FEDERAL UNIVERSITY OF SÃO CARLOS

CENTER OF EXACT SCIENCES AND TECHNOLOGY

POST-GRADUATION PROGRAM IN INDUSTRIAL ENGINEERING

SUSTAINING LEAN THINKING IN HEALTHCARE: CASE STUDIES

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THESIS ORIENTATION: PROF. DR. MOACIR GODINHO FILHO

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Thesis presented to the Post Graduation Program in Production Engineering at the Federal University of São Carlos, as part of the requirements for obtaining the Doctor's Degree in Production Engineering.

Thesis Orientation: Prof. Dr. Moacir Godinho Filho

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Dedico esse trabalho aos meus pais: minha fonte inesgotável de inspiração.

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"É impossível avaliar a força que possuímos sem medir o tamanho do obstáculo que podemos vencer, nem o valor de uma ação sem sabermos o sacrifício que ela comporta."

(H. W. Beecher)

ABSTRACT

Many hospitals have achieved high levels of lean performance only to lose it later on. These hospitals, which often achieved excellent results, neglected some specific aspects of sustaining lean improvements in their environments, and failed to maintain what was implemented. This research develops a theoretical understanding of how organizations can sustain lean in healthcare. Through the analysis of the literature, it was possible to compile 22 main critical success factors of lean sustainability in hospitals through three main pillars: people, method and tools. A comparative case study provides evidence to confirm these 22 theoretical propositions, and also to add other 5 new propositions to the framework. The proposed framework allows hospitals to conduct a structured process of change, with all the foundation needed to succeed and sustain the lean journey in the long-term. It differs from previous studies by integrating literature streams that have been previously disconnected and by specifying the components of lean healthcare sustainability. These new insights are revealed by studying hospitals after minimum 18 months of lean implementation and comparing the ones that have achieved a high level of lean sustainability with those that do not. To the best of our knowledge, this article is the first to attempt to bring together the key factors that influence hospitals to sustain lean improvements in the long term.

This research found evidence that external factors to the three pillars may also interfere to facilitate or difficult hospitals to achieve sustainability in their lean implementations. They are called “success variables moderators” and they are intrinsically linked to the organizational characteristics of each hospital. The variables “type of administration and financial objective” and “accreditation” have proved to influence the hospital to achieve success in its lean implementations in the long term.

Another interesting conclusion that can be drawn is that although it is notorious knowledge, several points brought by the theoretical framework proved to be difficult to implement and the hospitals are failing to implement the basics.

Keywords: Lean Healthcare, Lean Hospital, Lean Sustainability, Continuous improvement, Case Study.

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LIST OF ABBREVIATIONS AND ACRONYMS

CEO - *Chief Executive Officer*

CI - *Continuous Improvement*

CMS - Central od Material and Sterilization

DMAIC - Define, Measure, Analyse, Improve, Control

HA - *Historical archive analysis*

HPO - *Historical Archive Analysis and Participant Observation*

HPOQ - *Historical Archive analysis, Participant Observation, and Questionnaire*

ICU - Intensive Care Unit

IH - *Interviews and Historical archive analysis*

IHO - *Interviews, Historical Archive Analysis and Outside Observation,*

IHP - *Interviews, Historical archive analysis and Participant observation*

IHPOQ - *Interviews, Historical Archive Analysis, Participant Observation, and Questionnaire*

IHQ - *Interviews, Historical archive analysis and Questionnaire*

IN - *Interviews*

IOQ - *Interviews, Outside Observation and Questionnaire*

IQ - *Interviews and Questionnaire*

IT - Information Technology

JIT - *Just in Time*

KPIs - *Key Performance Indicators*

LT - *Lead Time*

OO - *Outside Observations*

PDCA - *Plan, Do, Check, Act*

PO - *Participant's Observations*

QU - *Questionnaire survey*

SMED - *Single Minute Exchange of Die*

SMEs - *Small and Medium sized enterprises*

TPS - *Toyota Production System*

VSM - *Value Stream Mapping*

SUMMARY

Chapter 1

INTRODUCTION

1.1 Motivation

Authors such as Porter (2014), Graban (2012) and Gill (2012) point out that hospitals are undergoing major changes in recent years, being forced to adapt and seek continuous improvement of their processes in order to remain competitive.

During the past 20 years, a growing interest has been given in the healthcare sector to the methods used in the industrial sector of process reorganization to improve efficiency of services and organizations. It is important to know that among the Continuous Improvement (CI) techniques coming from manufacturing, Lean and Six Sigma have gained prominence in healthcare (GLASGOW et al., 2010). The same authors affirm that based on the publication frequency, Lean, Six Sigma and Lean Six Sigma are the CI techniques most frequently used to improve quality in hospitals.

The term Lean was cited for the first time by Womack, Jones and Roos to describe the Toyota Production System (TPS) and the steps to continuously improve the efficiency and effectiveness of a waste-eliminating system (WOMACK et al., 1990).

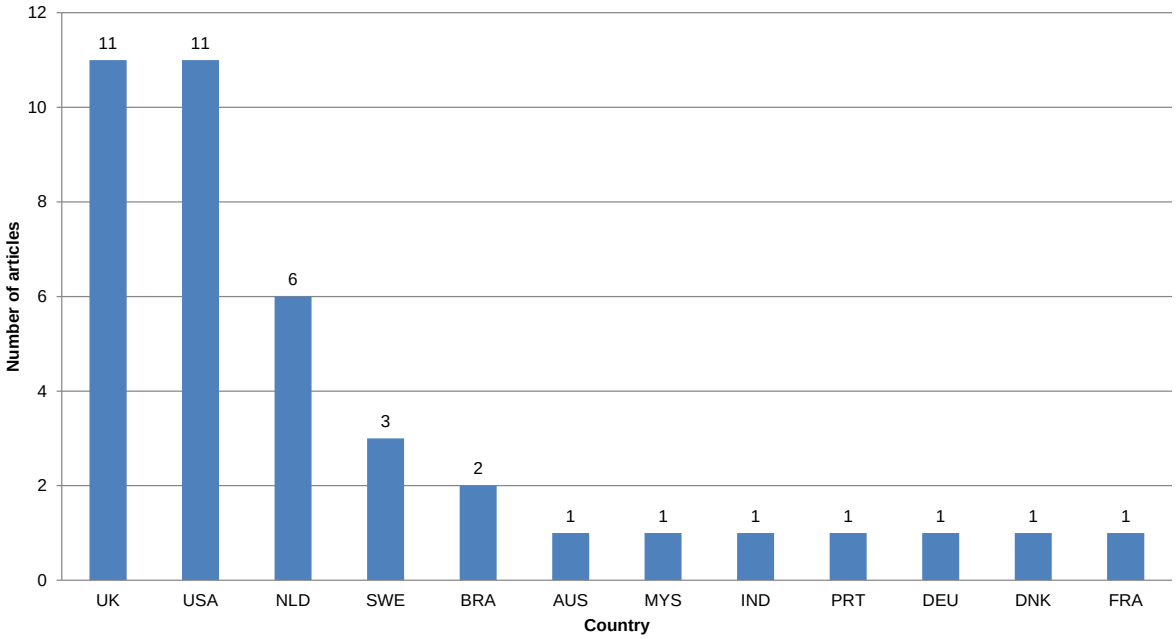
In the health context, according to Souza (2009), it is not known when the lean philosophy first appeared, but the first publications are dated in the year 2002. Also according to Souza (2009), lean healthcare appears as an effective philosophy to generate improvements in health organizations. In this sense, several authors have attributed success to lean healthcare, because it leads to expressive and sustainable results.

In Brazil, few studies on the application of lean production techniques in hospitals are still observed. Costa and Godinho Filho (2016) conducted a study on the state of the art related to this subject and found that between the years 2008 and 2013, there were only two publications on the application of lean concepts in Brazilian hospitals. Figure 1 shows the results found by the authors in terms of the distribution of the number of articles published on lean healthcare by country between 2008 and 2013. The key words used by the authors were "Lean health",

"Lean healthcare" and "Lean hospital", in the following database: Engineering village, Science Direct and Google Scholar.

The results found by Costa and Godinho Filho (2016) show that some aspects related to lean practices in the health area have remained similar to the previous reviews made by Mazzocato et al. (2010) and Souza (2009). The United States and the United Kingdom continue to be the countries with more articles published.

Figure 1 - Number of articles in lean healthcare by country (from 2008 to 2013)



Source: Costa and Godinho Filho (2016)

From the analysis of the review made by Costa and Godinho Filho (2016) it can also be verified that most studies do not mention aspects of the lean philosophy implementation process such as motivation, time and team, lessons learned, barriers and difficulties encountered during a lean healthcare project. The authors also found a lack of empirical studies in this area. Empirical research helps in theory building as well as theory verification (MARGERIE and JIANG, 2011). In recent years, the number of empirical articles in the field of operations management is rising dramatically compared to previous years (JASTI and KODALI, 2014). Roth (2007 p.12) defined the "empirical" term as "the systematic process of deriving and analysing data from direct or indirect observation". In this context, to the best of our knowledge there is no paper that systematically review the literature about empirical studies in Lean, Six Sigma and Lean Six Sigma in hospitals.

The application of lean in healthcare are being several reported in the modern literature (see NABELSI and GAGNON, 2016; Li, PAPADOPOULOS and ZHANG, 2016; CARDOEN, BELIËN and VANHOUCKE, 2015; HICKS et al., 2015). On the other hand, however, very little is known about how to sustain the quality of the lean implementations in the long term (BHASIN, 2012a; HINES et al., 2008).

Some authors estimate that less than 10 percent of the Lean implementations in all kinds of industries were successful in England (HINES et al., 2008; SIM and RODGERS, 2009; ATKINSON, 2010; BHASIN, 2011b; BHASIN, 2012a). In the literature, there is a consistent agreement among authors that at least two-thirds of change initiatives continue to fail (GRAHAM, 1991; ATKINSON 2010; SIRKIN et al., 2005; BHASIN, 2011b; BHASIN, 2012a). Because of the complexity of healthcare environments, the application of continuous improvement approaches as lean thinking in this sector may encounter unique challenges in comparison with others industries.

In this context, this thesis will present in the next chapters that 84.5 percent of the empirical articles published about lean, six sigma and lean six sigma in healthcare environments even not mentioned any sustainability aspect of the improvement realized and any of them have described the situation after 24 months of the beginning of the program. For D'Andreamatteo et al. (2015), when analysing lean healthcare, the implementation process itself and the sustainability remain key and under investigated issues. Indeed, many researchers assert that the literature in lean healthcare is specifically built on positive cases (see HOLDEN, 2011; MAZZOCATO et al., 2012). These authors also agree that would be important to learn from unsuccessful initiatives and, generally, to apply a more critical view to evaluate lean in healthcare. After this analysis, it is possible to conclude that a theoretical framework is necessary to guide both practitioners and academics on strategies to sustain lean in healthcare.

