following:

H_4. The positive effect of Lean Six Sigma practices on food industry performance is moderated by level of experience, such that the positive effect is greater when the level of experience is higher.

5.3 Methodology

This study used a survey research methodology to evaluate the effectiveness and the relevance of the adoption of LSS in the food industry context, i.e. its appropriateness to the sector. A theoretical research model (Figure 5.1) based on the literature review was developed to illustrates the main elements investigated in this study and the hypotheses stated. The aim is to answer three research questions: What is the degree of adoption of LSS practices in the food industry?; What is the impact of Food Industry characteristics on the adoption of LSS practices?; What is the impact of LSS adoption on food industry's performance?

Figure 5.1 - Theoretical research model



The study population consisted of food firms in Brazil and the United State. The sample frame was created from a list of 1,849 food industries found in Brazilian and American Food Industry Associations websites. The survey was hosted at an online survey platform (Qualtrics). An invitation email containing a link to the online questionnaire (APPENDIX C) including a cover page explaining the purpose of the study and assuring confidentiality and the benefit of receiving a summary of the survey results was sent. A total of 337 companies completed the online questionnaire, but only 145 (43%) had implemented L&SSi in their settings and their responses were used in this study.

The survey questionnaire was designed following a set of recommendation of Forza (2009) and Dillman, Smyth and Christian (2014). First, the question formulation was considered; the language of the questionnaire was checked to be consistent with the respondent's level of understanding, the close-ended question format was selected to allow immediate analysis. The most critical questions were asked in the first sections. The survey was sent to managers or supervisors from manufacturing and quality departments.

This instrument was developed using an initial set of constructs and items from the well-known multi-item measurement scales for Lean developed by Shah and Ward (2007) and for Six Sigma by Zu, Fredendall and Douglas (2008). These constructs and items were purified and refined to establish reliability and validity to measure LSS concept through four rounds of an item-sorting exercise as suggested by (MENOR; ROTH, 2007). Each round was analyzed using 3 interrater reliability estimators (Interjudge Agreement Percentage, Cohen's *k* and Perreault and Leigh's I_r), 3 validity estimators (the proportion of substantive validity, coefficient of substantive validity, overall placement ratio) (ANDERSON; GERBING, 1991; MOORE; BENBASAT, 1991). After that, a pretest with a sample of fifty food companies was conducted to confirm the reliability and validity of the scales, using composite reliability values, magnitude and sign of the standardized factor loadings of the measurement items and average variance extracted (FORNELL; LARCKER, 1981). Finally, a large sample of 229 food industries was used in order to confirm reliability and validity. The final instrument used 45 practices to measure LSS adoption in the food industry.

The 145 survey respondents were asked about their level of agreement to each of the 45 LSS practices, using a seven-point Likert scale range from (1) strongly disagrees to (7) strongly agree. They also answered questions about three control variables (plant size, country, level of experience).

To answer the second research question (What is the impact of Food Industry characteristics on the adoption of Lean Six Sigma practices?), section 2 of the questionnaire was built based on a systematic literature review about the implementation of Lean, Six Sigma and Lean Six Sigma in the food industry (see COSTA et al., 2018) to identify contingency variables associated to food industry characteristics that may impact the adoption of LSS practices.

Considering the third research question (What is the impact of LSS adoption on food industry's performance?), the items to measure performance were generated based on the benefits and motivation factors cited more than twice in the systematic literature review of Costa et al. (2018). The six benefits (productivity increase, cost reduction, inventory reduction, defect rate reduction, financial improvement, lead time reduction and waste reduction) and the four motivations factors (elimination/reduction of product or process variation; cost reduction; competitiveness improvement; production/process quality improvement) were selected. A seven point Likert scale (1 = strongly disagree to 7 = strongly agree) was used for all items.

A pilot test was conducted to ensure research rigor (MACCARTHY et al., 2013) and to identify and solve problems before the survey was distributed in the field (DILLMAN; SMYTH; CHRISTIAN, 2014). The questionnaire was submitted to 7 experts in the study domain (food industry) and/or with relevant survey research background. Their comments were used to refine and improve the survey instrument for distribution to the final sample. Based on their feedback, it was decided to narrow the scope of the research by eliminating some blocks of questions. Those questions that were not comprehensible were refined and all open answer questions were change to close ended questions.

Survey data were collected from September through November of 2018. Table 5.1 illustrates the respondents' characterization: hierarchical position, department and time in the company.

Table 5.1 - Respondent characteristics

Hierarchical position	Sample %	Departament	Sample %	Time in the company	Sample %
Manager/Coordinator	43	Manufacturing	48	Above ten years	30
Supervisor/Lead	29	Quality	26	Between one to four years	30
Director	11	Continuous improvement	10	Between 4 and 7 years	20
President/CEO	6	Other	10	Between 7 to 10 years	12
Did not want to answer	6	Did not want to answer	7	Less than one year	9
Other	5				

Response bias was investigated since it increases the generalizability of findings (FLYNN et al., 1990; LINDNER; MURPHY; BRIERS, 2001). It was conducted based on the approach suggested by Armstrong and Overton (1977) by comparing early respondents (responded following the first contact) to late respondents (answered on the following contacts). The late respondents are considered more similar to the nonresponse group than the earlier respondents (ARMSTRONG; OVERTON, 1977). After the comparison through an independent t-test, no statically significant differences were found.

In addition, Harmon's single-factor test was performed to test for the possibility common method bias (CMB) (PODSAKOFF et al., 2003), since we base our study on a single key informant approach. It reveals that one factor accounted for 36.6% of the variance explained. This means that no one factor emerged that counted for more than 50% of the variance explained, which suggests that common method bias is not a major concern in this study (PODSAKOFF et al., 2003).

5.4 Results and Discussion

Data was analyzed to evaluate the four hypotheses through the use of statistical techniques and Partial Least Square-Structural Equation Modeling (PLS-SME). Friedman two-way ANOVA was used to assess differences in the degree of adoption of LSS practices. Kruskall-Wallis was applied to evaluate the difference in adoption of practices among food industries with different characteristics. Partial Least Square-Structural Equation Modeling (PLS-SME) technique by SmartPLS 3.0 software was used to examine LSS practice loading and the path relationships hypothesized in this study.

PLS was used considering it is particularly suitable when the sample size is small, the data are not normally distributed, and the model is complex with many indicators and relationships to estimate (HAIR et al., 2014), and it is a preferred method for exploratory research (DUBEY et al., 2018; PENG; LAI, 2012; PENG; PRYBUTOK; XIE, 2019). To test the robustness of the model, a bootstrapping procedure with replacement (5000 resamples) was employed. It was used to determine the estimated standard errors and the significance of the parameter estimates (CHIN, 1998; HELM; EGGERT; GARNEFELD, 2009).

We divide this section according to the four hypotheses.

5.4.1 *The adoption of Lean Six Sigma in the food industry (H_1)*

Hypothesis 1 (Food industry implements LSS practices in a fragmented way) was supported by using a nonparametric test for k related samples (Friedman two-way ANOVA test). The result shows a difference in the degree of adoption of LSS practices at a 5 percent significance level ($\chi^2 = 895.91$, $df = 44$, $p = 0.000$) (see Table 5.2).

Eight of the 45 LSS practices were adopted by the majority of the respondents with a median equal to 6 and mean utilization of more than 5.4 (Table 5.2). Three of them are related to Six Sigma Focus on Metrics, two are related to Flow, one to Employee Involvement, one to Customer Involvement and one to Supplier Involvement (see Table 5.2). Otherwise, some LSS practices are limited adopted in the food industry. Nine LSS practices had a median less than 4.0 and mean utilization of less than 4.4 (see Table 5.2).

A Friedman test was employed to compare the degree of adoption of the practices within each of the eleven LSS constructs. Table 5.2 summarizes the results. Except by the Six Sigma Improvement construct, the other ten constructs presented differences between the degree of adoption of the practices that represent them, at a 5 percent significance level. These results show that the hypothesis 1 can be accepted, once the adoption of LSS practices in the food industry occurs in a fragmented manner.

Those practices with the lowest adoption in this sector are part of the Pull, Six Sigma role structure and SPC constructs. The low applicability of pull systems supports the previous findings of Panwar et al. (2018) and Dora et al. (2014) in the process and food industry, respectively, that also found the difficult to implement the pull construct, mainly due to the characteristics of their industries.

Six Sigma role structure is considered as an infrastructure practice, which includes the recruitment, selection, training, and development of talented individuals at various levels of belts (Master Black Belt, Black Belt, Green Belt, and Yellow Belt) (ARUMUGAM; ANTONY; LINDERMAN, 2014), involving large investments (JACOBS; SWINK; LINDERMAN, 2015), which is a challenge in a sector that often work with fairly low profit margins (AKKERMAN; VAN DER MEER; VAN DONK, 2010; DUDBRIDGE, 2011). SPC is viewed by food companies as being relatively complex and too advanced (LIM et al., 2015b). According to Lim et al. (LIM et al., 2015a) the sector lacks of statistical knowledge, which has an alarming contribution to the fear of employees towards the SPC technique. To Lim, Antony and Albliwi (LIM; ANTONY; ALBLIWI, 2014) such challenges can be addressed through continuous training, increasing the awareness and knowledge related to SPC implementation and subsequently, reducing the resistance to the implementation.

Table 5.2 - The degree of adoption of LSS practices among food industries

Construct	Mean	Median	Std. Dev.	Item Code	Item	Mean	Median	Std. Dev.	Min.	Max.	Frequency (%)						
											1	2	3	4	5	6	7
FLOW	5.38	6.00	1.32	FLOW_03	Equipment is grouped to produce a continuous flow of families of products	5.58*	6	1.153	3	7	0	0	6	12	28	30	26
				FLOW_01	Products are classified into groups with similar processing requirements	5.57*	6	1.129	2	7	0	1	3	14	28	30	24
				FLOW_04	Families of products determine our factory layout	5.29*	6	1.554	1	7	2	4	6	17	19	23	28
				FLOW_02	Products are classified into groups with similar routing requirements	5.10	5	1.351	1	7	1	3	6	21	29	23	17
SSMET	5.35	6.00	1.52	SSMET_01	Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance	5.59*	6	1.441	1	7	1	3	5	10	19	30	32
				SSMET_03	Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant	5.59*	6	1.372	1	7	1	3	5	13	16	32	30
				SSMET_02	Metrics are used to link quality performance to strategic goals	5.41*	6	1.437	1	7	1	3	7	12	22	28	27
				SSMET_04	Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance	4.81	5	1.679	1	7	2	10	11	16	21	20	19
SUPPINV	5.10	5.00	1.54	SUPPINV_03	We frequently are in close contact with our suppliers.	5.61*	6	1.198	2	7	0	1	3	19	19	30	28
				SUPPINV_02	We work with our key suppliers so they are contractually committed to annual cost reductions.	5.36*	6	1.475	1	7	1	5	6	14	23	23	28
				SUPPINV_01	We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis.	5.34*	6	1.335	2	7	0	2	8	17	21	29	23
				SUPPINV_05	We strive to establish long-term relationship with our suppliers.	4.68	5	1.581	1	7	2	9	12	21	21	22	13
				SUPPINV_04	We give our suppliers feedback on quality and delivery performance.	4.51	5	1.745	1	7	6	9	13	19	19	20	14
SSIMP	5.04	5.00	1.58	SSIMP_02	We use a structured approach to manage quality improvement activities	5.14	5	1.443	1	7	1	3	8	17	28	21	21
				SSIMP_03	We have a formal planning process to decide the major quality improvement projects	5.09	5	1.585	1	7	2	6	10	17	18	27	21
				SSIMP_04	All improvement projects are reviewed regularly during the process	5.01	5	1.451	1	7	1	3	10	25	23	19	20
				SSIMP_01	In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC-Define, Measure, Analyze, Improve and Control)	4.92	5	1.824	1	7	5	10	9	12	18	22	24

*p value < 0.05

Table 5.2 - The degree of adoption of LSS practices among food industries (continued)