Based on this context, it is possible to conclude that there is a gap in the literature regarding lean healthcare implementations and there is an opportunity to develop a doctoral thesis that could contribute to the evolution of knowledge in this area.

1.2 Research questions and objectives

A systematic literature review of empirical research in Lean, Six Sigma and Lean Six Sigma in Healthcare was conducted in this thesis to present a thorough review of the empirical literature in this field to find the state of the art and propose future directions, consistent with the needs of professionals and academics.

Some research questions that this systematic literature review will help to answer:

- What is the state of the art in empirical studies in lean, six sigma and lean six sigma in hospital settings?

- What are the most needed future empirical research in this area?

One of the conclusions of this review is that there is a need of studies describing the main aspects and lessons learned on how to sustain the improvements implemented. This thesis tries to fill this gap by examining the following research question:

- How do hospitals sustain lean initiatives in their operations?

To investigate this question, the authors conduct a comparative case analysis that iterates between the literature and the case data to develop a theory on lean healthcare sustainability. The analysis draws on literature from experiences in: i) lean sustainability (LIKER, 2004; BATEMAN, 2005; RENTES, 2000; BHASIN, 2012b; KOVACHEVA, 2010; DOMBROWSKI and MIELKA, 2013) and ii) lean sustainability in healthcare (HUNG et al., 2015; NIEMEIJER et al., 2011; GLASGOW, 2010; BRANDAO DE SOUZA and PIDD, 2011; GRABAN, 2011; POKSINSKA et al., 2013; TOUSSAINT and BERRY, 2013; MURPHREE and DAIGLE, 2011; BRANDAO DE SOUZA and PIDD, 2008a).

Other questions that this research tries to answer:

- What are the key points that differentiate hospitals that have been able to sustain lean improvements than hospitals that failed?

- What are the main factors that hospitals can not neglect to achieve long-term sustainability in lean initiatives?

In this context, the main objective of this thesis is:

- Propose a framework to sustain lean implementations in the healthcare sector.

The next section presents the methodology used in this thesis to answer the research questions and achieve the proposed objective.

1.3 Research development stages

Once the questions and objectives have been defined, the research development stages to reach them are presented. The work can be divided into six main steps, outlined in Figure 2. They are:

(1) Macro theme definition;

(2) Systematic literature review for found gaps;

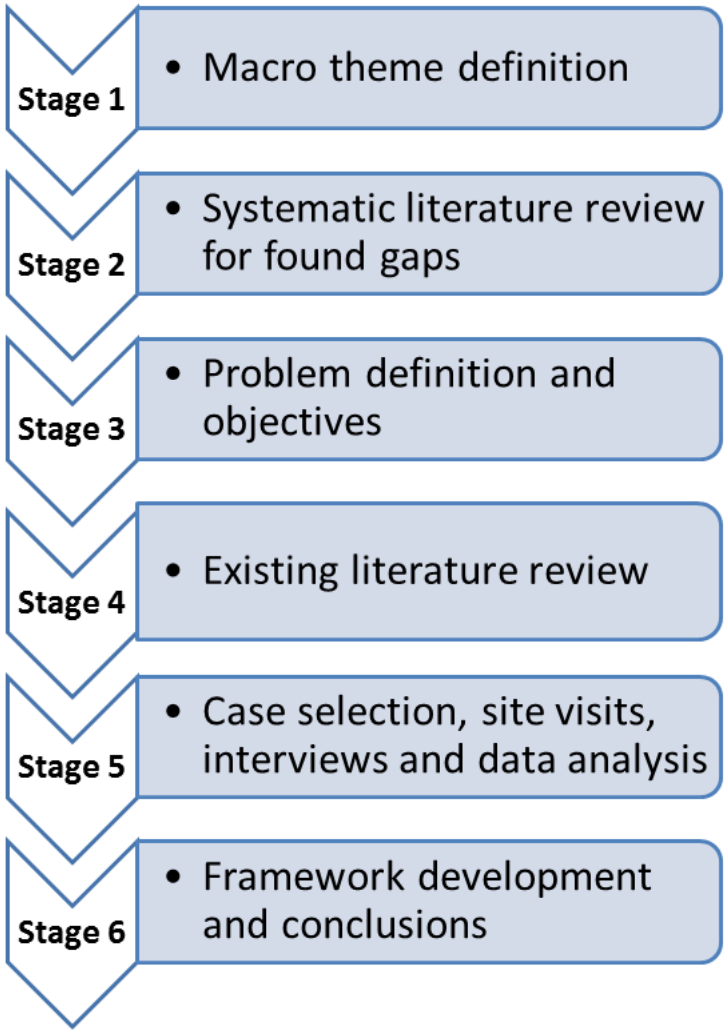
(3) Problem definition and objectives;

(4) Existing literature review;

(5) Case selection, site visits, interviews and data analysis;

(6) Framework development and conclusions.

Figure 2 - Research development stages



Source: Elaborated by the author

1.4 Methods

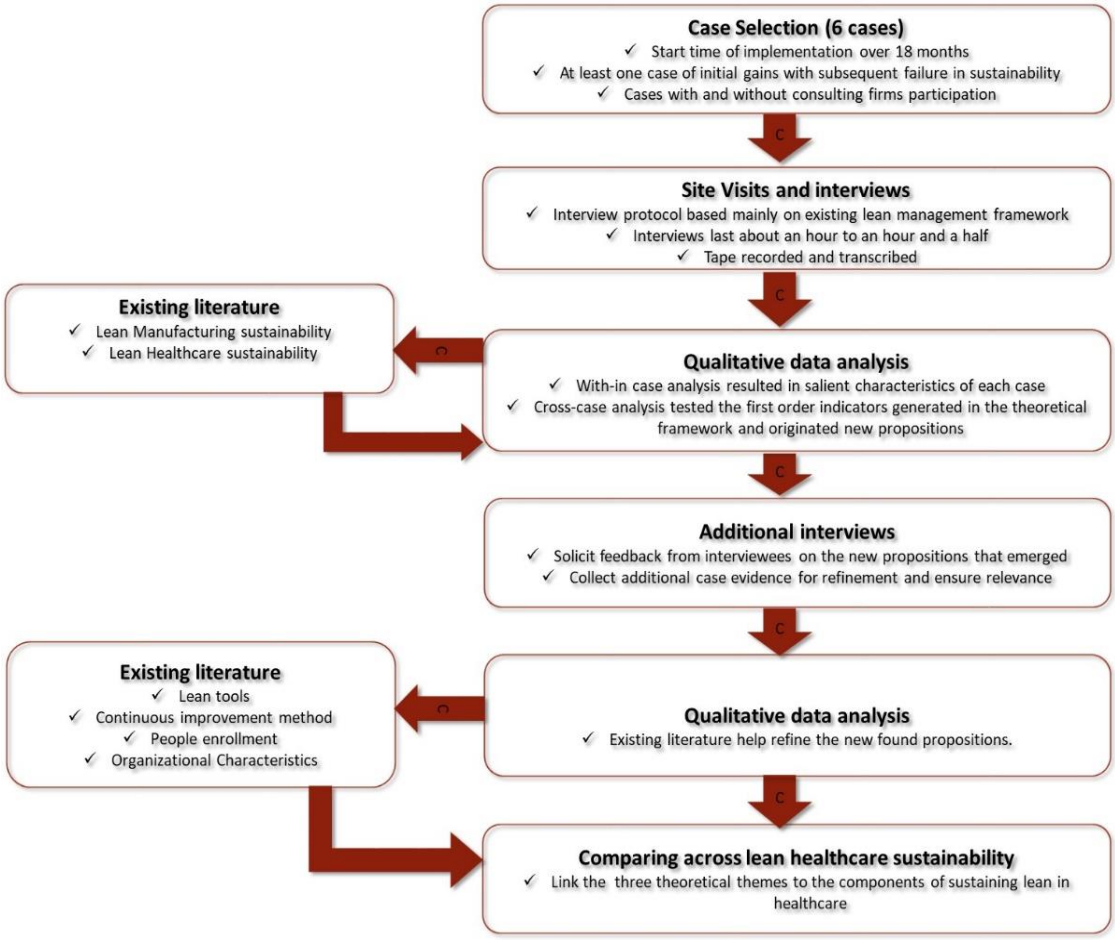
1.4.1 Data collection and research methods

This research conducts a comparative case study following the inductive theory-building approach (EISENHARDT, 1989; YIN, 2003). Since sustaining lean healthcare implementations in the long term has not been well studied, the inductive case study approach helps generate valuable insights. The qualitative data comes from six different hospitals in Brazil. Data collection involved multiple rounds of interviews over a two years' period. The research question focuses on designing a solution and describing the outcomes of the solution in use, so a longitudinal study of the case is appropriate (STUART et al., 2002). This approach allows us to study the experiences of managers in a real-life context and thus increases the practical relevance of the findings (YIN, 2013). The case analysis triangulates the qualitative data with the literature to establish a connection between concepts in different literature streams. Fig. 3 shows the overview of the research method.

1.4.2 Case selection

This study uses a purposive sampling strategy to include cases that span different hospital settings, which increases generalizability (PATTON, 1990). Still few hospitals in Brazil have already begun their lean journey (MAZZOCATO et al., 2012). The six hospitals chosen for the case study in question were selected from references obtained by the authors. Some of the criteria for this selection involved: i) Start time of lean implementation over 18 months; ii) At least one case of initial gains with subsequent failure in sustainability; iii) Cases with and without participation of different consulting firms. Following the principles of purposive sampling, the sample includes hospitals with varying degrees of lean sustainability. Appendix A provides detail descriptions of each hospital.

Figure 3 - Overview of the research method



Source: Elaborated by the author

1.4.3 Site visits

The researchers designed the initial interview protocol based on the literature. A separate interview protocol was designed for each managerial function. The initial interview protocol consisted of a series of open-ended questions about existing lean practices from the lean management literature and additional questions that request informant's opinion on sustaining lean performance (see Appendix B). The study used lessons from lean management sustainability in several industries (e.g. LIKER, 2004; BATEMAN, 2005; BHASIN, 2012b; HUNG et al., 2015; BRANDAO DE SOUZA and PIDD, 2011; GRABAN, 2011; BRANDAO DE SOUZA AND PIDD, 2008) as a starting point, and then investigated any additions, enhancements or deviations from the literature which could contribute to sustaining lean performance in healthcare. This served as a starting point in differentiating the sustaining from the non-sustaining hospitals. The visits were previously scheduled with the interviewees. In

addition to the interviews, during the visits, the researchers were able to walk through the hospitals, make observations, talk with employees, and analyze documents related to lean projects.

1.4.4 Interviews

The first round of interviews typically included two activities in parallel by the researchers: lead the discussion and take notes, asking additional questions. During the interview, the researchers probed informants with questions and encouraged them to discuss additional managerial practices or concepts that might affect the sustainability of lean in their hospitals. The interviews included the strategic level (CEO or director) and operational level (managers and leaders). All interviews lasted between one hour to one hour and a half, and specific questions were targeted to the informant's expertise. They were tape recorded, transcribed, and assembled into manuscripts that contain details of each of the six hospitals for the qualitative data analysis (ANDRIOPOULOS and LEWIS, 2009; GIOIA and THOMAS, 1996; MILES and HUBERMAN, 1994). Additional archival data such as internal audit reports of lean performance ratings, value stream maps, kaizen events presentations and historical key performance indicators were also collected to help minimize the retrospective bias (LANGLEY, 1999). In the first round of interviews, a total of 18 interviews were completed in 2016.

1.4.5 Qualitative data analysis

The qualitative data analysis began with a within-case analysis followed by a cross-case analysis (MILES and HUBERMAN, 1994). The researchers familiarized themselves with over 100 pages of transcribed interviews and had multiple meetings after the interviews to compare and contrast hospital units. The qualitative analysis started with a within-case analysis of each hospital unit to understand how they did or did not sustain the lean implementations. The researchers first read the interview transcripts closely and independently provided ideas of possible sustainability indicators. Case summary reports were prepared and reviewed by the researchers to improve validity (YIN, 2003). The researchers then conducted a cross-case analysis of hospital units to compare units with higher and lower levels of sustaining lean healthcare. The cross-case comparisons helped rule out hospital unit specific characteristics and extract the common indicators. This resulted in validating the first-order indicators of sustaining lean in healthcare found previously in the literature, and also originated new propositions. This

analysis came from comments, views made by informants, observations made by the researchers and materials analyzed. The relevant literature was incorporated at this stage to conceptually understand the emerging concepts, which also provided an additional source of validation (EISENHARDT, 1989). The lean manufacturing sustainability and lean healthcare sustainability literature streams provided a useful conceptual lens to interpret the qualitative data.

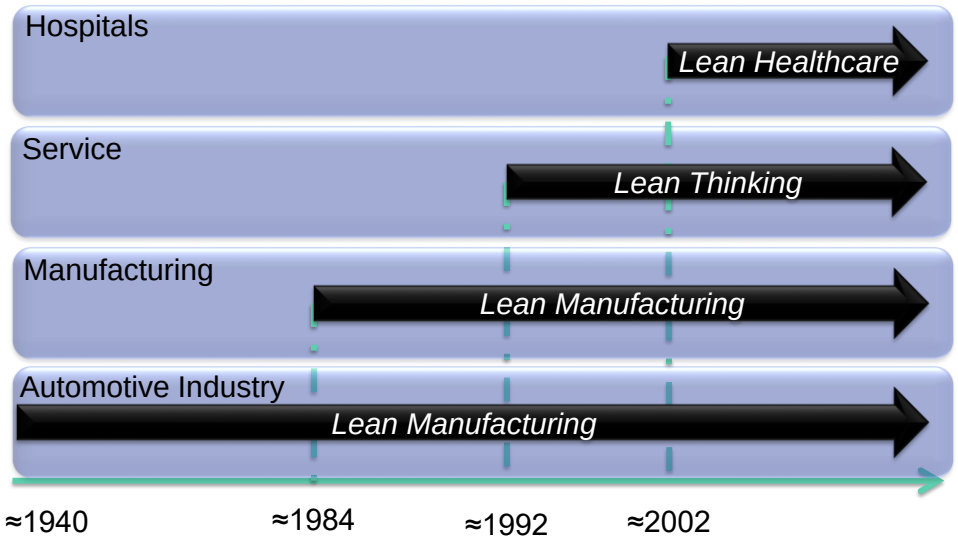
1.4.6 Additional interviews and data analysis

During the second-round interviews, the researchers gave interviewees an overview of the concepts that emerged from the first round of qualitative analysis and solicited their feedback about the emerging concepts. The second-round interviews also focused on gathering additional data that would help to verify or shape the new propositions that emerged from the first round of interviews. These interviews also provided additional information about changes in hospital unit's lean practices and performance. Multiple contacts with the informants also provided relevancy to the concepts and theory that emerged from this study (EMDEN et al., 2006; MADHAVAN and GROVER, 1998). The second round of interviews resulted in another 18 interviews performed in 2017. The researchers then went back and forth among the concepts, second round interview data, and existing literature to better refine the new propositions (EISENHARDT, 1989; YIN, 2003). Additional literature was brought in at this stage. This iteration process resulted in the proposal framework that emerged from the comparative case study and the existing literature.

1.5 Conceptual Background

Companies of several segments in the whole world apply concepts and techniques of lean production in order to improve the efficiency of its operations. Initially widespread in the automotive industry, lean philosophy has spread to the manufacturing industry as a whole and subsequently to other areas of business, expanding its field of application to the administrative and service sectors. More recently and specifically associated with this work, applications of lean in hospital environments have generated great results (LAURSEN et al., 2003). Figure 4 shows this evolution.

Figure 4 - Evolution of lean philosophy.



Source: Adapted from Laursen et al. (2003)

Womack (2005, p.64) endorses the Lean Thinking application in the hospital environment:

> [...] 'Lean thinking is not a manufacturing tactic or a cost reduction program, but rather a management strategy that is applicable to all organizations because it has to do with process improvement. All organizations - including health sector organizations - are composed of a series of processes, or sets of actions aimed at creating value for those who use or depend on them (clients / patients).'

One of the major goals associated with the application of lean concepts in hospitals is to increase the quality of patient care. By eliminating waste and activities that do not add value to patients' point of view, it is possible for nurses and doctors, for example, to focus on care (GRABAN, 2012).

Womack et al. (2005) cites cases of lean implantation at Virginia Mason Medical Center (USA) and Theda Care Inc. (USA). In the first hospital, expressive results were enumerated, such as a productivity increase of 36% and a reduction of inventories by 53%. At Theda Care Inc., the authors cite the drop in the coronary surgeries mortality rate from 4% to zero in two years. In addition, the mean time of hospitalization reduced from 6.3 days to 4.9 days and the cost of coronary surgery felt by 22%.

In the Mayo Medical Laboratories (USA), Rickard and Mustapha (2007) report a 13% gain in productivity, a 50% reduction in demand variation and a large increase in employee satisfaction.

Radnor et al. (2006) cite some results from the lean office in the public hospital sector in Edinburgh, Scotland. According to the authors, with the introduction of lean, it was possible to identify and eliminate several activities that did not add value, to reorganize the communication among the departments and to avoid several comings and goings of the patient at home. The authors also highlight the reduction of patient waiting time for the first consultation from 23 to 12 days and reduction of patient care lead time in 48%.

The state of the art on lean healthcare was raised by the reviews of Souza (2009), Mazzocato et al. (2010) and recently updated by Costa and Godinho Filho (2016). All these reviews show the United States and United Kingdom as the countries that publish the most on the subject. Costa and Godinho Filho (2016) cite in their review that in Brazil only 2 studies were found, which creates a huge opportunity for future research in the country.

Mazzocato et al. (2010) and Costa and Godinho Filho (2016) converge in their reviews on the most applied lean tools in hospital settings. The authors point out that the Value Stream Mapping (VSM), the Kaizen Events and the Standardization of Work are the most used techniques. Souza (2009) and Costa and Godinho Filho (2016) cite the reduction in waiting time, capacity increase and cost reduction as the most obtained results from lean implementations in hospitals.

The three reviews mention that the number of operational publications is preponderant, and that research with a more strategic vision and researches that brings contributions in the field of long-term sustainability of the improvements are still being little explored.

Another challenge is the definition of who is the client in a hospital environment, once there may be several clients. Some typical examples are the patient, the patient's family, physicians, hospital staff, the hospital itself, or even the health plan operators (McGrath et al, 2008). Womack et al. (2005), Filingham (2007) and McGrath et al. (2008) argue that it is extremely important that the value should be determined by the main client: the patient. This definition can be extremely important for sustainability, once the first principle of lean thinking is exactly to define what is value from the perspective of the client.

Most hospitals are designed around specialized functions or departments. These departments have their own physical space, their own budgets, their own employees and their own management structures. Each department has its own work to do, but also plays a direct or indirect role in patient care. (GRABAN, 2011). Still according to the author, many unsuccessful

lean healthcare implementations are conditioned to departmentalized projects, without focus on the patient flow as a whole.

Authors like Niemeijer et al. (2011), Glasgow (2010) and Brandao de Souza (2011) cite relevant factors that contributes to have a successful lean implementation in healthcare: i) engaging healthcare professionals in redesigning, implementing, and managing their new processes; ii) opening new lines of communication through the hospital hierarchy; iii) having a visual display of daily progress on performance metrics; iv) Division of responsibilities between doctors and medical assistants; v) rapid training sessions to minimize time away from patient care; and vi) gemba walks meetings with participation of the top and middle management, healthcare professionals and operational workers.

1.6 Thesis Structure

The present thesis is divided into 6 chapters presented previously, as follow:

In Chapter 1, there is the introduction and the research questions and objectives. It also presents the motivation of the research and its justification, the methodological aspects used to carry it out, as well as the theoretical foundations necessary for the understanding of the current research.

The subsequent two chapters (Chapters 2 and 3) are structured in the form of scientific articles. Their sections are constituted according to their specific objectives, results and conclusions. It is important to note here that due to this structure model, some parts of the thesis can be repeated between the chapters.

Thus, in Chapter 2, a systematic review of the literature on empirical research dealing with the implementation of lean in the health segment will be carried out, in order to identify the gaps and future works necessary in this area.

Next, Chapter 3 will propose a framework on how to structure the sustainability of lean improvements in hospitals in the long-term. For this, a case study in six Brazilian hospitals is constructed.

Chapter 4 aims to present the answers to the research questions proposed in this thesis, as well as the conclusions and the possible extensions of this work.

Finally, the bibliographic references used in the research are presented.

Chapter 2

EMPIRICAL RESEARCH IN LEAN, SIX SIGMA AND LEAN SIX SIGMA IN HEALTHCARE: A SYSTEMATIC LITERATURE REVIEW

Abstract

Purpose – The purpose of this paper is to review the existing literature on empirical research in lean, six sigma and lean six sigma in healthcare. It provides a critical assessment of empirical research methodology of 84 research articles published in 58 different journals.