Construct	Mean	Median	Std. Dev.	Item Code	Item	Mean	Median	Std. Dev.	Min.	Max.	Frequency (%) 1	2	3	4	5	6	7
EMPINV	4.98	5.00	1.60	EMPINV_01	Shop-floor employees are key to problem solving teams	5.56*	6	1.452	1	7	1	4	7	6	25	23	34
				EMPINV_04	Shop-floor employees undergo cross functional training	5.37*	6	1.389	2	7	0	2	9	17	21	23	28
				EMPINV_02	Shop-floor employees drive suggestion programs	4.50	5	1.65	1	7	4	10	12	21	19	21	11
				EMPINV_03	Shop-floor employees lead product / process improvement efforts	4.50	5	1.595	1	7	5	6	14	23	23	17	12
SETUP	4.86	5.00	1.53	SETUP_02	We are working to lower setup times in our plant	5.43*	5	1.466	1	7	2	2	8	6	32	19	30
				SETUP_01	Our employees practice setups to reduce the time required	4.94*	5	1.485	1	7	1	6	10	17	23	28	14
				SETUP_04	We have short production cycle times to quickly respond to customer requests	4.74	5	1.452	1	7	2	7	8	23	28	21	11
				SETUP_03	We have low set up times of equipment in our plant	4.32	4	1.536	1	7	1	11	20	23	20	14	10
CUSTINV	4.70	5.00	1.64	CUSTINV_01	Our customers give us feedback on quality and delivery performance	5.47*	6	1.405	1	7	1	3	6	10	28	23	29
				CUSTINV_02	Our customers are directly involved in current and future product offerings	4.78	5	1.539	1	7	2	8	9	23	24	19	15
				CUSTINV_04	We regularly conduct customer satisfaction surveys	4.42	4	1.755	1	7	7	8	15	21	15	20	13
				CUSTINV_03	Our customers frequently share current and future demand information with marketing department	4.14	4	1.532	1	7	6	12	12	26	23	17	3
TPM	4.65	5.00	1.77	TPM_02	We maintain all our equipment regularly	5.20*	6	1.597	1	7	1	8	7	14	19	26	25
				TPM_03	We maintain excellent records of all equipment maintenance related activities	4.92*	5	1.627	1	7	2	6	16	13	23	19	21
				TPM_01	We dedicate a portion of everyday to planned equipment maintenance related activities	4.48	5	1.667	1	7	3	13	12	17	26	17	12
				TPM_04	We post equipment maintenance records on shop floor for active sharing with everyone	4.01	4	1.949	1	7	11	18	14	15	14	15	13
SPC	4.54	5.00	1.81	SPC_04	We use fishbone type diagrams to identify causes of quality problems	5.10*	5	1.751	1	7	5	5	10	12	19	21	28
				SPC_03	Charts showing defect rates are used as tools on the shop-floor	4.57	5	1.836	1	7	7	10	13	17	14	24	16
				SPC_02	We extensively use statistical techniques to reduce process variance	4.33	4	1.752	1	7	6	13	12	21	19	18	12
				SPC_01	Large amount of process/equipment on the shop floor is currently under Statistical Process Control	4.14	4	1.768	1	7	7	17	11	19	22	14	10

*p value < 0.05

Table 5.2 - The degree of adoption of LSS practices among food industries (continued)

Construct	Mean	Median	Std. Dev.	Item Code	Item	Mean	Median	Std. Dev.	Min.	Max.	Frequency (%)						
											1	2	3	4	5	6	7
SSROLE	4.46	5.00	1.79	SSROLE_02	In our plant, members of improvement teams have their roles and responsibilities specifically identified	5.12*	5	1.554	1	7	1	6	10	13	25	21	23
				SSROLE_04	Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities	4.40	4	1.781	1	7	6	13	9	23	19	14	15
				SSROLE_03	The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience	4.19	4	1.761	1	7	10	9	14	25	16	17	10
				SSROLE_01	We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs	4.12	4	1.869	1	7	13	12	9	19	19	19	9
PULL	4.34	4.00	1.84	PULL_02	Production at stations is "pulled" by the current demand of the next station	4.79*	5	1.688	1	7	3	10	9	19	21	19	19
				PULL_01	Production is "pulled" by the shipment of finished goods	4.76*	5	1.737	1	7	6	8	9	18	23	18	19
				PULL_03	We use a "pull" production system (a method of production control in which downstream activities signal their needs to upstream activities)	4.13	4	1.811	1	7	10	10	19	21	16	12	13
				PULL_04	We use a Kanban, squares, or containers of signals for production control	3.68	4	1.907	1	7	15	17	18	18	12	8	12

*p value < 0.05
Source: Proposed by the author.

We control the degree of adoption for confounding effects of company size, level of experience, and country where the plant is located, as they have been often used as control variables by previous studies in the continuous improvement field (e.g. DESANCTIS et al., 2018; JAYARAM; AHIRE; DREYFUS, 2010; KULL et al., 2014; SHAH; WARD, 2007; NETLAND, 2016; YANG; HONG; MODI, 2011). We employed Kruskal-Wallis tests to check their association with the degree of adoption of LSS practices in the sector (see Table 5.3).

Company size was measured as the number of employees in the factory, and grouped into three categories: small companies (up to 99 employees), medium companies (between 100 and 499 employees) and large companies (above 499 employees). Most of the food industries in the sample are medium (46%), followed by large (32%), and then by small (22%). The mean adoption rates (mean rank) of ten practices were significantly different at the 0.05 confidence level, being most of them related to Six Sigma constructs (six of them). The other four are practices related to Statistical Process Control (two of them), Customer Involvement (one of them) and TPM (one of them) (see Table 5.3). The large companies adopted these practices in a high level, which is supported by evidence in previous literature, that suggests that large companies are more likely to implement L&SSi practices than small companies (GODINHO FILHO; GANGA; GUNASEKARAN, 2016; SHAH; WARD, 2003; WHITE; PEARSON; WILSON, 1999).

Six Sigma adoption often involve large investments in training, consulting support, reorganizations, and associated information systems (JACOBS; SWINK; LINDERMAN, 2015), which is a challenge to small companies that usually face financial and human resources constraints (TIMANS et al., 2014; NETLAND, 2016). In addition, according to Kumar, Antony and Douglas (2009) many small and medium-sized enterprises (SMEs), in spite of a number of Six Sigma success stories in large organizations, are yet to be convinced of the benefits from the introduction, development, implementation and deployment of Six Sigma. These authors concluded that it is imperative for small companies to have a strong management commitment and good leadership skills before embarking on the Six Sigma initiative. The lack of adequate funding also denies many SMEs the opportunity to hire their ideal management team, and that they, therefore, suffer from lack of astute leadership and planning, preventing SMEs from implementing Lean manufacturing, so unless small companies restructure their focus to become more receptive and capable of absorbing new ideas the implementation of Lean will be delayed or may not be achieved (ACHANGA et al., 2006).

Table 5.3 - The effect of control variables in the degree of adoption of LSS practices among food industries

LSS practices	Company Size				Level of experience				Country		
	Small Mean rank	Medium Mean rank	Large Mean rank	p-value	Low Mean rank	Intermediate Mean rank	High Mean rank	p-value	USA Mean rank	Brazil Mean rank	p-value
FLOW_01	71.78	76.14	69.41	0.67	64.76	67.38	88.15	0.01*	74.41	72.37	0.779
FLOW_02	69.38	77.80	68.72	0.43	68.47	71.31	80.31	0.24	76.86	71.27	0.447
FLOW_03	70.61	70.83	77.68	0.63	60.57	71.68	84.90	0.042*	61.72	78.08	0.025*
FLOW_04	81.28	70.72	70.56	0.43	70.63	75.89	73.57	0.16	65.38	76.43	0.133
SSMET_01	58.13	75.86	79.11	0.06	53.15	73.59	88.78	0.000*	74.21	72.46	0.809
SSMET_02	50.13	76.11	84.21	0.001*	47.94	73.52	90.63	0.000*	73.58	72.74	0.909
SSMET_03	67.86	75.84	72.51	0.66	65.16	73.37	79.44	0.318	71.36	73.74	0.743
SSMET_04	57.03	78.39	76.31	0.045*	58.06	67.80	90.03	0.003*	80.77	69.51	0.129
SUPPINV_01	84.84	64.81	76.44	0.06	71.82	68.81	80.13	0.48	60.48	78.64	0.013*
SUPPINV_02	77.11	71.33	72.55	0.80	73.93	65.97	82.97	0.12	75.67	71.80	0.599
SUPPINV_03	76.72	70.80	73.56	0.79	70.74	66.91	83.62	0.15	73.20	72.91	0.968
SUPPINV_04	79.50	71.23	71.06	0.60	70.44	72.73	76.46	0.69	62.48	77.74	0.040*
SUPPINV_05	58.55	75.92	78.73	0.08	68.31	67.01	83.36	0.15	69.06	74.78	0.44
SSIMP_01	53.97	78.02	78.90	0.013*	56.97	72.44	87.53	0.003*	65.99	76.16	0.170
SSIMP_02	55.66	77.61	78.33	0.025*	57.16	70.64	90.29	0.000*	66.78	75.80	0.220
SSIMP_03	62.53	76.99	74.52	0.25	47.34	77.10	87.53	0.000*	69.90	74.40	0.543
SSIMP_04	59.23	77.50	76.05	0.10	54.91	76.82	83.57	0.002*	69.53	74.56	0.496
EMPINV_01	70.11	68.60	81.15	0.24	69.19	67.20	84.62	0.093	65.90	76.20	0.157
EMPINV_02	57.63	76.21	78.96	0.06	64.88	65.70	88.64	0.019*	70.61	74.08	0.641
EMPINV_03	72.42	67.94	80.50	0.28	60.46	72.92	82.85	0.106	53.58	81.74	0.000*
EMPINV_04	65.95	67.99	84.83	0.05	64.03	70.53	84.62	0.047*	54.49	81.33	0.000*
SETUP_01	67.55	72.69	77.15	0.59	53.99	69.86	91.62	0.001*	61.40	78.22	0.023*
SETUP_02	61.22	79.30	72.18	0.12	63.12	73.40	81.97	0.045*	70.89	73.95	0.674
SETUP_03	75.02	75.34	68.34	0.64	66.94	71.44	78.46	0.520	69.47	74.59	0.489
SETUP_04	64.52	72.65	79.27	0.29	71.16	71.78	77.18	0.653	61.60	78.13	0.025*

*p value < 0.05

Table 5.3 - The effect of control variables in the degree of adoption of LSS practices among food industries (continued)

	Company Size				Level of experience				Country		
LSS practices	**Small**	**Medium**	**Large**	**p-value**	**Low**	**Intermediate**	**High**	**p-value**	**USA**	**Brazil**	**p-value**
	Mean rank	**Mean rank**	**Mean rank**		**Mean rank**	**Mean rank**	**Mean rank**		**Mean rank**	**Mean rank**	
CUSTINV_01	68.86	80.86	64.78	0.10	73.54	70.46	75.38	0.89	82.06	68.93	0.072
CUSTINV_02	79.11	72.63	69.36	0.58	68.90	70.40	78.52	0.59	61.69	78.09	0.027*
CUSTINV_03	55.67	75.03	81.95	0.018*	58.57	75.85	79.34	0.13	72.50	73.23	0.922
CUSTINV_04	58.94	75.71	78.77	0.09	60.65	71.02	86.22	0.021*	66.68	75.85	0.218
TPM_01	61.89	71.18	83.12	0.07	58.82	74.40	83.05	0.035*	67.21	75.61	0.258
TPM_02	64.14	69.01	84.64	0.05	57.57	73.59	82.64	0.051	67.59	75.44	0.287
TPM_03	52.42	74.11	85.46	0.002*	61.59	67.82	89.20	0.009*	67.54	75.46	0.285
TPM_04	69.59	67.37	83.22	0.12	60.88	73.95	82.36	0.057	58.58	79.49	0.005*
SPC_01	66.38	74.26	75.74	0.58	62.49	68.94	87.20	0.026*	65.40	76.42	0.138
SPC_02	66.75	77.89	70.39	0.40	59.34	74.01	83.47	0.028*	67.27	75.58	0.264
SPC_03	47.44	77.01	84.78	0.000*	58.60	71.48	87.07	0.010*	68.98	74.81	0.433
SPC_04	45.56	77.08	85.96	0.000*	63.46	70.35	85.56	0.023*	68.13	75.19	0.339
SSROLE_01	59.28	71.55	84.38	0.028*	56.75	73.61	85.54	0.011*	60.19	78.77	0.013*
SSROLE_02	61.72	71.82	82.34	0.09	64.72	68.42	86.43	0.038*	53.70	81.69	0.000*
SSROLE_03	55.41	79.05	76.49	0.023*	51.09	74.30	89.00	0.000*	60.12	78.80	0.012*
SSROLE_04	65.08	68.43	84.81	0.06	50.74	71.00	92.22	0.000*	63.24	77.39	0.057
PULL_01	75.53	74.75	68.82	0.70	68.12	71.90	77.73	0.76	69.11	74.75	0.447
PULL_02	73.89	69.45	77.37	0.60	68.03	72.24	76.89	0.74	59.17	79.23	0.007*
PULL_03	65.02	75.42	75.04	0.47	61.57	72.60	82.51	0.15	66.64	75.86	0.216
PULL_04	69.84	66.31	84.54	0.06	65.76	72.73	80.19	0.25	59.50	79.08	0.009*

*p value < 0.05

There were 24 practices whose adoption greatly differed depending on the level of experience of the company with L&SSi (see Table 5.3). In this study the level of experience was assessed by asking the duration that companies have L&SSi implemented. Companies with less than 1 year of implementation are classified in the low level of experience category, companies that implemented the initiative for more than 1 year and less than 3 years are classified in the intermediate stage, and above 3 years companies are in the high stage. Most of companies surveyed are in the intermediate stage (43%), followed by high (33%), and low (24%).

The experience in years considerably impact the degree of adoption of LSS practices, especially related to Six Sigma constructs. Excepted by one Six Sigma practice ("Financial performance is part of the criteria for evaluating the outcomes of quality improvements in our plant."), all the others were affected by the level of experience. The greater the level of experience, the higher is the degree of adoption of these practices.

The level of experience also strongly affected SPC, since all its four practices are mostly adopted by companies with a high stage of implementation. A large impact on Flow, Setup, Employee Involvement, and TPM was also identified. Two practices of each were affected by level of experience. Finally, one practice related to Customer Involvement was affected. Food organizations in the low category lack the experience necessary to implement all Lean Six Sigma dimensions completely. As organizational experience grows, so too do the opportunities to benefit from knowledge accumulated. Furthermore, prior experience may also promote trust concern the effectiveness of L&SSi in the food industry, so companies increase the adoption of their practices.

The country where company is located was the last control variable analyzed. We analyzed the adoption of LSS practices in Brazilian and American food industries. Both countries differentiate between their culture and their level of development. As defined by Hofstede scale (HOFSTEDE; HOFSTEDE, 2005) plants located in countries that score 50 or lower on the Hofstede Individualism dimension were categorized as collectivistic cultures, as Brazil, whereas those with a score above 50 were categorized as individualistic cultures, as the USA. In relation to the level of development, Brazil is classified as a developing country and the United State as a developed country (UNITED NATIONS, 2018).

The result indicates a high level of LSS adoption in Brazilian food industries, 14 practices are more adopted in Brazilian companies than in the USA, in spite of the fact that in recent literature reviews (CHERRAFI et al., 2016; COSTA; GODINHO FILHO, 2016; D'ANDREAMATTEO et al., 2015; JASTI; KODALI, 2015; YADAV; DESAI, 2016) developed countries are ahead considering the number of publications in the continuous improvement field. A possible reason for that could be the collectivistic culture of Brazil, since Lean Six Sigma involves work in group and collectivism increases the involvement of employees (PAKDIL; LEONARD, 2015), which may lead to a more successful implementation. Another possible explanation is the fact that most of Brazilian companies in the sample are large factories (37%) and the American are mostly dominated by medium factories (67%). As observed before, the degree of adoption of some Lean Six Sigma practices is highly adopted in large companies.

5.4.2 *Food industry inherent characteristics and the adoption of LSS practices (H_2)*

We analyzed the contingency effect of food industry characteristics in the adoption of LSS practices, since LSS adoption in this sector is not well studied and the food industry's inherent characteristics are cited as barriers to implementation (see COSTA et al., 2018). A Kruskal-Wallis test was employed to evaluate the hypothesis 2 (Food industry characteristics impact the adoption of Lean Six Sigma practices in the sector), and to check the contingency effect of food industry characteristics (cleaning impact, demand response strategy, process type, equipment type) in the adoption of LSS practices. Table 5.4 shows the characteristics of the companies surveyed.

Table 5.4 – Companies characteristics

Company characteristic	Category	Sample %
Cleaning impact	Low	28
	Moderate	28
	High	44
Demand response strategy	MTS	46
	Mix to Order	8
	MTO	22
	Hybrid	24
Process type	Batch	39
	Continuous	35
	Hybrid	26
Equipment type	General-Purpose	38
	Mix	35
	Specialized	27

Most of the companies stated that changeover time is highly affected by cleaning time. The Kruskal-Wallis test confirmed that the compulsory cleaning process in the food industries make the adoption of the set-up time reduction difficult. The greater is the cleaning impact, the lower is the adoption of SETUP_03 practice ("We have low set up times of equipment in our plant.") at p-value <0.05. However, there was not found difference in the practices associated with the effort to reduce set-up time ("Our employees practice setups to reduce the time required." and "We are working to lower setup times in our plant."), which indicate the food companies are searching for ways to reduce their set-up time. For this purpose LSS tools such as SMED (single minute exchange of dies) could be considered and could be more applied. SMED refers to the target of reducing changeover times to a single digit, or less than 10 minutes, first separating internal setup operations, which can be done only when a machine is stopped (such as inserting a new die) from external operations that can be performed while the machine is running (such as transporting the new die to the machine), and then converting internal setup operations to external operations (LEAN LEXICON, 2008). Lopes and Freitas (2015) applied this tool in a beverage industry. They reported gains in productivity with negligible investment, and savings in manufacturing costs estimated to amount to 35.000 Euros/year.

The effects of the demand response strategy used by the food industry factories on L&SSi adoption was also considered. Most of the companies surveyed manufacture their products to stock (MTS), possibly to minimize the losses caused by the perishability of their raw materials or to ensure the availability of the food during the year. The factories demand response strategy did not impact the level of adoption of pull practices. No statistical significance (at $p < 0.05$) was observed. Moreover, no significant relationship was found between the adoption of pull practices and process type, neither between pull practices and equipment type. The lack of knowledge about practices related to Pull dimension could be a possible reason, since it was the LSS dimension less adopted by the sector.

More knowledge about the Pull practices and their benefits may facilitate its adoption. In addition, some actions to produce using other demand response strategies instead of pure MTS may facilitate its adoption. Make to order (MTO), in the food industry, is applied when MTS is not viable because of unpredictable demand and the perishable nature of the products, and the hybrid strategy (MTS-MTO) is adopted as a consequence of the huge increase in product variety and shorter lead-time requirements of the customers (SOMAN; VAN DONK; GAALMAN, 2007). However, pure MTO can be ruled out because of the large number of relatively long, costly set-ups that are required (SOMAN; VAN DONK; GAALMAN, 2007).

Another strategy few used by the sector, the mix-to-order (when flexible recipes are stored and subsequently mixed when customer orders arrive) (AKKERMAN;

DONK, 2010) could be more employed, since food-processing companies can sometimes produce the same end products in different ways: either in packaging form, size, label, or product recipe.

The process type affected the adoption of two practices related to TPM ("We maintain excellent records of all equipment maintenance related activities" and "We post equipment maintenance records on shop floor for active sharing with everyone"). In continuous companies they were greater (significance $p < 0.05$) as expected, since equipment reliability and availability would be critical in this sector. The other two TPM practices had higher adoption in continuous flow factories, but they were not statically different ($p < 0.05$).

These results indicate that hypothesis 2 is partially supported since the adoption of some LSS practices are affected by the food industry characteristics; however, their effect is low compared to the effect of level of experience. The findings suggest the lack of knowledge stated by some studies as a barrier to the adoption of L&SSi in the sector (see DORA et al., 2014; UPADHYE; DESHMUKH; GARG, 2010; VLACHOS, 2015) may lead managers to hesitate before adopting some LSS practices.

Table 5.5 provides the descriptive statistics of managerial related barriers in the food industry. These factors were the lack of skilled workers; lack of management support; poor employee participation; resistance to change. These factors had previously been found to be barriers to the adoption of L&SSi in the food industry (COSTA et al., 2018). A five-point Likert scale ranges from 1 (the factor does not impact at all the adoption of L&SSi) to 5 (the factor impact in a great extent the adoption) were used to ask respondents the impact of these factors on the adoption of L&SSi.

Table 5.5 - Managerial related barriers in the food industry

Barriers	Median	Mean	Std. Dev.	Min.	Max.	Frequency (%)				
						1	2	3	4	5
Lack of knowledge	4	3.51	1.06	1	5	3	14	28	35	19
Lack of skilled workers	4	3.76	1.02	1	5	1	11	26	34	28
Lack of management support	4	3.32	1.44	1	5	15	17	17	21	30
Poor employee participation	3	3.37	1.19	1	5	7	17	28	27	21
Resistance to change	4	3.82	1.07	1	5	3	9	20	37	30

Except for one item, "Poor employee participation" whose median was 3.0, these managerial barriers had a median score of 4.0. This means that they had a moderate/high impact of adoption of LSS practices, which indicates the lack of familiarity and uncertainty that food industry has about the effectiveness of L&SSi.

5.4.3 *The effect of Lean Six Sigma adoption in the Food industry's Performance (H_3 and H_4)*

A reflexive hierarchical component model was constructed to analyze the relevance of adopting LSS practices in the sector and evaluate the impact of LSS practices in food industry performance hypothesized (H_3: The adoption of Lean Six Sigma practices positively impacts food industry performance). The model simultaneously maps the lower constructs (i.e., the 11 LSS dimensions) and a higher-level construct (i.e., the LSS initiative. This reduces the number of relationships in the structural model, creating a PLS path model that is more parsimonious and easier to apprehend (HAIR et al., 2017).

The model estimation was conducted following two stages recommended by Peng and Lai (2012), examining validity and reliability of the measurement model and analyzing the structural model. A confirmatory factor analysis was employed to evaluate the reliability and convergent and discriminant validity of the model. Convergent validity was tested using the Fornell and Larcker's (1981) criteria, that considers the average variance extracted (AVE) which measures the amount of variance that is captured by the construct in relation to amount of variance due measurement error, and it was also assessed using the magnitude and sign of the standardized factor loadings (λ). The reliability was assessed using composite reliability values (CR) to check whether the measurement items sufficiently represent their respective constructs.

The constructs and its practices exceeded the recommended values of reliability and convergent validity estimators (i.e. AVE > 0.5, $\lambda > 0.7$ and CR > 0.7) (HAIR et al., 2009), except by five items that presented loading factor value (λ) between 0.5 and 0.7. A bootstrapping procedure was performed, all items showed high statistical significance (at $p < 0.05$) related to their corresponding construct and all LSS dimensions showed high statistical significance (at $p < 0.05$) related to LSS, so we decided to keep all the item in the instruments. The results are illustrated in Table 5.6.