Design/methodology/approach – The article reviewed a set of 84 empirical research articles in lean, six sigma and lean six sigma research in healthcare with respect to empirical research design and its related aspects. The research articles are collected from two different databases: Engineering Village and Web of Science. The approach for the critical review of the 84 empirical research articles selected is based on the empirical research approach given by Flynn et al. (1990).

Findings – It is concluded from the analysis of the results that the number of empirical research articles in lean, six sigma and lean six sigma in healthcare is increasing in a very fast way. Despite of this fact, the researchers have still unexplored various aspects of empirical research, such as: different types of researches designs; other types of respondents; longitudinal data collection methods; and more complex statistical data techniques analysis. Finally, it is concluded that there is a need of studies describing: i) how to create a continuous improvement culture in practice; ii) the main aspects and lessons learned on how to sustain the improvements implemented, and iii) the specific barriers for conducting improvements in the healthcare sector.

Originality/value – To the best knowledge of the authors, this paper is the first to attempt to critically review the empirical research articles in lean, six sigma and lean six sigma in healthcare.

Keywords Literature review, Empirical research, Lean, Lean Six Sigma, Six Sigma

Paper type Literature review

2.1 Introduction

During the past 20 years, a growing interest has been given in the healthcare sector to the methods used in the industrial sector of process reorganization to improve efficiency of services and organizations. It is important to know that among the Continuous Improvement (CI) techniques coming from manufacturing, Lean and Six Sigma have gained prominence in healthcare (GLASGOW et al. 2010). The same authors affirm that based on the publication frequency, Lean, Six Sigma and Lean Six Sigma are the CI techniques most frequently used to improve quality in hospitals. Seidl and Newhouse (2012) also reinforce that Lean, Six Sigma and Lean Six Sigma have been the most popular methods of CI published in the healthcare sector, and they complement saying that most of these articles are conceptual and not empirical in nature.

Empirical research helps in theory building as well as theory verification (MARGERIE and JIANG, 2011). In recent years, the number of empirical articles in the field of operations management is rising dramatically compared to previous years (JASTI and KODALI, 2014). Roth (2007) defined the "empirical" term as "the systematic process of deriving and analysing data from direct or indirect observation".

In this context, to the best of our knowledge there is no paper that systematically review the literature about empirical studies about Lean, Six Sigma and Lean Six Sigma in hospitals. This is exactly the main goal of the present paper: to present a thorough review of the empirical literature in this field to find their present approach and propose future directions consistent with the needs of professionals and academics.

The process of categorization and review article in this study is supported by a six-stage methodology of empirical research as described by Flynn et al. (1990). Soni and Kodali (2011) conducted the same type of analysis in their article of supply chain management literature review and Jasti and Kodali (2014) in their article of Lean Manufacturing literature review.

This paper is organized as follow: Section 1 is the Introduction. Section 2 is a conceptual basis necessary for understanding the work. Section 3 describes the methodology adopted for the selection of articles including the time horizon, the data basis selection, articles selection and the classification of articles. The analysis of empirical research is discussed in Section 4. Section 5 describe the gaps for future empirical research in lean, six sigma and lean six sigma

in healthcare. The summary of results and conclusions are discussed in Section 6. Finally, the references are in Section 7.

2.2 Conceptual Basis

The application of CI techniques is increasing in popularity in the health sector (DELLIFRAINE et al., 2010). About ninety five percent of healthcare operations are considered operations that do not add value, what leaves a substantial space for efficiency improvement (HAGAN, 2011). To solve different kinds of problems, CI initiatives are recently ranked as more important than previously reported and experienced in patient safety, quality, employee satisfaction and competitiveness (LIGHTER, 2011).

Based on the publication frequency, Lean, Six Sigma and Lean Six Sigma are the most frequently used CI techniques to improve quality in hospitals (GLASGOW et al., 2010). According to a survey conducted by the American Society for Quality, 53 percent of US hospitals use some type of lean management initiative (HENKE, 2009). Similarly, numerous articles have described Six Sigma experience in health care environments (BOADEN et al., 2008).

The term "Lean Management" or "Lean Production" was popularized first by Womack et al. in their book entitled “The Machine that Changed the World” published in 1990 by the Institute of Technology, Massachusetts (USA). The movement that began in the manufacturing sector found new dimensions in other segments such as construction, healthcare, hotels, etc. Lean is considered a very powerful philosophy that aims to maximize operational efficiency, quality, speed and cost (HOLWEG, 2007). The first publications of lean appeared in the health service in the UK in 2001 and in the US in 2002. One interesting point, however, is the fact that the literature suggests considerable variability in the implementation of lean in healthcare, with differences in approach, conducting methodology and scope. Despite becoming extensive, research on lean in healthcare focuses on distinct characteristics of the system rather the system as a whole (RICH and PIERCY 2013). In this context, most hospitals seems to tend to small lean projects closed creating 'pockets of best practice" rather than adopting an organization approach or the entire system (SOUZA, 2009, RADNOR et al., 2012). Souza (2009) emphasizes that the United States is the country with the highest number of publications related

to lean healthcare with 57 percent of the publications, and the UK is in second place with 29%. According to Mazzocato et al. (2010), some of the main results observed in lean healthcare implementations are wait time reduction, reduction in the time of stay, capacity increase/liberation and cost reduction. The same authors report that the VSM, Kaizen events and work standardisation are among the most used lean tools in hospital environments. Recently, in their lean healthcare literature review, Costa et al. (2015), indicate that reducing patient lead times, reducing costs, and making financial improvements were the primary factors that motivated lean healthcare implementation. The application of lean in healthcare are being several reported in the modern literature (see NABELSI and GAGNON, 2016; LI, PAPADOPOULOS and ZHANG, 2016; CARDOEN, BELIËN and VANHOUCKE, 2015; HICKS et al., 2015)

The term Six Sigma was first used by Motorola in the early 1980s (RAISINGHANI et al., 2005). The history of Six Sigma and its development has been widely reported in order to relate the expressive savings that the methodology create in various types of industries (GOH, 2002; PRABHUSHANKAR and DEVADASAN, 2008). Several different types of reports from improvement efforts using Six Sigma in healthcare have been reported in radiology (BAHENSKY et al., 2005; CHERRY and SESHADRI, 2000), nursing (VAN HEUVEL et al., 2004), medication errors (REVERE and BLACK, 2003), and decreasing the response time between surgical cases (ARTHUR, 2011). To conduct projects in Six Sigma, a structured series of phases, described as define, measure, analyze, improve and control comprises the DMAIC methodology. Some crucial elements of six sigma are employee training green / black belt, process control and statistical quality (FURTERER, 2011). In recent literature, many authors have cited cases of six sigma in the health industry (see CHUNG and KWON, 2016; BEGEN, PUN and YAN, 2016; SAREMI et al., 2013; ARUMUGAM, ANTONY and KUMAR, 2013).

A clear difference between lean and six sigma is that they deal with different kinds of problems. While lean focuses on improving the value stream, the patient flow, trying to eliminate wastes and bringing the problems visible (ARTHUR, 2011), Six Sigma focuses on precision and accuracy, in specific points of the processes, with statistical tools to improve quality, while reducing the variation in performance (ANTONY and KUMAR, 2012). However, both focus on customer needs, reducing costs and improving processes (ARTHUR, 2011). So, in the last times, a great tendency in CI in healthcare organizations is the combination of lean with Six Sigma (BISGAARD, 2009).

2.3 Research Method

The following aspects of the research method used in the present paper are discussed in the following subsections: time horizon of review, selection of journals, article selection, article classification and articles analysis.

2.3.1 Time horizon

The authors have not chosen the review duration over a specific period. The reason for not selecting a specific period is the fact that it is important to know when empirical publications of Lean, Six Sigma and Lean Six Sigma began in health environments and how is the comportment along the years since the first article publication.

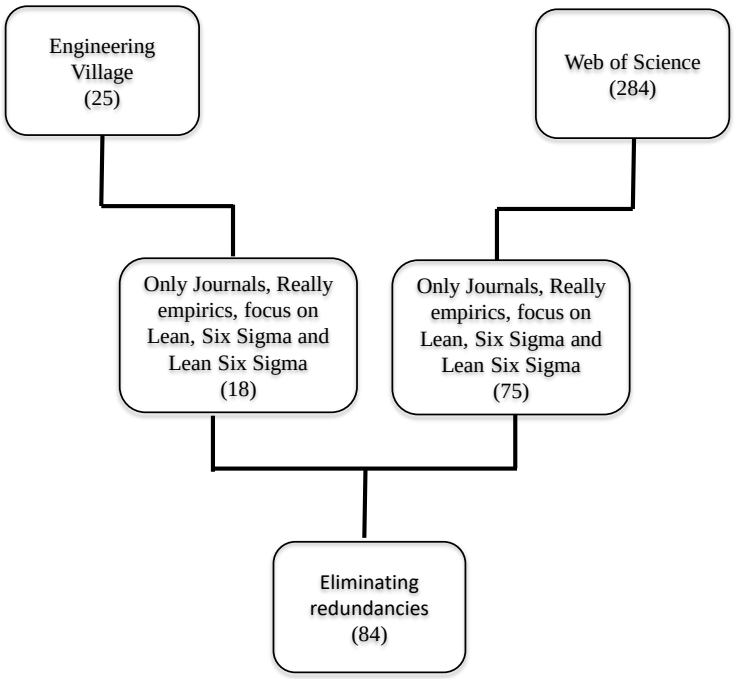
2.3.2 Selection of Journals

The literature related to theory and practices of Lean, Six Sigma and Lean Six Sigma in healthcare is available in various publications and conferences. The authors have searched for the related articles appeared in two different databases: Engineering Village and Web of Science. These data basis were chosen because of their high relevance in terms of publications on the subject of this paper.

For the search criteria, the authors have used the combination of the follow terms: "Lean" or "Six Sigma" or "Lean Six Sigma" and "healthcare" or "health care" or "hospital" and "survey" or "single case study" or "multiple case study" or "action research" or "focus group study" or "panel study". Flynn et al. (1990) state that any empirical research article can have one or more of the following empirical research designs, known as: multiple case study, single case study, focus group study, panel study and survey. Additionally, the authors increment the action research design for considering it as a very important empirical research design. Action research requires that the research team participates in the implementation process and engages with the practitioners to observe the process. Therefore, action research is

considered as an empirical research design with great power on the implementation of change management in the field of operations (see, e.g. WESTBROOK 1995; COUGHLAN and COGHLAN 2002; HENDRY, HUANG, and STEVENSON 2013). In the present study, the authors have considered the searched articles as empirical research articles if any of the six research designs described are present in the article. Figure 5 shows a schematic tree of filtered articles. The schematic tree shows the selection process of Lean, Six Sigma and Lean Six Sigma empiric articles publications in healthcare environments. 72 journals were found leading to a total of 309 articles.