Table 5.6 - Results of validity and reliability

LSS scales and measurement items	λ	t value	AVE	CR	t value
Supplier Involvement					
We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis	0.75	*17.82*	*0.54*	*0.85*	*22.07*
We work with our key suppliers so they are contractually committed to annual cost reductions	0.69	*12.30*			
We frequently are in close contact with our suppliers	0.75	*15.69*			
We give our suppliers feedback on quality and delivery performance	0.74	*17.63*			
We strive to establish long-term relationship with our suppliers	0.75	*17.12*			
Customer involvement					
Our customers give us feedback on quality and delivery performance	0.65	*8.45*	*0.52*	*0.81*	*13.02*
Our customers are directly involved in current and future product offerings	0.71	*10.65*			
Our customers frequently share current and future demand information with marketing department	0.74	*12.06*			
We regularly conduct customer satisfaction surveys	0.78	*17.47*			
Pull					
Production is "pulled" by the shipment of finished goods	0.77	*15.71*	*0.59*	*0.85*	*13.31*
Production at stations is "pulled" by the current demand of the next station	0.80	*20.30*			
We use a "pull" production system (a method of production control in which downstream activities signal their needs to upstream activities)	0.88	*38.79*			
We use a Kanban, squares, or containers of signals for production control	0.58	*6.36*			
Continuous flow					
Products are classified into groups with similar processing requirements	0.81	*24.77*	*0.55*	*0.83*	*13.87*
Products are classified into groups with similar routing requirements	0.76	*13.20*			
Equipment is grouped to produce a continuous flow of families of products	0.77	*16.36*			
Families of products determine our factory layout	0.59	*7.02*			
Set up time reduction					
Our employees practice setups to reduce the time required	0.80	*19.47*	*0.52*	*0.81*	*22.61*
We are working to lower setup times in our plant	0.78	*18.00*			
We have low set up times of equipment in our plant	0.73	*12.75*			
We have short production cycle times to quickly respond to customer requests	0.52	*5.72*			
Statistical Process Control					
Large amount of process/equipment on the shop floor is currently under Statistical Process Control	0.85	*25.15*	*0.6*	*0.87*	*35.14*
We extensively use statistical techniques to reduce process variance	0.84	*31.47*			
Charts showing defect rates are used as tools on the shop-floor	0.79	*19.94*			
We use fishbone type diagrams to identify causes of quality problems	0.70	*12.07*			

Table 5.6 - Results of validity and reliability (continued)

LSS scales and measurement items	**λ**	**t value**	**AVE**	**CR**	**t value**
Employee involvement					
Shop-floor employees are key to problem solving teams	0.76	*15.38*			
Shop-floor employees drive suggestion programs	0.80	*20.16*	*0.66*	*0.89*	*32.53*
Shop-floor employees lead product / process improvement efforts	0.86	*33.92*			
Shop-floor employees undergo cross functional training	0.83	*29.92*			
Total productive/preventive maintenance					
We dedicate a portion of everyday to planned equipment maintenance related activities	0.79	*19.77*			
We maintain all our equipment regularly	0.85	*29.53*	*0.68*	*0.89*	*31.20*
We maintain excellent records of all equipment maintenance related activities	0.86	*14.96*			
We post equipment maintenance records on shop floor for active sharing with everyone	0.80	*24.21*			
Six Sigma role structure					
We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs	0.90	*46.76*			
In our plant, members of improvement teams have their roles and responsibilities specifically identified	0.70	*13.81*			
The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience	0.86	*32.56*	*0.71*	*0.91*	*28.88*
Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities	0.89	*48.83*			
Six Sigma structured improvement procedure					
In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC-Define, Measure, Analyze, Improve and Control)	0.83	*30.01*			
We use a structured approach to manage quality improvement activities	0.86	*24.75*	*0.72*	*0.91*	*64.25*
We have a formal planning process to decide the major quality improvement projects	0.87	*40.10*			
All improvement projects are reviewed regularly during the process	0.81	*29.90*			
Six Sigma focus on metrics					
Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance	0.89	*48.93*			
Metrics are used to link quality performance to strategic goals	0.86	*30.32*			
Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant	0.77	*15.86*	*0.67*	*0.89*	*23.23*
Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance	0.74	*14.66*			

The discriminant validity among the constructs was assessed by comparing the shared variance (squared correlation) between each pair of constructs against the average of the AVE (FORNELL; LARCKER, 1981). Table 5.7 shows that all the AVE values meet these criteria as they are greater than the square of the correlation between all possible pairs of constructs. Further evidence of discriminant validity was obtained, once the factor loading for each item on its intended construct was higher than its cross-loadings for all other constructs (HAIR et al., 2014) (see Table 5.8).

Table 5.7 - Results of discriminant validity

	CUSTINV	EMPINV	FLOW	PULL	SETUP	SPC	SSIMP	SSMET	SSROLE	SUPPINV	TPM
CUSTINV	0.724										
EMPINV	0.490	0.813									
FLOW	0.501	0.482	0.740								
PULL	0.389	0.521	0.449	0.767							
SETUP	0.435	0.610	0.461	0.519	0.718						
SPC	0.509	0.670	0.449	0.519	0.612	0.795					
SSIMP	0.506	0.732	0.554	0.538	0.623	0.778	0.847				
SSMET	0.529	0.571	0.464	0.457	0.601	0.680	0.733	0.817			
SSROLE	0.457	0.746	0.412	0.486	0.608	0.685	0.747	0.630	0.842		
SUPPINV	0.644	0.606	0.580	0.518	0.572	0.527	0.604	0.463	0.483	0.735	
TPM	0.495	0.678	0.519	0.498	0.653	0.643	0.706	0.599	0.673	0.602	0.824

Table 5.8 - Cross-loading analysis

	CUSTINV	EMPINV	FLOW	PULL	SETUP	SPC	SSIMP	SSMET	SSROLE	SUPPINV	TPM
CUSTINV_01	0.655*	0.312	0.347	0.280	0.346	0.289	0.344	0.405	0.260	0.443	0.306
CUSTINV_02	0.710*	0.351	0.434	0.258	0.284	0.234	0.275	0.259	0.304	0.456	0.350
CUSTINV_03	0.742*	0.292	0.303	0.288	0.267	0.349	0.395	0.448	0.290	0.386	0.295
CUSTINV_04	0.785*	0.445	0.373	0.300	0.357	0.549	0.434	0.413	0.441	0.563	0.460
EMPINV_01	0.249	0.760*	0.311	0.315	0.392	0.505	0.489	0.450	0.529	0.351	0.432
EMPINV_02	0.447	0.798*	0.341	0.352	0.418	0.502	0.555	0.441	0.581	0.486	0.501
EMPINV_03	0.360	0.864*	0.425	0.550	0.576	0.545	0.670	0.434	0.607	0.530	0.585
EMPINV_04	0.509	0.827*	0.468	0.451	0.568	0.616	0.644	0.529	0.693	0.575	0.658
FLOW_01	0.357	0.415	0.810*	0.310	0.420	0.409	0.479	0.431	0.333	0.440	0.435
FLOW_02	0.412	0.360	0.763*	0.261	0.275	0.311	0.401	0.340	0.246	0.408	0.338
FLOW_03	0.380	0.376	0.772*	0.437	0.452	0.365	0.471	0.421	0.412	0.460	0.480
FLOW_04	0.350	0.249	0.594*	0.315	0.138	0.205	0.235	0.097	0.179	0.419	0.226
PULL_01	0.216	0.260	0.307	0.771*	0.311	0.238	0.317	0.245	0.237	0.352	0.325
PULL_02	0.321	0.458	0.481	0.804*	0.437	0.495	0.437	0.398	0.412	0.503	0.449
PULL_03	0.369	0.439	0.360	0.880*	0.520	0.447	0.481	0.423	0.414	0.437	0.424
PULL_04	0.257	0.409	0.180	0.581*	0.270	0.357	0.385	0.295	0.399	0.253	0.296
SETUP_01	0.327	0.542	0.365	0.491	0.804*	0.504	0.530	0.416	0.539	0.489	0.531
SETUP_02	0.385	0.525	0.327	0.354	0.784*	0.512	0.541	0.584	0.483	0.446	0.508
SETUP_03	0.238	0.310	0.298	0.313	0.727*	0.411	0.349	0.339	0.368	0.418	0.461
SETUP_04	0.286	0.324	0.344	0.312	0.523*	0.293	0.324	0.359	0.317	0.256	0.355
SPC_01	0.471	0.535	0.473	0.482	0.590	0.851*	0.624	0.527	0.581	0.502	0.536
SPC_02	0.446	0.577	0.379	0.493	0.574	0.836*	0.664	0.571	0.593	0.497	0.593
SPC_03	0.349	0.456	0.274	0.371	0.382	0.789*	0.602	0.515	0.480	0.317	0.449
SPC_04	0.335	0.559	0.279	0.276	0.367	0.696*	0.582	0.555	0.515	0.333	0.452
SSIMP_01	0.429	0.614	0.445	0.462	0.465	0.681	0.834*	0.630	0.687	0.441	0.571
SSIMP_02	0.426	0.645	0.413	0.405	0.577	0.694	0.864*	0.666	0.642	0.549	0.593
SSIMP_03	0.504	0.599	0.509	0.538	0.584	0.679	0.875*	0.650	0.620	0.563	0.601
SSIMP_04	0.347	0.622	0.512	0.412	0.479	0.576	0.813*	0.529	0.580	0.489	0.630
SSMET_01	0.527	0.538	0.444	0.435	0.535	0.591	0.692	0.887*	0.590	0.409	0.537
SSMET_02	0.445	0.501	0.383	0.404	0.487	0.659	0.664	0.861*	0.562	0.385	0.543
SSMET_03	0.415	0.451	0.430	0.357	0.497	0.447	0.547	0.768*	0.407	0.470	0.440
SSMET_04	0.318	0.356	0.240	0.281	0.443	0.513	0.462	0.745*	0.487	0.234	0.424
SSROLE_01	0.380	0.684	0.322	0.419	0.587	0.646	0.651	0.581	0.895*	0.399	0.543
SSROLE_02	0.420	0.555	0.420	0.447	0.440	0.543	0.569	0.478	0.703*	0.417	0.592
SSROLE_03	0.341	0.620	0.306	0.376	0.531	0.581	0.648	0.539	0.863*	0.378	0.563
SSROLE_04	0.395	0.643	0.341	0.392	0.477	0.528	0.638	0.515	0.890*	0.431	0.568
SUPPINV_01	0.504	0.415	0.387	0.522	0.440	0.435	0.464	0.317	0.362	0.751*	0.501
SUPPINV_02	0.529	0.422	0.448	0.430	0.474	0.472	0.511	0.440	0.400	0.685*	0.437
SUPPINV_03	0.455	0.470	0.455	0.319	0.377	0.303	0.386	0.238	0.352	0.751*	0.399
SUPPINV_04	0.454	0.478	0.446	0.318	0.414	0.394	0.472	0.439	0.350	0.738*	0.491
SUPPINV_05	0.404	0.442	0.385	0.285	0.376	0.304	0.359	0.231	0.295	0.747*	0.360
TPM_01	0.349	0.508	0.406	0.408	0.535	0.468	0.552	0.467	0.525	0.433	0.790*
TPM_02	0.380	0.465	0.381	0.359	0.478	0.452	0.508	0.486	0.497	0.446	0.848*
TPM_03	0.455	0.536	0.416	0.337	0.576	0.547	0.583	0.537	0.554	0.470	0.859*
TPM_04	0.435	0.695	0.491	0.519	0.551	0.627	0.662	0.478	0.624	0.609	0.796*

* higher loading in the original constructs.

PLS-SEM was used to estimate the relationships among LSS adoption and food industry performance and test hypotheses 3. Figure 5.2 gives the result of this relationship. The path coefficient (β) between LSS and Food Industry's Performance is 0.678 ($R^2 = 0.459$), and statistically significant at p-value <0.01 (see Table 5.9). A good model fit is established since the model has significant path coefficients and acceptably (moderate) R-square value. To assess the predictive relevance of the endogenous variables in our PLS model, we calculated the Stone-Geisser test criterion Q2 using the blindfolding procedure (GEISSER, 1974; STONE, 1974). The positive value of Q2 (0.211) indicates that the proposed model has predictive relevance (PENG; LAI, 2012).

The findings confirm the effect of LSS adoption in food industry performance is positive, so hypothesis 3 can be accepted. LSS adoption contributes to improve food industry performance.

Figure 5.2 - Generated hierarchic structural model

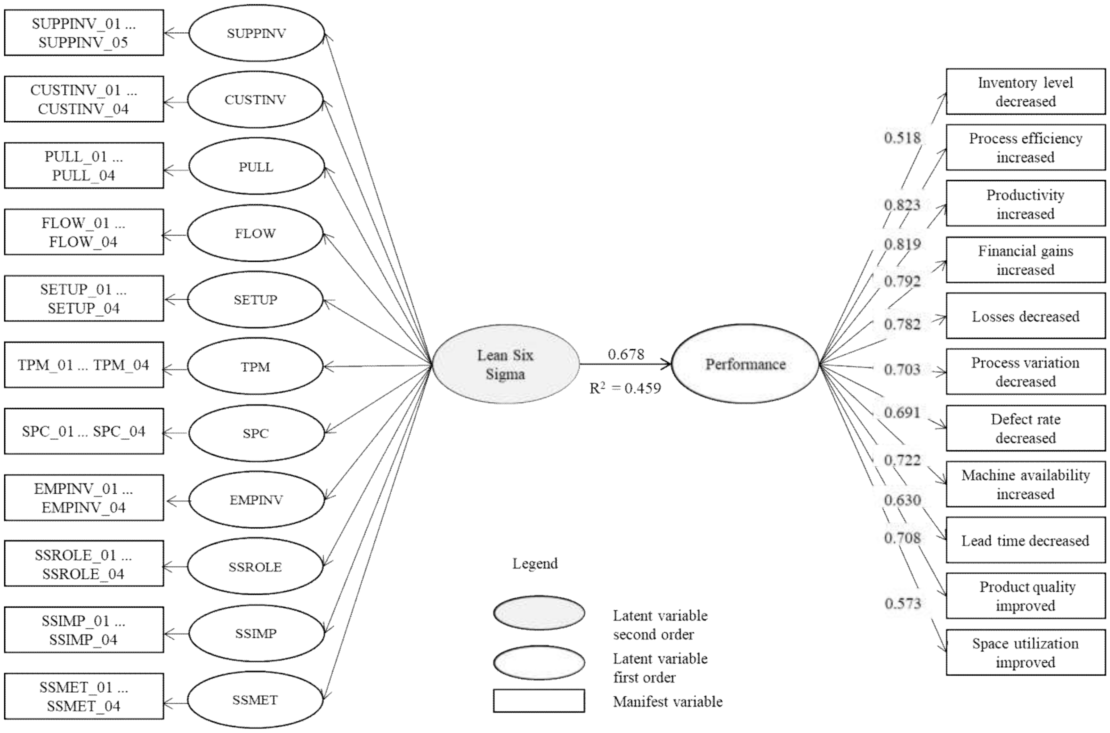


Table 5.9 - Significance analysis of the structural model relationships

Relation	t value	p value
LSS → Performance (H_3)	14.064	0.000
Performance → Performance 1 (Inventory level decreased)	6.691	0.000
Performance → Performance 2 (Process efficiency increased)	22.529	0.000
Performance → Performance 3 (Productivity increased)	22.515	0.000
Performance → Performance 4 (Financial gains increased)	23.043	0.000
Performance → Performance 5 (Losses decreased)	20.429	0.000
Performance → Performance 6 (Process variation decreased)	14.560	0.000
Performance → Performance 7 (Defect rate decreased)	10.838	0.000
Performance → Performance 8 (Machine availability increased)	15.715	0.000
Performance → Performance 9 (Lead time decreased)	9.140	0.000
Performance → Performance 10 (Product quality improved)	15.851	0.000
Performance → Performance 11 (Space utilization improved)	8.639	0.000

The data from our sample confirms that adopting LSS practices at a higher rate improves firm performance. These findings demonstrate that the food industry benefits from the adoption of LSS practices. This finding supports prior research that there is a positive relationship between the adoption of CI initiatives and performance (FULLERTON et al., 2014; HOFER; EROGLU; ROSSITER, 2012; MARIN-GARCIA; BONAVIA, 2015; NAWANIR; TEONG; OTHMAN, 2013; SWINK; JACOBS, 2012).

To further explore the relationships among LSS implementation and food industry performance, we also tested the moderate effect of level of experience (i.e. duration of implementation) in the existing relationship. No significant effect was found in the latent performance variable (Table 5.10). So, we employed a Kruskal-Wallis test in order to analyze the moderator effect in the manifest performance variables (see Table 5.11).

Table 5.10 - The moderator effect of level of experience in food industry performance (latent variable)

Relation	Path	p value
LSS → Performance (H_3)	0.678	0.000
LSS → Performance (Level of experience_High)	0.735	0.000
LSS → Performance (Level of	0.688	0.000
Difference	**0.047**	**0.301**

*sig.<0.05

Table 5.11 - The moderator effect of level of experience in food industry performance (manifest variables)

Performance	Level of experience			p-value
	Low	Intermediate	High	
Inventory level decreased	66.84	73.07	74.32	0.691
Process efficiency increased	67.50	72.72	74.31	0.739
Productivity increased	65.01	70.35	79.23	0.260
Financial gains increased	54.96	72.56	83.60	0.007*
Losses decreased	62.47	71.20	79.95	0.150
Process variation decreased	69.26	67.94	79.34	0.314
Defect rate decreased	71.06	65.13	81.74	0.102
Machine availability increased	67.71	68.49	79.73	0.275
Lead time decreased	74.94	71.77	70.17	0.870
Product quality improved	69.26	64.99	83.22	0.058**
Space utilization improved	69.63	74.50	70.41	0.809

*sig.<0.05; **sig.<0.1

The results show the level of experience positively moderates two performance indicators, highly valued by the sector, financial gains and product quality, to a level of significance of 0.05 and 0.1, respectively. For both, the higher is the level of experience, the better is the performance. The seven other indicators showed high values to the highest level of experience, however, they were not statically significant (at $p < 0.05$). These findings demonstrate the importance of level of experience in adopting LSS practices to obtain better results to the food industry sector.

5.5 Conclusion

This study of L&SSi adoption in the food industry used a survey methodology to evaluate the relevance of the initiative in a sector that views “quality” as a safety and hygiene factor, which is one characteristic that differentiate it from other sectors. The sector also lacks familiarity with the L&SSi initiatives.

Our findings suggest that LSS adoption in the food industry is greatly affected by the level of experience of the individual company. We found that the adoption level of more than half of the LSS practices studied was affected by the company’s experience with LSS. There was a smaller impact of adoption due to the size of the company and the country in which the firm was located. Small companies adopt some of the practices in a lower level, possibly because their financial and human resources constraints. In relation to the country, Brazilian food industries adopt the practices in a higher level compared to American firms, which may be associated with the collectivism culture of Brazil and the higher number of large companies in Brazilian sample.

The adoption of LSS practices is to a certain extent affected by the sector’s characteristics. The set-up time reduction is affected by the compulsory cleaning process, which must be properly performed in the sector to avoid contamination and ensure food safety. The TPM is mostly adopted by companies that present a higher percentage of specialized equipment considering the criticality of maintaining the reliability and availability of this type of equipment. However, it was not perceived a difference in the level of adoption of Pull practices concern the differences in demand response strategy, type of operation and type of equipment as expected, possibly because of the lack of knowledge of the sector about this LSS dimension. The Pull practices are low adopted despite of the company’s characteristics.

Moreover, the findings show that Six Sigma role structure and Statistical Process Control dimensions are among the least adopted practices by the sector. Their practices require financial resources to training the belt team, which can be a challenge in a sector with low margins that are constantly looking for ways to reduce cost, and depend on statistical techniques knowledge, which is considered relatively complex and too advanced in the sector. In the first instance these practices are less considered by the sector, however their adoption increases with the companies' level of experience, indicating they are appropriate to the sector.

In sum, the study contributes to provide empirical and statistical evidence of the effect of contingencies factors related to food industry characteristics in the adoption of LSS practices and the effect of control variables (level of experience, size of the company and country). Further, it was observed an opportunity to the sector in applying tools such as SMED to decrease set-up time; in increasing the adoption of pull system by better know it and by use other demand response strategy such as mix to order instead of make to stock; in increasing the application of SPC to reduce process variation, often associated with deviation in product size/weight, reducing costs and losses; and in increasing the involvement of employees and the use of belt specialists, who has expertise in the application of continuous improvement programs and can contribute to enhance the benefits of the implementation of LSS in the sector. There are also other practices low adopted that should be more explored by the sector.

Another contribution is the evidence that, LSS is relevant and effective to the sector. Food industry performance is positively affected by the adoption of LSS practices. Moreover, the Practice Based View theory is supported, since two performance indicators, very valued by the sector (financial gains and product quality) are moderated by the level of experience. More experience in implementation increases the potential benefits to food organizations.

Therefore, these findings suggest the necessity of increasing the level of experience of organizations in the sector and the managerial awareness about the relevance of applying LSS practices to improve food industry performance. Further studies are recommended to examine multiple measures of experience (e.g. individual experience, organizational experience, team leader experience, among others) and their relationship to the performance of LSS adoption. The study is also limited by the country of investigation, only Brazil and the USA. Further studies should investigate other countries to compare the results found. Moreover, there are a host of other performance effects that should be examined.

6 CONCLUSION

This study aimed to evaluate the relevance for food industry to adopt Lean Six Sigma practices. The low rates of Lean, Six Sigma and Lean Six Sigma implementation in the sector have led to the speculation of its effectiveness.

First, a systematic literature review was conducted to analyze the state of the art concerning Lean, Six Sigma and Lean Six Sigma initiatives in the food industry. The findings show the topic is an under research area. There are a limited number of papers published about the subject; most of them are Lean manufacturing studies. The hybrid approach, Lean Six Sigma, was only studied in the sector in 2013, thirteen years after the emergence in other industries during the early 2000´s. Most of the studies are concentrated in Europe and Asia, which provide a great opportunity of study in other countries.

The sector faces challenges to implement the initiative, mainly related with managerial factors and the inherent characteristics of the food industry. Lack of skilled workers, lack of knowledge and resistance to change are among the managerial barriers most cited by implementation studies. Demand uncertainty, high cleaning time and high setup time are among the characteristics that mostly impacted the adoption of L&SSi in the implementation studies reviewed.

The sector lacks familiarity and experience concern the application of these continuous improvement initiatives. This is further evidenced by the necessity of external support, like a consultancy reported by some studies in the literature, the lack of awareness that seem to exist in the selection of team members and lack of concern about continue/sustain actions.

Despite of that, some studies show a large number of benefits obtained with their adoption. They are predominantly cost related. The most found were productivity increase, cost reduction and inventory reduction. In a smaller proportion they are also defect, time and value related. This suggests the initiatives can assist the sector and should be more widely implemented to improve food industries' performance and competitiveness.

Considering these findings, we performed a survey research to better investigate the degree of adoption of Lean Six Sigma practices in the sector. First we developed a new multi-item measurement scales reflecting the multidimensional construct, Lean Six Sigma, in the food industry sector, based on Contingency theory, following a two-stage approach to ensure validity and reliability of the measurement items and scales.

The result was 11 complementary first-order dimensions to reflect the Lean Six Sigma construct in the food industry: Supplier Involvement, Customer Involvement, Pull, Continuous flow, Set up time reduction, Statistical Process Control, Employee involvement, Total productive/preventive maintenance, Six Sigma role structure, Six Sigma structured improvement procedure, Six Sigma focus on metrics.

The rigorous development of the measurement instrument to represent Lean Six Sigma can be used to academics to better explore the adoption of these initiative in the sector and can also contribute for practitioners, that intend to adopt Lean Six Sigma in their settings or that have already adopted to assess and monitor the state of the implementation, allowing firms to keep records of Lean Six Sigma implementation and progress. It can be used as a tool to identify improvement opportunities, and, consequently, enhance companies' performance and competitiveness.

In this study the instrument was used to verify the adoption of Lean Six Sigma in the food industry; analyze the contingency effect that food industry characteristics may have on Lean Six Sigma adoption; and evaluate the effect of Lean Six Sigma adoption in the food industry performance, moderated by companies' experience.

The findings showed a fragmented use of Lean Six Sigma practices, affected by country of adoption, size of the company, and especially by level of experience. Some characteristics of the food industry, such as cleaning time and type of equipment also affected the adoption of Lean Six Sigma practices (e.g. set-up time and TPM). Other Lean Six Sigma dimensions, such as Pull may be affected by the lack of knowledge of the sector concern these CI initiatives. Statistical knowledge and financial constraints can also play an important role in practices low adopted as Six Sigma role structure and Statistical Process Control.

In spite of that, the survey confirmed the relevance of implement Lean Six Sigma practices in the food industry. Their adoption positively affects companies' performance. It has shown to improve process efficiency, productivity, financial gains, machine availability, product quality, space utilization, and decrease losses, process variation, defect rate, lead time, and inventory level. Moreover, organizational experience increases the chance of success of Lean Six Sigma.

Therefore, there is a great potential for the food industries to adopt Lean Six Sigma practices and improve its performance; there are opportunities to increase the level of adoption of some practices low explored; expand sector's maturity in this field, and consequently, increase the benefits of implement Lean Six Sigma practices to the sector.

Futures studies should examine multiple measures of experience (e.g. individual experience, organizational experience, team leader experience, among others) and their relationship to the performance of Lean Six Sigma adoption. They should investigate other countries to compare the results found. Moreover, other performance indicators should be examined.