Figure 5 - A schematic tree of filtered articles



Source: Elaborated by the author

2.3.3 Selection of articles

To select the articles to be analysed in this paper, the authors filter only the articles published in English, and eliminated the publications out of the subject. For example, many articles in technical medicine were found and were not considered for this study. Another filter was done to check if the articles were really empirics. According to Flynn et al. (1990) and Jasti and Kodali (2014) the term “empirical” refers to researches based on real world observation.

Soni and Kodali (2011) complement stating that empirical articles are used to describe "field-based" experiences, which uses data collecting procedures from naturally occurring situations, instead of via laboratory or simulation studies. For final, the redundancies were eliminated off this list and the remaining 84 articles selected in 58 journals composed the final list of works considered in the bibliographic review in this paper. The complete list of journals along with the number of articles in empirical study is shown in Table 1. As observed from Table 1 the trend toward empirical investigation varied among journals and some of the journals have very limited publications as well as narrow focus on empirical articles in the subject. Another finding is that the most reputed journals in the field of operations management have published articles on empirical research in Lean, Six Sigma and Lean Six Sigma implementations in healthcare.

2.3.4 Article Classification

The present study have adopted the classification scheme defined by Flynn et al. (1990) to classify the empirical research articles. According to Flynn et al. (1990), an empirical research consists of six stages. Table 2 adapted and summarized the six stages of empirical research proposed by Flynn el al. (1990). In stage I, the selected articles are classified according to the purpose of empirical research, establishing a theoretical foundation by theory building and theory verification. In stage II the articles are classified based on the research design; single case study, multiple case studies, action research, panel study, focus group study and survey. Stage III involves the selection of data collection method, where the selected articles are analysed under an historical archive analysis, participant observations, outside observations, interviews and questionnaire survey. In stage IV, the articles are classified per sample size, qualitative/quantitative/triangulated data, cross-sectional or longitudinal data collection and type of respondents. Stage V analysis of data by means of descriptive statistics, tests of differences/similarities, measures of dimensionalities and statistical interpretation of parameters. Stage VI concludes and reports the findings.

Table 1 - List of journals along with the number of articles in empirical study

Sl. no.	Journal Title	No. Articles	Percentage
1	Quality Engineering	6	7%
2	Bmc Health Services Research	5	6%
3	Quality Management in Health Care	4	5%
4	International Journal of Health Care Quality Assurance	3	4%
5	Production Planning & Control	3	4%
6	Total Quality Management & Business Excellence	3	4%
7	Bmc Medical Informatics and Decision Making	2	2%
8	European Journal of Oncology Nursing	2	2%
9	European Journal of Operational Research	2	2%
10	Herd-Health Environments Research & Design Journal	2	2%
11	International Journal of Operations & Production Management	2	2%
12	Journal of Operations Management	2	2%
13	Operations Management Research	2	2%
14	Quality and Reliability Engineering International	2	2%
15	American Journal of Managed Care	1	1%
16	American Journal of Medical Quality	1	1%
17	Annals of Emergency Medicine	1	1%
18	Applied Ergonomics	1	1%
19	Bmj Open	1	1%
20	Clinical Orthopaedics and Related Research	1	1%
21	Critical Care Medicine	1	1%
22	Decision Sciences	1	1%
23	Engineering Management Journal	1	1%
24	European Journal of Cancer	1	1%
25	European Journal of Internal Medicine	1	1%
26	Gynecologic Oncology	1	1%
27	Indian Journal of Ophthalmology	1	1%
28	Industrial Management & Data Systems	1	1%
29	International Journal for Quality in Health Care	1	1%
30	International Journal of Industrial Engineering	1	1%
31	International Journal of Information Management	1	1%
32	International Journal of Information Systems and Change Management	1	1%
33	International Journal of Nursing Studies	1	1%
34	International Journal of Physical Distribution & Logistics Management	1	1%
35	International Journal of Public Sector Management	1	1%
36	Investigaciones Europeas De Direccion Y Economia De La Empresa	1	1%
37	Journal of Cases on Information Technology	1	1%
38	Journal of Evaluation in Clinical Practice	1	1%
39	Journal of Medical Systems	1	1%
40	Journal of Nursing Management	1	1%
41	Journal of Pediatric Nursing-Nursing Care of Children & Families	1	1%
42	Journal of Quality	1	1%
43	Journal of the American College of Surgeons	1	1%
44	Journal of the American Medical Directors Association	1	1%
45	Journal of Vascular Surgery	1	1%
46	Laryngoscope	1	1%
47	Leadership in Health Services	1	1%
48	Mayo Clinic Proceedings	1	1%
49	Nordic Journal of Working Life Studies	1	1%
50	Nursing Economics	1	1%
51	Pediatric Critical Care Medicine	1	1%
52	Personal and Ubiquitous Computing	1	1%
53	Safety Science	1	1%
54	Service Business	1	1%
55	Social Science & Medicine	1	1%
56	Supply Chain Management-an International Journal	1	1%
57	Technology and Health Care	1	1%
58	Work-a Journal of Prevention Assessment & Rehabilitation	1	1%
	Total	**84**	**100%**

Source: Elaborated by the author

Table 2 - Six stages of empirical research.

	Action	Type
Stage I	Establishing a theoretical foundation	.Theory building (TB) .Theory verification (TV)
Stage II	Selecting a research design	.Single Case stydy .Multiple case study .Action Research .Panel study .Focus group .Survey
Stage III	Data collection method	.Historical archive analysis .Participants observations .Outside observations .Interviews .Questionnaire survey
Stage IV	Implementation	.Population selection .Sample selection .Scale development .Questionnaire construction .Pilot testing .Mailing .Analysis of non-respondent data characteristics .Data entry
Stage V	Analysis of data	.Descriptive statistics .t-tests .w2-test .Regression/correction .Path analysis .Cluster analysis .Factor analysis
Stage VI	Conclusion	Reporting the analysis

Source: Adapted from Flynn et al. (1990)

2.4 Analysis of empirical research in Lean, Six Sigma and Lean Six Sigma in healthcare environments

2.4.1 Empirical research growth in Lean, Six Sigma and Lean Six Sigma in healthcare environments

It is observed that the first empirical research article in this field was in Six Sigma and it has appeared in the journal "Quality and Reliability Engineering International" in the year 2004. The article reported a Six Sigma implementation in a Dutch Hospital, specifically in the nursing department. The first empirical research article in Lean Healthcare appeared in 2006 in the journal "Total Quality Management & Business Excellence". The article reported an implementation of lean using the Value Stream Mapping (VSM) in an American Outpatient department. The frequency distribution of empirical articles in journals since 2004 is given in Table 3. Over the last 12 years, there has been exponential growth in the number of empirical research articles published in this subject. To have some idea, the number of empirical research articles published between 2010 and 2016 represent 85 percent (71 articles) of the amount of articles considered in this paper, while only 15 percent (13 articles) are articles published between 2004 and 2010.

It is also observed that only 14 journals published more than one empiric article selected for this paper. Six journals have some prominence and published three or more articles: "Quality Engineering" (QE), "BMC Health Services Research" (BHSR), "Quality Management in Health Care" (QMHC), "International Journal of Health Care Quality Assurance" (IJHCQA), "Production Planning & Control" (PPC), "Total Quality Management & Business Excellence" (TQMBE). The distribution of empirical research articles on Lean, Six Sigma and Lean Six Sigma in healthcare environments according to year of publication is demonstrated in Figure 6. The graphical representation of the empirical research articles clearly indicates the increasing trend. The histogram clearly indicates that the growth of the empirical research articles in the last five years is continuously increasing. The year 2015 have the highest number of published articles.

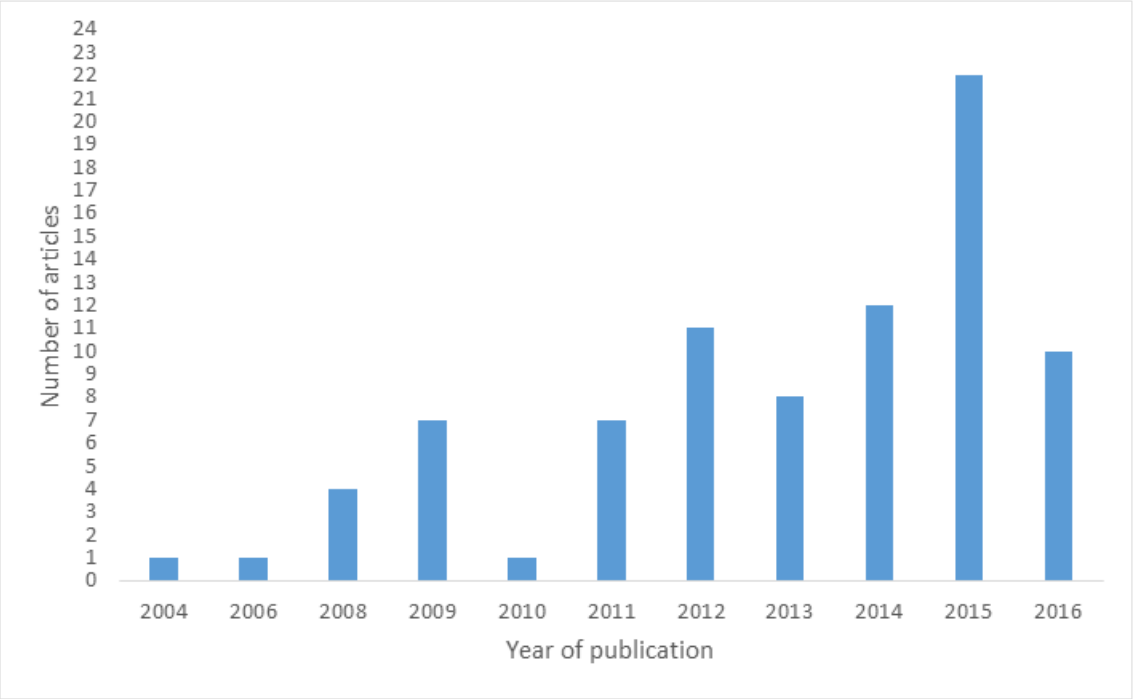
Table 3 - Frequency distribution of empirical research articles in journals

Journal Title	2004	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Quality Engineering				2		1	1	1		1		6
Bmc Health Services Research							2		2	1		5
Quality Management in Health Care								1		2	1	4
International Journal of Health Care Quality Assurance										2	1	3
Production Planning & Control			1						1		1	3
Total Quality Management & Business Excellence		1						1			1	3
Bmc Medical Informatics and Decision Making							1			1		2
European Journal of Oncology Nursing									1	1		2
European Journal of Operational Research							1				1	2
Herd-Health Environments Research & Design Journal							1	1				2
International Journal of Operations & Production Management						1				1		2
Journal of Operations Management						1					1	2
Operations Management Research					1					1		2
Quality and Reliability Engineering International	1								1			2
American Journal of Managed Care									1			1
American Journal of Medical Quality								1				1
Annals of Emergency Medicine				1								1
Applied Ergonomics										1		1
Bmj Open								1				1
Clinical Orthopaedics and Related Research									1			1
Critical Care Medicine							1					1
Decision Sciences			1									1
Engineering Management Journal										1		1
European Journal of Cancer				1								1
European Journal of Internal Medicine							1					1
Gynecologic Oncology										1		1
Indian Journal of Ophthalmology									1			1
Industrial Management & Data Systems										1		1
International Journal for Quality in Health Care									1			1
International Journal of Industrial Engineering				1								1

Journal Title	2004	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
International Journal of Information Management									1			1
International Journal of Information Systems and Change Management				1								1
International Journal of Nursing Studies									1			1
International Journal of Physical Distribution & Logistics Management			1									1
International Journal of Public Sector Management										1		1
Investigaciones Europeas De Direccion Y Economia De La Empresa										1		1
Journal of Cases on Information Technology							1					1
Journal of Evaluation in Clinical Practice										1		1
Journal of Medical Systems										1		1
Journal of Nursing Management				1								1
Journal of Pediatric Nursing-Nursing Care of Children & Families											1	1
Journal of Quality						1						1
Journal of the American College of Surgeons						1						1
Journal of the American Medical Directors Association											1	1
Journal of Vascular Surgery								1				1
Laryngoscope											1	1
Leadership in Health Services										1		1
Mayo Clinic Proceedings								1				1
Nordic Journal of Working Life Studies											1	1
Nursing Economics			1									1
Pediatric Critical Care Medicine						1						1
Personal and Ubiquitous Computing										1		1
Safety Science										1		1
Service Business							1					1
Social Science & Medicine							1					1
Supply Chain Management-an International Journal										1		1
Technology and Health Care						1						1
Journal of Prevention Assessment & Rehabilitation									1			1
Total	1	1	4	7	1	7	11	8	12	22	10	**84**

Source: Elaborated by the author

Figure 6 - Distribution of empirical research articles according to the year of publication



Source: Elaborated by the author

2.4.2 Purpose of empirical research

Every article investigated on empirical research should have the aim of theory building or theory verification (JASTI and KODALI, 2014). Theory building must use theories and practices already developed to elaborate new concepts and generate new contributions (LYNHAM, 2000). According to Svensson (2013), before the findings of an empirical research be considered a new theory through a theory building, these findings need to be validated or falsified and further confirmed by other studies by theory verification.

According to Meredith (1993), theory verification tests hypotheses generated within specific variables for the existing theory. The same concept was used in this paper to classify the selected articles. This type of research is very common among the empirical research because it is useful for researchers to test theories proposed in various circumstances and sectors (JASTI and KODALI, 2014). Table 4 compares the number of articles on theory building and theory verification. Table 4 shows that since 2004, when there was the publication of the first empirical research in six sigma in healthcare environments, there is a little prevalence for theory verification articles. Only in 2008 and 2011 there was a prevalence for theory building articles. In general, 60 percent (50 articles) of the total selected articles for this paper (84) are theory verification, while 40 percent (14 articles) are theory building.

Table 4 - Number of articles on theory building and theory verification

	2004	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Theory Building	0	0	3	1	1	4	4	2	5	9	5	34
Theory Verification	1	1	1	6	0	3	7	6	7	13	5	50
Total	1	1	4	7	1	7	11	8	12	22	10	84

Source: Elaborated by the author

2.4.3 Selection of research design

Various research design methods are used to develop empirical articles in the field of operations management. Flynn et al. (1990) clarified that any empirical research article can have one or more of the following empirical research designs, called multiple case study, single case study, focus group study, panel study and survey. Additionally, the authors of this paper increment the "action research" to this list, considering that action research has been used in a series of recent empirical studies related with the implementation of change.

According to the present study, it is observed that the most popular research design was the Single Case Study with 42 publications, corresponding to 50 percent of the 84 selected articles. The number of articles in each research design is given in Table 5.

Table 5 - Number of articles in each research design

Research design	Number of articles	Percentage
Single Case Study	42	50,0%
Action Research	23	27,4%
Survey	9	10,7%
Multiple Case Study	6	7,1%
Panel Study	3	3,6%
Focus Group	1	1,2%
Total Geral	84	100,0%

Source: Elaborated by the author

The next most popular choice is the Action Research design, which contains 27.4 percent (23 articles) of the total empirical articles (84 articles). Survey is in third position with 10.7 percent (9 articles). Multi-case studies are reporting only 6 articles (7.1 percent). Panel study and Focus Group articles constitute only three and one articles, respectively. Frequency distribution of single case study articles is shown in Table 6. Trends in Table 6 shows that 50 percent of the single case studies articles selected are from only 08 different journals. The maximum number of articles published in single case studies were from the journal "Quality

Engineering" (05 articles), followed by "Bmc Health Services Research" (03 articles) and "Quality Management in Health Care" (03 articles). Analysing only journals that have published more than one article among the total of the selected articles for this paper, it is interesting to note that the journals "European Journal of Oncology Nursing", "European Journal of Operational Research" and "Quality and Reliability Engineering International" have reported only single case study articles. On the other hand, journals like "Total Quality Management & Business Excellence", "Journal of Operations Management" and "Operations Management Research" have not a single case study publications.

Other journals like "Quality Engineering", "Bmc Health Services Research", "Quality Management in Health Care", "International Journal of Health Care Quality Assurance", and "Production Planning & Control" reported more than 50 percent of their articles on single case study. The first publication in Lean, Six Sigma and Lean Six Sigma in healthcare environments was a single case study in 2004. After that, between 2004 and 2008, there was not any one single case study published. On the other hand, in 2008, 75 percent (three of the four articles published during that year) were single case studies. In 2010, there was also no one single case study publication. Following the trends of the total publications, the year of 2015 has 55 percent of the publications on single case study design, totalising 12 single case studies of the 22 articles of Lean, Six Sigma and Lean Six Sigma selected for this paper in that year. Table 7 gives frequency distribution of action research articles. In action research, the journal "Operations Management Research" was the only journal with more than one publication (2 articles). On the other hand, 15 of the 22 journals have only published action research articles. The study is aimed to find out, what is the most used research design applied to theory building and theory verification. Table 8 shows the number of articles in research design vs theory building and theory verification. Table 8 indicates that the single case study research design is equally distributed between theory building and theory verification articles, with 22 publications on each (50 percent). On the other hand, action research reveals to have some preponderance in theory verification articles with 17 of the 23 total of articles (74%). Multiple case studies had 100 percent (06 articles) in theory verification and survey had a similar distribution between theory verification (45 percent) and theory building (55 percent). The only one focus study article is for developing new theory, and panel study had one theory building article and two theory verification articles.

Table 6 - Frequency distribution of single case study articles

Journal Title	2004	2008	2009	2011	2012	2013	2014	2015	2016	Total	Percentage of total case studies	Percentage of case studies in this journal
Quality Engineering			2	1	1	1				5	11,9%	83%
Bmc Health Services Research					1		1	1		3	7,1%	60%
Quality Management in Health Care						1		2		3	7,1%	75%
European Journal of Oncology Nursing							1	1		2	4,8%	100%
European Journal of Operational Research					1				1	2	4,8%	100%
International Journal of Health Care Quality Assurance								1	1	2	4,8%	67%
Production Planning and Control		1					1			2	4,8%	67%
Quality and Reliability Engineering International	1						1			2	4,8%	100%
Bmc Medical Informatics and Decision Making								1		1	2,4%	50%
Bmj Open						1				1	2,4%	100%
Decision Sciences		1								1	2,4%	100%
Herd-Health Environments Research & Design Journal					1					1	2,4%	50%
International Journal of Industrial Engineering			1							1	2,4%	100%
International Journal of Information Management							1			1	2,4%	100%
International Journal of Operations & Production Management				1						1	2,4%	50%
International Journal of Public Sector Management								1		1	2,4%	100%
Investigaciones Europeas De Direccion Y Economia De La Empresa								1		1	2,4%	100%
Journal of Cases on Information Technology					1					1	2,4%	100%
Journal of Medical Systems								1		1	2,4%	100%
Journal of Pediatric Nursing-Nursing Care of Children & Families									1	1	2,4%	100%
Journal of Quality				1						1	2,4%	100%
Journal of the American Medical Directors Association									1	1	2,4%	100%
Leadership in Health Services								1		1	2,4%	100%
Safety Science								1		1	2,4%	100%
Nursing Economics		1								1	2,4%	100%

Source: Elaborated by the author

Table 7 - Frequency distribution of Action Research articles

Journal Title	2006	2009	2010	2011	2012	2013	2014	2015	2016	Total Action Research	Total of Articles per Journal	Percentage
Operations Management Research			1					1		2	2	100%
Annals of Emergency Medicine		1								1	1	100%
Bmc Medical Informatics and Decision Making					1					1	2	50%
Critical Care Medicine					1					1	1	100%
Engineering Management Journal								1		1	1	100%
European Journal of Cancer		1								1	1	100%
European Journal of Internal Medicine					1					1	1	100%
Gynecologic Oncology								1		1	1	100%
Herd-Health Environments Research & Design Journal						1				1	2	50%
Indian Journal of Ophthalmology							1			1	1	100%
Industrial Management & Data Systems								1		1	1	100%
International Journal of Operations & Production Management								1		1	2	50%
Journal of Evaluation in Clinical Practice								1		1	1	100%
Journal of Nursing Management		1								1	1	100%
Journal of Operations Management				1						1	2	50%
Journal of the American College of Surgeons				1						1	1	100%
Journal of Vascular Surgery						1				1	1	100%
Pediatric Critical Care Medicine				1						1	1	100%
Production Planning & Control									1	1	3	33%
Quality Engineering								1		1	6	17%
Supply Chain Management-an International Journal								1		1	1	100%
Total Quality Management & Business Excellence	1									1	3	33%
Total	1	3	1	3	3	2	1	8	1	23	36	64%

Source: Elaborated by the author

Table 8 - Number of articles in research design vs theory building and theory verification

Research Design	Theory Building	Theory Verification	Total
Action Research	6 (17,6%)	17 (34,0%)	23 (27,8%)
Case Study	21 (61,8%)	21 (42,0%)	42 (50,0%)
Focus Group	1 (2,9%)	0 (0%)	1 (1,2%
Multiple Case Study	0 (0%)	6 (12,0%)	6 (7,1%)
Panel Study	1 (2,9%)	2 (4,0%)	3 (3,6%)
Survey	5 (14,7%)	4 (8,0%)	9 (10,7%)
Total	34 (100%)	50 (100%)	84 (100%)

Source: Elaborated by the author

2.4.4 Selection of data collection method

According to Jasti and Kodali (2014) and Flynn (1990), data collection is an essential step for any empirical literature review research. Still according to these authors, the main methods of data collection used in empirical research are: 1) participant's observations (PO); 2) outside observations (OO); 3) interviews (IN); 4) historical archive analysis (HA); and 5) questionnaire survey (QU).