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APPENDIX A - L&SSi original constructs and items (continued)

Construct Name	**Construct Definition**	**Items**
Supplier relationship	The organization actively seeks close contact with suppliers including performance feedback and visits.	- We frequently are in close contact with our suppliers - Our suppliers frequently visit our plants - We give our suppliers feedback on quality and delivery performance - We strive to establish long-term relationship with our suppliers
Supplier development	The organization develops suppliers, so they can be more involved in the production process and deliver the right quantity at the right time in the right place.	- Suppliers are directly involved in the new product development process - We work with our key suppliers, so they can deliver to plant on Just in Time (JIT) basis - We work with our key suppliers, so they are contractually committed to annual cost reductions - Our key suppliers manage our inventory
Customer involvement	The organization focuses on their customers and their needs.	- We frequently are in close contact with our customers - Our customers give us feedback on quality and delivery performance - Our customers are directly involved in current and future product offerings - Our customers frequently share current and future demand information with marketing department - We regularly conduct customer satisfaction surveys
Pull	The organization facilitates just-in-time (JIT) production by using tools such as kanban to signal when to start or stop production.	- Production is 'pulled' by the shipment of finished goods - Production at stations is 'pulled' by the current demand of the next station - We use a "pull" production system - We use a Kanban, squares, or containers of signals for production control
Continuous flow	The organization establishes mechanisms that enable and ease the continuous flow of products.	- Products are classified into groups with similar processing requirements - Products are classified into groups with similar routing requirements - Equipment is grouped to produce a continuous flow of families of products - Families of products determine our factory layout
Set up time reduction	The organization seeks to reduce process downtime between product changeovers.	- Our employees practice setups to reduce the time required - We are working to lower setup times in our plant - We have low set up times of equipment in our plant - Long production cycle times prevent responding quickly to customer requests
Total productive/ preventive maintenance	The organization addresses equipment downtime by using total productive maintenance to achieve a high level of equipment availability.	- We dedicate a portion of everyday to planned equipment maintenance related activities - We maintain all our equipment regularly - We maintain excellent records of all equipment maintenance related activities - We post equipment maintenance records on shop floor for active sharing with everyone

APPENDIX A – L&SSi original constructs and items

Construct Name	Construct Definition	Items
Statistical process control	The organization ensures that each process will supply defect free units to subsequent process.	- Large amount of process/equipment on the shop floor is currently under Statistical Process Control - We extensively use statistical techniques to reduce process variance - Charts showing defect rates are used as tools on the shop-floor - We use fishbone type diagrams to identify causes of quality problems
Employee involvement	The organization's employees have a role in problem solving and cross functional teams.	- Shop-floor employees are key to problem solving teams - Shop-floor employees drive suggestion programsweeww3 - Shop-floor employees lead product / process improvement efforts - Shop-floor employees undergo cross functional training
Six Sigma role structure	The organization uses improvement specialists who are developed through Six Sigma training and certification programs and who have specific leadership roles and responsibilities in improvement teams.	- We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs - In our plant, members of improvement teams have their roles and responsibilities specifically identified - The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience - Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities
Six Sigma structured improvement procedure	The organization follows a standardized procedure in planning and conducting improvement projects or design projects and it uses appropriate Quality Management tools and techniques as prescribed in each step of the structured procedure.	- In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC—Define, Measure, Analyze, Improve and Control) - We use a structured approach to manage quality improvement activities - We have a formal planning process to decide the major quality improvement projects - All improvement projects are reviewed regularly during the process
Six Sigma focus on metrics	The organization uses quantitative metrics to measure performance, and to set improvement goals.	- Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance - Metrics are used to link quality performance to strategic goals - Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant - Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance

APPENDIX B – Donation

"A suprema missão do homem é saber o que precisa para ser Homem"

Prezada amiga Luana Bonome Message Costa,

Somos chamados por Deus a ser Cidadãos do Infinito (Fil.3,20) e acreditamos que quanto mais nos aproximamos Dele (Sl. 82,6), mais e mais os valores recebidos na educação vão sendo lapidados para o bem do próximo. Porém, vivemos uma época de inversão de princípios, que não podemos deixar que nos contamine. Somos chamados a fazer desse mundo um lugar justo e fraterno e não devemos nos esquecer dos valores cristãos.

Portanto nosso testemunho é fundamental para que os outros aprendam com nosso gesto de partilha e, por isso, agradecemos a sua doação de R$ 807,00 que foi realizada no dia 18/04/2019 por cartão de crédito. Você acreditou em nossa proposta para cura de todos os males, ou seja, o Amor. O Amor só não prospera em corações que se amedrontam com as sombras. Tenha certeza: você investiu no único bem que a ferrugem não corrói e os ladrões não roubam (Mt 6,19). Você investiu na vida. Alguém já nos disse que nem o sol poderá brilhar se o céu não se abrir.

Em nome de nossos pacientes, familiares, médicos e colaboradores, nosso muito obrigado!

Atenciosamente,

Luiz Antônio Zardini
Gerente Captação de Recursos

hospitaldeamor.com.br

Donation Summary

Your receipt is below, and we've emailed a copy to lubomes@hotmail.com.

Date:
5/11/2019

Gift Type:
A Gift in Honor of Luana Bonome Message Costa.

Gift Amount:
$71.74

Frequency:
This is a one time gift.

Payment Type:
PayPal

Account Number:
lubomes@hotmail.com (T9H4DJ9DWZGM2)

ACS Tax ID:
13-1788491

ACS Mailing Address:
The American Cancer Society
PO Box 22718
Oklahoma City, OK 73123-1718
USA

Order ID:
556092913093021

Transaction Number:
0GE44923M1378014H

Authorization Code:
EC-59B675456E003574V

APPENDIX C - Questionnaire

Portuguese version:
https://clemson.ca1.qualtrics.com/jfe/form/SV_78Uj3AeqLkmSXNb

1. Introdução

Melhoria Contínua na Indústria de Alimentos

Eu, Luana Bonome Message Costa, doutoranda vinculada ao Departamento de Engenharia de Produção da Universidade Federal de São Carlos (UFSCar), convido você para participar da pesquisa entitulada Iniciativas Lean & Seis Sigma na Indústria de Alimentos, desenvolvida sob a orientação do professor Dr. Moacir Godinho Filho (UFSCar, Brasil) e professor Dr. Lawrence D. Fredendall (Clemson University, EUA).

O objetivo da pesquisa é avaliar o potencial de adoção das iniciativas de melhoria contínua, Lean & Seis Sigma, na indústria alimentícia. Para isso será avaliado o grau de adoção das práticas no setor, o impacto das características da indústria de alimentos no grau de adoção, e o impacto da adoção no desempenho do setor.

O resultado da pesquisa será divulgado de forma agregada, não sendo possível a identificação dos respondentes e das empresas estudadas. Se houver interesse, um relatório executivo poderá ser disponibilizado para a empresa ao final da pesquisa.

Para cada resposta será doado o valor de R$3,00 (três reais) para o Hospital do Câncer de Barretos-SP.

O tempo médio para responder o questionário é de 15 minutos.

A pesquisa é financiada pela fundação CAPES do Ministério da Educação e conta com o apoio da Associação Brasileira das Indústrias da Alimentação (ABIA).

A carta informativa abaixo contém informações adicionais sobre a pesquisa, aprovada pelo Comitê de Ética da Universidade de Clemson nos Estados Unidos (IRB2017-423).

Carta informativa

No caso de dúvidas e/ou sugestões, por favor, sinta-se a vontade para nos contatar, por e-mail (luana@dep.ufscar.br) ou por telefone (16 -).

Agradecemos pela atenção e contamos com a sua participação em nossa pesquisa.

Clique no botão "concordo" para indicar que:
• Você leu a informação acima
• Você voluntariamente concorda em participar
• Você tem pelo menos 18 anos de idade

○ Concordo
○ Não concordo

2. Características do Setor

Em relação à <u>unidade</u> da empresa em que você trabalha, por favor, assinale a alternativa que responda da melhor forma cada questão.

1. Qual é o número de produtos finais (SKU) fabricados por sua empresa?

○ Menos de 10
○ Entre 10 e 100
○ Entre 101 e 500
○ Entre 501 e 1000
○ Mais de 1000
○ Não sei avaliar/não quero responder

2. Qual é o número de matérias-primas utilizadas por sua empresa? Observação: não considerar embalagens.

○ Menos de 10
○ Entre 10 e 100
○ Entre 101 e 500
○ Entre 501 e 1000
○ Mais de 1000
○ Não sei avaliar/não quero responder

3. Qual é o prazo de validade das <u>principais</u> matérias-primas utilizadas por sua empresa? Selecione mais de uma alternativa, se necessário.

☐ Menor ou igual a 9 dias ☐ Entre 10 dias e 1 mês ☐ Maior que 1 mês ☐ Não sei avaliar/não quero responder

4. Qual é o prazo de validade dos produtos finais fabricados por sua empresa? Selecione mais de uma alternativa, se necessário.

☐ Menor ou igual a 9 dias ☐ Entre 10 dias e 1 mês ☐ Maior que 1 mês ☐ Não sei avaliar/não quero responder

5. Qual tipo de equipamento listado abaixo sua empresa possui? Selecione mais de uma alternativa, se necessário.

☐ Não Dedicado-Uso Geral: equipamento que podem ser usado para produzir diferentes produtos (uso geral), e o seu uso não é limitado a um tipo particular de produto (não dedicado).

☐ Dedicado – Uso Geral: equipamento que podem ser usado para produzir diferentes produtos (uso geral), porém seu uso é restrito a uma operação específica para um ou um número limitado de produtos (dedicado).

☐ Não Dedicado – Especializado: equipamentos que produzem um único tipo de produto (especializado), com diferentes variações (não dedicado).

☐ Dedicado – Especializado: equipamentos que produzem um único tipo de produto (especializado), geralmente com uma única variação.

☐ Não sei avaliar/não quero responder

6. Em média, quanto tempo é necessário para realizar a troca de um produto para outro na linha de produção? Selecione mais de uma alternativa, se necessário.

0-9 min	10-30 min	31-60 min	61-120 min	Mais de 2 horas	Não sei avaliar/não quero responder
☐	☐	☐	☐	☐	☐

7. Qual é o grau de impacto do tempo de limpeza no tempo de troca da questão anterior?

Nenhum 1	2	3	4	Alto 5

8. Qual tipo de operação melhor caracteriza sua empresa? Selecione mais de uma alternativa, se necessário.

- ☐ Produção contínua (quando o produto segue uma rota e não há interrupção no fluxo)
- ☐ Produção em lotes pequenos (equivalente a uma semana de demanda)
- ☐ Produção em lotes médios (equivalente a algumas semanas de demanda)
- ☐ Produção em lotes grandes (equivalente a alguns meses de demanda ou mais)
- ☐ Produção híbrida (parte contínua, parte em lote)
- ☐ ____________ Outro
- ☐ Não sei avaliar/não quero responder

9. As matérias-primas utilizadas por sua empresa apresentam disponibilidade sazonal?

- ○ Sim, a maioria
- ○ Sim, poucas
- ○ Não sei avaliar/não quero responder
- ○ Sim, algumas
- ○ Não

10. Os produtos fabricados por sua empresa apresenta padrão de demanda sazonal?

- ○ Sim, a maioria dos produtos
- ○ Sim, poucos produtos
- ○ Não sei avaliar/não quero responder
- ○ Sim, alguns produtos
- ○ Não

11. Como a empresa atende os pedidos dos seus clientes? Selecione mais de uma alternativa, se necessário.

- ○ O atendimento do pedido é realizado com estoque já existente.
- ○ O processo de produção somente é iniciado após o pedido do cliente.
- ○ Produtos intermediários são produzidos e estocados, e após o pedido do cliente são misturados/embalados em produtos finais.
- ○ Não sei avaliar/não quero responder

3. Adoção das práticas

Em relação à utilização de práticas de melhoria contínua adotadas no cotidiano das operações da empresa, indique o seu nível de concordância:

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nós temos contato frequente com nossos fornecedores	O	O	O	O	O	O	O
Nossos fornecedores frequentemente visitam nossa empresa	O	O	O	O	O	O	O
Nós damos retorno aos nossos fornecedores sobre o desempenho deles em qualidade e entrega	O	O	O	O	O	O	O
Nós trabalhamos intensamente para estabelecer relacionamentos duradouros com nossos fornecedores	O	O	O	O	O	O	O
Os fornecedores estão diretamente envolvidos no processo de desenvolvimento de novos produtos	O	O	O	O	O	O	O
Nós trabalhamos com nossos fornecedores-chave para que eles entreguem em nossa empresa com base num programa Just-in-Time, ou seja, na quantidade certa, na hora certa, no lugar certo	O	O	O	O	O	O	O
Nós trabalhamos com nossos fornecedores para que eles estejam contratualmente compromissados em cada ano para redução de custos	O	O	O	O	O	O	O
Nossos fornecedores-chave gerenciam nossos estoques	O	O	O	O	O	O	O
Nós temos contato frequente com nossos clientes	O	O	O	O	O	O	O