These methods are used in many types of combinations to obtain better results. To facilitate the classification method used in their empirical review of literature papers, Jasti and Kodali (2014) made the follow combinations, suggesting that they are the most commonly combinations of data collection methods used in empirical research: 1) historical archive analysis and questionnaire (IHQ) or 2) interviews, historical archive analysis and participant observation (IHP) or 3) interviews and historical archive analysis (IH), or 4) Interviews and questionnaire (IQ) or 5) Participants observations (PO) and outside observations (OO). This paper will use the same classification of data collection method utilized by the mentioned author and additionally the following data collection combinations, that were found during the research in the analysed papers: 6) Interviews, Outside Observation and Questionnaire (IOQ); 7) Interviews, Historical Archive Analysis, Participant Observation, and Questionnaire (IHPOQ); 8) Participant Observation and Historical Archive Analysis (HPO); 9) Participant Observation, Historical Archive analysis and Questionnaire (HPOQ); Outside Observation, Interviews and Historical Archive Analysis (IHO).

The frequency distribution of data collection methods in empirical research in this research is shown in Table 9. It is observed that the combination between Participant Observation and Historical Archive Analysis (HPO) is the most widely used data collection method (33.3 percent). Interviews, historical archive analysis and participant observation (IHP) is the second most preferred technique

accounting for 14.3 percent of the total. Questionnaires (QU) with 13.1 percent of the total is the most commonly data collection method utilized by itself. Table 10 shows the frequency distribution of data collection methods in research designs. It is observed in Table 10 that action research design has utilized 15 times the "Participant Observation and Historical Archive Analysis" (HPO) combination data collection method. It can also be observed that HPO is the most commonly combination of data collection method used by case studies design.

Table 9 - Frequency distribution of data collection methods in this empirical research

Data collection methods	Number of articles	Percentage
HPO	28	33,3%
IHP	12	14,3%
QU	11	13,1%
IQ	6	7,1%
HPOQ	5	6,0%
IH	5	6,0%
IHO	3	3,6%
IN	3	3,6%
PO and OO	3	3,6%
HA	2	2,4%
IHPOQ	2	2,4%
IHQ	2	2,4%
IOQ	1	1,2%
PO	1	1,2%
Total	84	100%

Source: Elaborated by the author

Table 10 - Frequency distribution of data collection methods in research designs

Designs	HA	HPO	HPOQ	IH	IHO	IHP	IHPOQ	IHQ	IN	IOQ	IQ	PO	PO and OO	QU	Total
Action Research		15	2			3	1	1					1		23
Case Study	2	12	3	3	3	7	1	1	1	1	4	1	2	1	42
Focus Group									1						1
Multiple Case Study		1		2		2			1						6
Panel Study											1			2	3
Survey											1			8	9
Total	2	28	5	5	3	12	2	2	3	1	6	1	3	11	84

Source: Elaborated by the author

2.4.5 Implementation

Soni and Kodali (2011), to analyse empirical research on supply chain management have used a generalized classification scheme for implementation steps. Jasti and Kodali (2014) had used the same approach to analyse empirical research on lean manufacturing. This paper will utilizes the same approach, with some adaptations.

The implementation steps are classified like above:

- country from which the data was collected;
- longitudinal / cross-sectional data;
- qualitative / quantitative / triangulated research method; and
- type of respondents.

2.4.5.1 Country from which the data was collected

Table 11 indicates the country from which the data is collected. Only 15 countries published 100 percent of the empirical researches analysed in this paper. It is interesting to observe that important countries like Australia, China, Germany and France, for example, not appeared in this research. The USA is the number one with 40.5 percent of the total publications. A little surprise is the Netherlands with 15.5 percent of the total publications, followed by Sweden with 11.9 percent.

Table 11 - Frequency of data collection with respect to country

Country	Number of articles	Percentage
USA	34	40,5%
Netherlands	13	15,5%
Sweden	10	11,9%
UK	6	7,1%
India	4	4,8%
Taiwan	4	4,8%
Brazil	2	2,4%
Italy	2	2,4%
Norway	2	2,4%
Spain	2	2,4%
Canada	1	1,2%
Colombia	1	1,2%
Jordan	1	1,2%
Korea	1	1,2%
Malaysia	1	1,2%
Total	84	100,0%

Source: Elaborated by the author

2.4.5.2 Longitudinal / Cross-sectional data

This section analyses the time horizon of the research and discusses on longitudinal data or cross-sectional data. A cross-sectional study collects data at one point in time from a sample selected to represent a larger population. On the other hand, the longitudinal data studies the same group individuals over an extended period of time (RINDFLEISCH et al., 2008). Table 12 shows the frequency of use of longitudinal/cross-sectional data in the papers analysed in this research. It indicates that cross-sectional data (63.1 percent) is predominant in comparison to longitudinal data (36.9 percent). This frequency can be better understand looking to Table 13, which shows the frequency distribution of time horizon in the respective research designs. It is possible to observe that action research brings up the longitudinal data, with 17 publications. In all others researches designs, the cross-sectional data is prominent.

Table 12 - Frequency of use of longitudinal / cross sectional data

Data	Number of articles	Percentage
Cross Sectional data	53	63,1%
Longitudinal	31	36,9%
Total	84	100,0%

Source: Elaborated by the author

Table 13 - Frequency distribution of time horizon in research designs

	Action Research	Case Study	Focus Group	Multiple Case Study	Panel Study	Survey	Total
Cross Sectional data	6	30	1	4	3	9	53
Longitudinal	17	12	0	2	0	0	31
Total Geral	23	42	1	6	3	9	84

Source: Elaborated by the author

2.4.5.3 Qualitative / Quantitative / Triangulated research methods

According to Meredith (1998), the quantitative approach generally makes use of statistical tools and often seeks to provide for the generalization of the results and conclusions reached. In contrast, the focus of qualitative research is to capture the perspective of the individual being studied to understand the environment in which it is inserted and analyse their ideas and opinions. Both the approaches have their strengths and weaknesses. However, they can be more efficient when used

together, i.e. triangulation research method (JOHNSON and CHRISTENSEN, 2010). Table 14 shows the frequency of articles on the basis of qualitative / quantitative / triangulated research method used in the empirical research analysed in this paper. It was a surprise to the authors that triangulation was the most common type of data collection (45.2 percent). Between qualitative and quantitative research, the qualitative is predominant over the quantitative with 35 publications against 11. This shows a qualitative tendency in continuous improvement empirical research in healthcare in number of publications. It is also very important to know the type of data used in theory building and theory verification. Table 15 shows frequency of use of qualitative / quantitative / triangulated data for theory building and theory verification. It is possible to observe that the qualitative data type is prevalent in theory building (47.1 percent), while triangulation appeared with the majority publications in theory verification (52.0 percent).

Table 14 - Frequency of articles on the basis of qualitative / quantitative / triangulated data

Type of data	Number of articles	Percentage
Qualitative	35	41,7%
Quantitative	11	13,1%
Triangulated data	38	45,2%
Total	84	100,0%

Source: Elaborated by the author

Table 15 - Frequency of use of qualitative / quantitative / triangulated data for theory building and theory verification

	Qualitative	Quantitative	Triangulated data	Total
Theory Building	16	6	12	34
	47,1%	17,6%	35,3%	100,0%
Theory Verification	19	5	26	50
	38,0%	10,0%	52,0%	100,0%
Total	35	11	38	84

Source: Elaborated by the author

2.4.5.4 Type of respondents

The type of respondents indicates the function of the individuals who were subject of the research design sample. When type of respondent(s) is missing then it is termed as not mentioned (NA). Table 16 shows the frequency of the type of respondents in lean, six sigma and lean six sigma in healthcare. The majority of the publications analysed not mentioned the type of respondents (44.0

percent), mainly because not all researches had applied interviews or questionnaires as a data collect method. Many researchers preferred data collections through multiple respondents in general (10.7 percent) and physicians and nurses (8.3 percent) instead of single type respondents. When this study considered single respondents, it was found that many of the researchers collected data from the managers (9.5 percent) and from the employees (9.5 percent) to get effective information to their empirical analysis. Besides this, few researchers have also solicited the opinion of executives, directors and CEOs (top-level management).

Table 16 - Frequency of type of respondents

Type of respondents	Number of articles	Percentage
Multiples	9	10,7%
Employees	8	9,5%
Managers	8	9,5%
Physicians and nurses	7	8,3%
Patients	5	6,0%
Physicians	2	2,4%
Lean Leaders	2	2,4%
Nurses	2	2,4%
CEO/Directors	2	2,4%
Medicine Residents	1	1,2%
Participants	1	1,2%
NA	37	44,0%
Total	84	100,0%

Source: Elaborated by the author

2.4.6 Data analysis techniques (DATs)

According to Flynn et al. (1990) and Jasti and Kodali (2014), quantitative empirical data needs to be analyzed looking for generalization, in such way to elaborate new hypothesis or to validate an existing theory. According to Montoya-Weiss and Calantone (1994) the DATs could be classified in four different groups widely used in empirical research as shown in Table 17. Table 18 shows the frequency of the use of empirical data analysis techniques in lean, six sigma and lean six sigma in healthcare empirical research, according to these suggested groups. The contents of the table not only show the quantitative DAT's but also consist of qualitative analysis. In total, 35 articles have used qualitative analysis techniques to analyse their data (41.7 percent), becoming the most chosen DAT. The descriptive statistics have the highest number (19.0 percent) of the quantitative DAT published in the articles, closely followed by Tests of differences / similarities (17.9 percent).