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nossos clientes nos dão retorno sobre o nosso desempenho em qualidade e entrega	O	O	O	O	O	O	O
Nossos clientes estão diretamente envolvidos na oferta de produtos atuais e futuros	O	O	O	O	O	O	O
Nossos clientes frequentemente compartilham informações de demanda atual e futura com o departamento de marketing	O	O	O	O	O	O	O
Nós conduzimos regularmente pesquisas de satisfação com nossos clientes	O	O	O	O	O	O	O
A produção é "puxada" pela expedição de produtos acabados	O	O	O	O	O	O	O
A produção nas estações de trabalho é "puxada" pela demanda atual da próxima estação	O	O	O	O	O	O	O

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nós usamos um sistema de produção "puxada" (método de controle da produção em que as atividades fluxo abaixo avisam às atividades fluxo acima sobre suas necessidades)	○	○	○	○	○	○	○
Nós usamos kanbans, quadros ou contenedores com cartões para controlar a produção	○	○	○	○	○	○	○
Os produtos são classificados em grupos de acordo com necessidades de programação (sequenciamento) similares	○	○	○	○	○	○	○

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Os produtos são classificados em grupos de acordo com necessidades de roteamento similares	○	○	○	○	○	○	○
Os equipamentos são agrupados para produzir em fluxo contínuo uma família de produtos	○	○	○	○	○	○	○
As famílias de produtos determinam o layout da fábrica	○	○	○	○	○	○	○
Nossos empregados se esforçam para reduzir o tempo de setup	○	○	○	○	○	○	○
Nós trabalhamos com baixos tempos de setup em nossa fábrica	○	○	○	○	○	○	○
Os equipamentos de nossa fábrica possuem baixo tempo de setup	○	○	○	○	○	○	○
Nós temos curtos tempos de ciclo para responder rapidamente as necessidades dos nossos clientes	○	○	○	○	○	○	○
Grande quantidade de equipamentos/processos no chão de fábrica encontram-se sob Controle Estatístico de Processo	○	○	○	○	○	○	○
Nós utilizamos extensivamente técnicas estatísticas para reduzir a variabilidade de processo	○	○	○	○	○	○	○

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Painéis visuais com gráficos e cartas de controle que ilustram taxa de defeitos são usados como ferramentas no chão de fábrica	○	○	○	○	○	○	○
Nós usamos diagrama de espinha de peixe para identificar as causas de problemas em qualidade	○	○	○	○	○	○	○
	○	○	○	○	○	○	○

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Os empregados de chão de fábrica são fundamentais para compor as equipes de solução de problemas							
Os empregados de chão de fábrica direcionam os programas de sugestões de melhorias	O	O	O	O	O	O	O
Os empregados de chão de fábrica conduzem os esforços de melhoria de produtos e processos	O	O	O	O	O	O	O
Os empregados de chão de fábrica passam por treinamento funcional	O	O	O	O	O	O	O
Nós dedicamos uma considerável parcela de cada dia para planejar atividades relacionada à manutenção dos equipamentos	O	O	O	O	O	O	O
Nós realizamos manutenção regularmente em todos nossos equipamentos	O	O	O	O	O	O	O
Nós mantemos excelentes registros de todas as atividades de manutenção realizadas nos equipamentos	O	O	O	O	O	O	O

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nós disponibilizamos e compartilhamos entre os empregados de chão de fábrica registros de todas as atividades de manutenção realizadas nos equipamentos	O	O	O	O	O	O	O
Nós empregamos uma estrutura black/green belt (ou equivalente) para preparar os empregados para os programas de melhoria contínua	O	O	O	O	O	O	O
Na nossa planta, membros de equipes de qualidade têm seus papéis e responsabilidades especificamente identificados	O	O	O	O	O	O	O
A estrutura black/green belt (ou equivalente) auxilia a nossa empresa a reconhecer os treinamentos e experiências dos empregados	O	O	O	O	O	O	O
Nossa planta usa treinamentos diferenciados para que os empregados com papéis diferentes na estrutura black/green belt (ou equivalente) possam obter os conhecimentos e habilidades necessários para cumprir suas responsabilidades	O	O	O	O	O	O	O
Projetos de melhoria contínua são conduzidos seguindo um procedimento formalizado (como o DMAIC-Definir, Medir, Analisar, Melhorar e Controlar)	O	O	O	O	O	O	O
Nós usamos uma abordagem estruturada para gerenciar atividades de melhoria de qualidade	O	O	O	O	O	O	O

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nós temos um processo de planejamento formal para decidir os principais projetos de melhoria de qualidade	○	○	○	○	○	○	○
Todos os projetos de melhoria são revisados regularmente durante o processo	○	○	○	○	○	○	○

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Nossa planta usa métricas para estabelecer objetivos estratégicos para melhoria da qualidade a fim de melhorar o desempenho financeiro	○	○	○	○	○	○	○
Métricas são usadas para conectar desempenho de qualidade com os objetivos estratégicos da empresa	○	○	○	○	○	○	○
Desempenho financeiro (como redução de custos, vendas) faz parte do critério de avaliação dos resultados das melhorias de qualidade da empresa	○	○	○	○	○	○	○
Nossa planta usa sistematicamente um conjunto de medidas (defeitos por milhão de oportunidades, nível sigma, índice de capacidade do processo, defeitos por unidade, e rendimento) para avaliar desempenho	○	○	○	○	○	○	○

4. Implementação

Qual iniciativa de melhoria contínua sua empresa possui formalmente implementada?

- ○ Lean manufacturing
- ○ Seis Sigma
- ○ Lean Seis Sigma
- ○ Nenhuma

4.1. Características da implementação

Em relação à implementação das iniciativas de melhoria contínua (Lean, Seis Sigma ou Lean Seis Sigma), por favor, assinale as alternativas que respondam da melhor forma cada questão.

Há quanto tempo a iniciativa foi implementada?

- ○ Menos de 6 meses
- ○ Entre 6 meses e 1 ano
- ○ Entre 1 ano e 3 anos
- ○ Entre 3 anos e 5 anos
- ○ Mais de 5 anos
- ○ Não sei avaliar/não quero responder

Indique o seu nível de concordância com as declarações abaixo.

"Os benefícios obtidos com a implementação da iniciativa de melhoria contínua na empresa foram ..."

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Aumento da produtividade	O	O	O	O	O	O	O
Redução dos níveis de estoque	O	O	O	O	O	O	O
Melhora do desempenho financeiro	O	O	O	O	O	O	O
Redução de desperdícios	O	O	O	O	O	O	O
Redução da taxa de defeito	O	O	O	O	O	O	O
Redução de lead time	O	O	O	O	O	O	O
Redução da variância em características críticas para a qualidade	O	O	O	O	O	O	O
Melhora no controle das características de processo (ex.: temperatura)	O	O	O	O	O	O	O
Melhora na competitividade	O	O	O	O	O	O	O
Melhora na qualidade da produção	O	O	O	O	O	O	O
Melhora na qualidade do processo	O	O	O	O	O	O	O
	O	O	O	O	O	O	O

	Discordo Totalmente 1	2	3	4	5	6	Concordo Totalmente 7
Outros ______							
Outros ______	O	O	O	O	O	O	O
Outros ______	O	O	O	O	O	O	O

Qual o grau de impacto dos fatores abaixo na implementação da iniciativa?

	Nenhum 1	2	3	4	Alto 5
Falta de conhecimento sobre a iniciativa	O	O	O	O	O
Falta de empregados qualificados	O	O	O	O	O
Falta de apoio da alta gestão	O	O	O	O	O
Baixa participação dos empregados	O	O	O	O	O
Resistência à mudança	O	O	O	O	O
Outro ______	O	O	O	O	O
Outro ______	O	O	O	O	O
Outro ______	O	O	O	O	O

5. Características Gerais da Empresa

Em relação a empresa em que você trabalha, por favor, assinale a alternativa que responda da melhor forma cada questão.

1. Qual é o número de empregados da empresa (na sua unidade)?

Entre 0 e 99	Entre 100 e 499	Maior que 499	Não sei avaliar/Não quero responder
○	○	○	○

6. Informação do respondente

Em relação à sua atuação na empresa, por favor, assinale a alternativa que responda da melhor forma cada questão.

1. Qual é o seu nível hierárquico na empresa?

○ Presidência ○ Gerência ○ Outro ______

○ Diretoria ○ Supervisão ○ Não quero responder

2. Em qual departamento você atua?

○ Qualidade ○ Outro ______

○ Produção ○ Não quero responder

3. Há quanto tempo trabalha na empresa?

○ Menos de 1 ano ○ Entre 4 e 7 anos ○ Mais de 10 anos

○ Entre 1 e 4 anos ○ Entre 7 e 10 anos ○ Não quero responder

Se houver interesse em receber um relatório executivo insira o seu e-mail no campo abaixo.

Informação sobre Participar de uma Pesquisa Acadêmica

Iniciativas Lean & Seis Sigma na Indústria de Alimentos

Descrição do Estudo e sua Participação nele

Luana Bonome Message Costa, juntamente com professor Dr. Moacir Godinho Filho e Lawrence D. Fredendall, convidam você para participar de uma pesquisa acadêmica. Moacir Godinho Filho é professor na Universidade Federal de São Carlos e Lawrence D. Fredendall é professor na Universidade de Clemson nos Estados Unidos. Luana Bonome Message Costa é doutoranda do programa de Engenharia de Produção da Universidade Federal de São Carlos.

O objetivo da pesquisa é avaliar o potencial de adoção das práticas de melhoria contínua, Lean & Seis Sigma, na indústria alimentícia. Para isto será avaliado o grau de adoção das práticas Lean & Seis Sigma no setor, o impacto das características da indústria de alimentos no grau de adoção, e o impacto da adoção no desempenho do setor.

O tempo médio para responder o questionário é de 15 a 20 minutos.

Riscos e Desconfortos

Nós não conhecemos qualquer risco ou desconforto para você nesta pesquisa. Para garantir que nenhuma informação, que possa constranger você ou sua empresa, seja divulgada, somente dados agregados serão informados.

Benefícios possíveis

Nós não conhecemos qualquer benefício direto devido à participação nesta pesquisa. No entanto, serão fornecidos insights sobre o valor das melhores práticas (Lean & Seis Sigma) para os profissionais da indústria de alimentos. Os resultados desta pesquisa também serão utilizados como base para futuros estudos de casos sobre formas de facilitar a adoção destas iniciativas no setor.

Proteção de Privacidade e Confidencialidade

Nós faremos tudo o que for possível para proteger sua privacidade e confidencialidade. Nós não contaremos a ninguém fora da equipe de pesquisa que você participou deste estudo ou quais informações coletamos sobre você em particular. Todos os registros e dados coletados nesta pesquisa serão mantidos em sigilo através de sites e/ou arquivos protegidos por senha. O resultado deste estudo poderá ser publicado em revistas científicas, publicações profissionais, ou apresentações educacionais; no entanto, nenhum participante individual ou empresa será identificado.

Escolhendo participar deste Estudo

Você não precisa participar deste estudo. Você pode optar por não participar ou por parar de participar a qualquer momento. Você não será punido de forma alguma.

Informação para Contato

Em caso de dúvida sobre este estudo, ou se surgir algum problema, sinta-se à vontade para nos contatar por e-mail (luana@dep.ufscar.br) ou por telefone (16 -).

Se você tiver alguma dúvida sobre os seus direitos nesta pesquisa, por favor entre em contato com o Comitê de Ética da Universidade de Clemson (Clemson University Office of Research Compliance) por e-mail irb@clemson.edu ou por telefone 1-866-297-3071.

English version:
https://clemson.ca1.qualtrics.com/jfe/form/SV_5drjcnnnxvB9MWh

1. Introduction

Continuous Improvement in the Food Industry

Information about Being in a Research Study
Clemson University

Lean Six Sigma in the Food Industry

Lawrence D. Fredendall, along with Luana Bonome Message Costa, is inviting you to take part in a research study. Lawrence Fredendall is a Professor at Clemson University. Luana Costa is a PhD student at Clemson University working with Lawrence Fredendall.

The purpose of this research is to evaluate the potential for the Food Industry to adopt Lean, Six Sigma and/or Lean Six Sigma practices. This survey will measure the degree of practice adoption by industry sector and the impact of the practices adopted on performance by industry sector.

It will take you about 15 - 20 minutes to be in this study.

The informational letter below contains additional information about Being in a Research Study.
Informational letter

Clicking on the "agree" button indicates that:

- You have read the above information
- You voluntarily agree to participate
- You are at least 18 years of age

You may print a copy of this informational letter for your files.

- ○ Agree
- ○ Disagree

2. Food industry characteristics

Considering just the unit of the company in which you work, please select the alternative(s) that best answer each question.

1. What is the number of end products (SKU) manufactured by your unit in your company?

- ○ Less than 10
- ○ Between 10 and 100
- ○ Between 101 and 500
- ○ Between 501 and 1000
- ○ Above 1001
- ○ Do not know/Do not want to answer

2. What is the number of raw materials that your unit in your company buy? Note: do not consider packaging materials.

- ○ Less than 10
- ○ Between 10 and 100
- ○ Between 101 and 500
- ○ Between 501 and 1000
- ○ Above 1001
- ○ Do not know/Do not want to answer

3. What is the shelf life of the main raw material used by your unit in your company? Select more than one alternative if necessary.

- ☐ Less than or equal to 9 days
- ☐ Between 10 days and 1 month
- ☐ Above 1 month
- ☐ Do not know/Do not want to answer

4. What is the shelf life of the end products manufactured by your unit in your company? Select more than one alternative if necessary.

- ☐ Less than or equal to 9 days
- ☐ Above 1 month

☐ Between 10 days and 1 month ☐ Do not know/Do not want to answer

5. What type of equipment listed below does your unit in your company own? Select more than one alternative if necessary.

☐ Non-dedicated - general-purpose equipment: is used to produce different products, with equipment use not limited to any particular type of products.

☐ Dedicated - general-purpose equipment: is used to produce different products but their use is restricted to a specific operation for one or a limited number of products.

☐ Specialized - non-dedicated equipment: is used to produce a specific product with some variations.

☐ Specialized - dedicated equipment: is used to produce one type of product, often dedicated to one or few variations.

☐ Do not know/Do not want to answer

6. On average, how much time is needed to change from one product to another on the production line (changeover time)? Select more than one alternative if necessary.

Between 0 and 9 minutes	Between 10 and 15 minutes	Between 16 and 30 minutes	Between 31 and 60 minutes	Above 1 hour	Do not know/Do not want to answer
☐	☐	☐	☐	☐	☐

7. To what extent does the cleaning time affect the equipment changeover time in the question above?

Not at all 1	2	3	4	To a great extent 5

8. Which type of operation best characterizes your unit in your company? Select more than one alternative if necessary.

☐ Continuous production (when the product follows one route and there is no interruption in the flow)

☐ Small batch production (equivalent to one week of demand)

☐ Medium batches production (equivalent to a few weeks of demand)

☐ Large batch production (equivalent to a few months of demand or more)

☐ Hybrid production (partly continuous, partly in batch)

☐ ______ Other

☐ Do not know/Do not want to answer

9. Does your unit in your company use raw materials that have seasonal availability?

Yes, most of them	Yes, some of them	Yes, few of them	No	Do not know/Do not want to answer
☐	☐	☐	☐	☐

10. Does your unit in your company have a seasonal demand pattern?

Yes, most of the products	Yes, some products	Yes, few products	No	Do not know/Do not want to answer
☐	☐	☐	☐	☐

11. How does your unit in your company respond a customer order? Select more than one alternative if necessary.

○ Customer orders are filled from stocked finished products (make-to-stock).

○ The production process starts only after a customer order accept (make-to-order).

○ Intermediate products are produced and after a customer order arrive they are mixed/packaged in finished products (mix-to-order).

○ ______ Other

○ Do not know/Do not want to answer

3. Practice adoption

Indicate your level of agreement with the statements below.
"In my unit of my company, ..."

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Equipment is grouped to produce a continuous flow of families of products	○	○	○	○	○	○	○

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
We regularly conduct customer satisfaction surveys	O	O	O	O	O	O	O
Our suppliers frequently visit our plants	O	O	O	O	O	O	O
We strive to establish long-term relationship with our suppliers	O	O	O	O	O	O	O
We work with our key suppliers so they can deliver to plant on Just in Time (JIT) basis	O	O	O	O	O	O	O
We use a structured approach to manage quality improvement activities	O	O	O	O	O	O	O
We have a formal planning process to decide the major quality improvement projects	O	O	O	O	O	O	O
Products are classified into groups with similar processing requirements	O	O	O	O	O	O	O
We frequently are in close contact with our customers	O	O	O	O	O	O	O

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance	O	O	O	O	O	O	O
We frequently are in close contact with our suppliers	O	O	O	O	O	O	O
We use a "pull" production system	O	O	O	O	O	O	O
We maintain excellent records of all equipment maintenance related activities	O	O	O	O	O	O	O
Products are classified into groups with similar routing requirements	O	O	O	O	O	O	O
We use a Kanban, squares, or containers of signals for production control	O	O	O	O	O	O	O
Our employees practice setups to reduce the time required	O	O	O	O	O	O	O
Our customers frequently share current and future demand information with marketing department	O	O	O	O	O	O	O
We have low set up times of equipment in our plant	O	O	O	O	O	O	O

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Large amount of process/equipment on the shop floor is currently under Statistical Process Control	O	O	O	O	O	O	O
All improvement projects are reviewed regularly during the process	O	O	O	O	O	O	O
We use fishbone type diagrams to identify causes of quality problems	O	O	O	O	O	O	O
Shop-floor employees undergo cross functional training	O	O	O	O	O	O	O
We dedicate a portion of everyday to planned equipment maintenance related activities	O	O	O	O	O	O	O

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Production at stations is 'pulled' by the current demand of the next station	○	○	○	○	○	○	○
In our plant, continuous improvement projects are conducted by following a formalized procedure (such as DMAIC—Define, Measure, Analyze, Improve and Control)	○	○	○	○	○	○	○
Production is 'pulled' by the shipment of finished goods	○	○	○	○	○	○	○
Charts showing defect rates are used as tools on the shop-floor	○	○	○	○	○	○	○

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
We have short production cycle times to quickly respond to customer requests	○	○	○	○	○	○	○
We maintain all our equipment regularly	○	○	○	○	○	○	○
In our plant, members of improvement teams have their roles and responsibilities specifically identified	○	○	○	○	○	○	○
Shop-floor employees are key to problem solving teams	○	○	○	○	○	○	○
Suppliers are directly involved in the new product development process	○	○	○	○	○	○	○
Our plant uses metrics to set strategic goals for quality improvement in order to improve plant financial performance	○	○	○	○	○	○	○
The black/green belt role structure (or equivalent structure) helps our plant to recognize the depth of workers' training and experience	○	○	○	○	○	○	○
Our customers give us feedback on quality and delivery performance	○	○	○	○	○	○	○
We extensively use statistical techniques to reduce process variance	○	○	○	○	○	○	○

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Our plant uses differentiated training so that workers who have different roles in the black/green belt role structure (or equivalent structure) can obtain the necessary knowledge and skills to fulfill their job responsibilities	○	○	○	○	○	○	○
Shop-floor employees drive suggestion programs	○	○	○	○	○	○	○
We use a black/green belt role structure (or equivalent structure) to prepare and deploy individual workers for continuous improvement programs	○	○	○	○	○	○	○
Our key suppliers manage our inventory	○	○	○	○	○	○	○
We give our suppliers feedback on quality and delivery performance	○	○	○	○	○	○	○
Families of products determine our factory layout	○	○	○	○	○	○	○
Metrics are used to link quality performance to strategic goals	○	○	○	○	○	○	○
We work with our key suppliers so they are contractually committed to annual cost reductions	○	○	○	○	○	○	○

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
We post equipment maintenance records on shop floor for active sharing with everyone	O	O	O	O	O	O	O

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
Our customers are directly involved in current and future product offerings	O	O	O	O	O	O	O
Shop-floor employees lead product / process improvement efforts	O	O	O	O	O	O	O
We are working to lower setup times in our plant	O	O	O	O	O	O	O
Financial performance (e.g., cost savings, sales) is part of the criteria for evaluating the outcomes of quality improvements in our plant	O	O	O	O	O	O	O

4. Implementation

What continuous improvement initiatives has your unit of your company formally implemented?

- O Lean manufacturing
- O Six Sigma
- O Lean Six Sigma
- O None

4.1. Implementation characteristics

Regarding the implementation of the continuous improvement initiatives (Lean, Six Sigma or Lean Six Sigma), please select the alternative (s) that best answers each question.

How long has the initiative been implemented?

- O Less than 6 months
- O Between 6 months and 1 year
- O Between 1 and 3 years
- O Between 3 and 5 years
- O Above 5 years
- O Do not know/Do not want to answer

Indicate your level of agreement with each statement below.
"The benefits we received from implementation of the improvement initiative are ..."

	Strongly disagree 1	2	3	4	5	6	Strongly agree 7
The productivity of our company increased	O	O	O	O	O	O	O
The financial gains of our company increased	O	O	O	O	O	O	O
The inventory level of our company decreased	O	O	O	O	O	O	O
The waste of our company decreased	O	O	O	O	O	O	O
The defect rate of our company decreased	O	O	O	O	O	O	O
The lead time of our company decreased	O	O	O	O	O	O	O
Variance in critical to quality characteristics decreased	O	O	O	O	O	O	O
Key process characteristics (e.g. temperature) were controlled better	O	O	O	O	O	O	O
The competitiveness improved	O	O	O	O	O	O	O
The production quality improved	O	O	O	O	O	O	O
The process quality improved	O	O	O	O	O	O	O
Other ______	O	O	O	O	O	O	O
Other ______	O	O	O	O	O	O	O
Other ______	O	O	O	O	O	O	O

To what extent have the following factors affected the practices adoption?

	Not at All 1	2	3	4	To a great extent 5
Lack of knowledge	O	O	O	O	O
Lack of skilled workers	O	O	O	O	O
Lack of management support	O	O	O	O	O
Lack of training	O	O	O	O	O
Poor employee participation	O	O	O	O	O
Resistance to change	O	O	O	O	O
Others ______	O	O	O	O	O
Others ______	O	O	O	O	O
Others ______	O	O	O	O	O

5. General company information

Considering just the unit of the company in which you work, please select the alternative (s) that best answers each question.

1. How many employees are there at this location?

0–99	100–499	Above 499	Do not know/Do not want to answer
O	O	O	O

6. Respondent information

In relation to your work in the company, please select the alternative (s) that best answers each question.

1. What is your current role within the organization?

- O President/CEO
- O Manager
- O Other ______
- O Director
- O Supervisor
- O Do not want to answer

2. In which department do you work?

- O Quality
- O Other ______
- O Manufacturing
- O Do not want to answer

3. How long have you worked at the company?

- O Less than 1 year
- O Between 4 and 7 years
- O Above 10 years
- O Between 1 and 4 years
- O Between 7 and 10 years
- O Do not want to answer

If you are interested in receiving an executive report, insert your email in the field below:

______

Information about Being in a Research Study
Clemson University

Lean Six Sigma in the Food Industry

Description of the Study and Your Part in It

Lawrence D. Fredendall, along with Luana Bonome Message Costa, is inviting you to take part in a research study. Lawrence Fredendall is a Professor at Clemson University. Luana Costa is a PhD student at Clemson University working with Lawrence Fredendall.

The purpose of this research is to evaluate the potential for the Food Industry to adopt Lean, Six Sigma and/or Lean Six Sigma practices. This survey will measure the degree of practice adoption by industry sector and the impact of the practices adopted on performance by industry sector.

It will take you about 15 - 20 minutes to be in this study.

Risks and Discomforts

We do not know of any risks or discomforts to you in this research study. To ensure that no information is released that could embarrass you or your company, only aggregate data will be reported.

Possible Benefits

We do not know of any way you would benefit directly from taking part in this study. However, practicing managers will be provided insights about the value of these best practices for their industry. The findings from this survey will also be used as a basis for future case studies about how companies facilitate adoption.

Protection of Privacy and Confidentiality

We will do everything we can to protect your privacy and confidentiality. We will not tell anybody outside of the research team that you were in this study or what information we collected about you in particular. All records and data collected in this survey will be kept confidential through password protected websites and/or password protected files. The results of this study may be published in scientific journals, professional publications, or educational presentations; however, no individual participant or company will be identified.

Choosing to Be in the Study

You do not have to be in this study. You may choose not to take part and you may choose to stop taking part at any time. You will not be punished in any way if you decide not to be in the study or to stop taking part in the study.

Contact Information

If you have any questions or concerns about this study or if any problems arise, please contact Lawrence D. Fredendall at Clemson University at 864- .

If you have any questions or concerns about your rights in this research study, please contact the Clemson University Office of Research Compliance (ORC) at 864-656-0636 or irb@clemson.edu. If you are outside of the Upstate South Carolina area, please use the ORC's toll-free number, 866-297-3071.