Table 17 - List of widely used data analysis techniques with methods in empirical research

Data analysis techniques	Methods
Descriptive statistics	Means, frequencies and proportions
Tests of differences / similarities	t-test, binominal test, analysis of variance (ANOVA), multiple ANOVA (MANOVA), and w2 test
Measures of dimensionalities	Factor analysis, cluster analysis and discriminate analysis
Statistical interpretation of parameters	Correlation analysis, canonical correlation analysis, regression analysis, path analysis and structural equation models (SEMs)

Source: Adapted from Jasti and Kodali (2014)

Table 18 - Frequency of data analysis techniques in lean, six sigma and lean six sigma empirical research in healthcare

Data analysis techniques	Number of articles	Percentage
Qualitative analysis	35	41,7%
Descriptive statistics	16	19,0%
Tests of differences / similarities	15	17,9%
Statical interpretation	9	10,7%
Combination	8	9,5%
Measures of dimensionalies	1	1,2%
Total	84	100,0%

Source: Elaborated by the author

2.5 Finding the gaps for future empirical research in lean, six sigma and lean six sigma in healthcare

After the analysis performed in the last section, an important contribution of this paper is to identify possible gaps in the literature of empirical publications in lean, six sigma and lean six sigma in healthcare. To this end, this paper also performs 5 types of analysis in the reviewed papers, as follows:

- area / department of study;
- elements / techniques of lean, six sigma and lean six sigma;
- continuous improvement methodology;
- barriers / lessons learned;
- sustainability aspects.

2.5.1 Area / department of study

Despite the fact that numerous empirical articles are being published on lean, six sigma and lean six sigma in hospitals, it is not known where specifically these works are being carried out. To investigate where there is a concentration of researches in a particular area of the institution and if there is any area with little or no research developed, we construct the analysis shown in Table 19. When the area is not cited then it is termed as not mentioned (NA). The most widely area explored in lean, six sigma, and lean six sigma in healthcare is the Hospital Ward with 12 publications (14.3 percent), followed by the Emergency Department and Hospital wide, both with 9 publications each (10.7 percent each). It was also verified that the lean initiatives also tend to have a rather narrow scope, which contradicts the holistic view defended for many authors in the literature. Some areas have very few publications, like the Intensive Care Unit (ICU), Purchasing and Central of Material and Sterilization, with two, one and one publications respectively. Some areas are not even mentioned, like for example the Billing area, the Nutrition area and the Hospitality area, which are great opportunities of future empirical studies. All researches were conducted in hospitals, clinics and laboratories. Therefore, another important observation is that not a single study was conducted in a health insurance organization, for example, which is another opportunity for future researches.

Table 19 - Hospital area versus number of articles

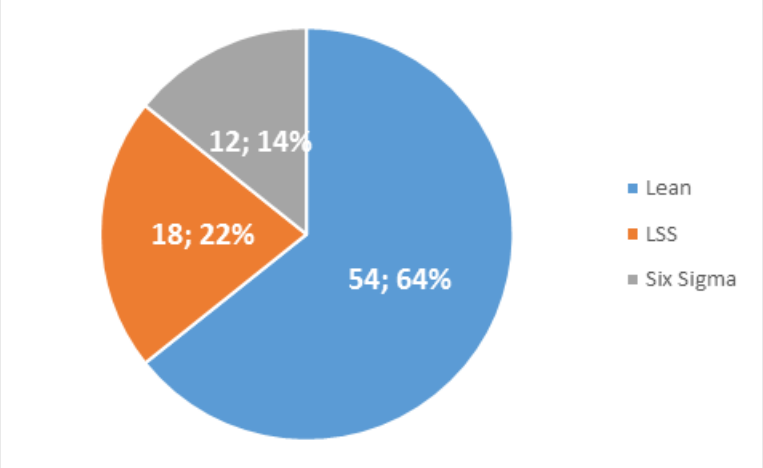
Hospital area	Number of articles	Percentage
Ward	12	14,3%
Emergency department	9	10,7%
Hospital Wide	9	10,7%
Outpatient department	8	9,5%
Oncology	6	7,1%
Pharmacy	5	6,0%
Operation theatre	4	4,8%
Laboratory	4	4,8%
Mental health unit	2	2,4%
Home Care	2	2,4%
Intensive Care Unit (ICU)	2	2,4%
Purchasing	1	1,2%
Infusion	1	1,2%
Information Technology	1	1,2%
Central of Material and Sterilization (CMS)	1	1,2%
NA	17	20,2%
Total	84	100%

Source: Elaborated by the author

2.5.2 Elements / techniques of lean, six sigma and lean six sigma

Before analyse the elements and techniques, it is important to know the frequency of distribution on lean, six sigma and lean six sigma in healthcare in the empirical researches studied, as shown in Figure 7. Lean is predominant among six sigma and lean six sigma with 54 publications (64.0 percent). Lean six sigma appears in the second place with 18 publications (22.0 percent), followed by Six sigma with 12 publications (14.0 percent). It is important to know that, because it influences the number of times each continuous improvement elements was cited shown in Table 20. The most used techniques were the Value Stream Mapping (VSM), Standardization of Work and Visual Management, with 34, 18 and 16 applications, respectively. Interesting to say that VSM was many times cited, but any article has described a framework or a set of steps for constructing the future situation.

Figure 7 - Distribution of lean, six sigma and lean six sigma in the empirical papers studied



Source: Elaborated by the author

Despite the fact that Visual Management has been cited many times too, there is any empirical study that explore the details and how the Visual Management was projected, the aspect of the boards and their effects in creating a continuous improvement culture.

Kanban, another knowledge lean technique was cited only four times, but not a single empirical study describes how it was implemented and the differences between the calculations for dimensioning a hospital inventory levels against a manufacturing one.

Cell, Single Minute Exchange of Die (SMED) and Poka-Yoke were cited only one time each, what is a good opportunity to be explored in future empirical researches in this field.

Table 20 - The most used CI techniques

Elements/techniques of lean, six sigma and lean six sigma	Times cited	Percentage
VSM	34	23%
Standardization of Work	18	12%
Visual Management	16	11%
Cause-and-Effect Diagram	10	7%
Kaizen Event	9	6%
Process mapping	6	4%
5S	5	3%
Kanban	4	3%
Control Chart	4	3%
SIPOC	4	3%
Audit checklists	4	3%
Continuous Flow	3	2%
Pareto	3	2%
Information Flow Map	3	2%
Performance measurement	3	2%
A3	3	2%
Gemba Walk	3	2%
Flowchart	3	2%
FMEA	2	1%
Production leveling	2	1%
Workload	2	1%
Simulation	2	1%
Spaguetti diagram	2	1%
Re-layout	2	1%
Cell	1	1%
5 Whys	1	1%
SMED	1	1%
Poka Yoke	1	1%
Total	151	100%

Source: Elaborated by the author

2.5.3 Continuous improvement methodology

The application of process improvement techniques has increased in popularity especially for healthcare, and to implement these techniques, researchers in generally apply some type of conducting methodology (DELLIFRAINE et al., 2010). The most known methodology are the Define, Measure, Analyse, Improve and Control (DMAIC) and the Plan Do Check and Act (PDCA). This study verified if the researches have really applied some type of methodology to conduct their change initiative, and with how frequency depending on the approach they have followed. Table 21 shows that the majority (66.7 percent) of the works have not cited any continuous improvement methodology to conduct their implementations. DMAIC seems to be predominant over PDCA with 23 publications over only four publications, respectively. A new methodology was found, called DEAPS, with one publication. Only the perception that Table 21 brings is not sufficient to understand the whole context. It is also necessary

to see separately which methodology is applied when the article is on lean, or six sigma or lean six sigma. Table 22 brings this information. It is possible to observe that Lean is the continuous improvement approach with the largest number of articles without any methodology of conducting (48 of the 54 lean articles not described any methodology). The four PDCA articles are specifically on lean. DMAIC naturally is concentred in Six Sigma and Lean Six Sigma articles.

Table 21 - Frequency of the continuous improvement methodology applied

Methodology	Number of articles	Percentage
DMAIC	23	27,4%
PDCA	4	4,8%
DEAPS	1	1,2%
Not described	56	66,7%
Total Geral	84	100%

Source: Elaborated by the author

Table 22 - Frequency of the continuous improvement methodology applied in respect of the approach

	Lean	LSS	Six Sigma	Total
DEAPS	0	1	0	1
DMAIC	2	14	7	23
PDCA	4	0	0	4
Not described	48	3	5	56
Total	54	18	12	84

Source: Elaborated by the author

2.5.4 Barriers / lessons learned

Because of the complexity of healthcare environments, application of continuous improvement approaches like lean, six sigma and lean six sigma may encounter unique challenges in comparison with others industries. To elucidate this point, the authors' exanimated the selected articles in order to evaluate if they are bringing relevant information about barriers and lessons learned in each phase of the implementation, divided in: i) pre-implementation; ii) implementation and; iii) post implementation.

Table 23 shows the gap between the articles that describe and the articles that do not describe some barrier or lesson learned in the respectively phase of implementation. Just 25.4% of the articles

have some citation about barriers or lessons on all phases of implementation. The phase with the lowest number of articles describing the barriers is the implementation phase, with 17.9%. It is also interesting to let the lector know that only six papers have described barriers or lessons learned in all of the three implementations phases. It is a great opportunity for future researches to explore this gap.

Physicians were cited as being the most resistant professionals in the improvement process. Other barriers cited were: i) lack of investment in a team focused on making improvements; ii) lack of participation of the hospital board during the process of change; iii) pressure for quick results in detriment of long-term thinking and culture of continuous improvement; iv) top down decisions; v) distrust of techniques born and applied in manufacturing.

Table 23 - Articles that describe and articles that do not describe some barrier or lesson learned in the respectively phase of implementation

	Articles that described	Not described	Total
Barriers / lessons learned during the **pre** implementation phase	29	55	84
	34,5%	65,5%	100,0%
Barriers / lessons learned during the **implementation** phase	15	69	84
	17,9%	82,1%	100,0%
Barriers / lessons learned during the **post** implementation phase	20	64	84
	23,8%	76,2%	100,0%
Total	**64**	**188**	**252**
Percentage	**25,4%**	**74,6%**	**100,0%**

Source: Elaborated by the author

2.5.5 Sustainability aspects

Most of the organizations that were studied in this article have used tools to achieve isolated "pockets of best practice" rather than trying to see the whole system as a basis for process change, reinforcing what cited by Souza (2009) and Radnor et al. (2010). Tools for process improvement are important, but their final effectiveness depends on the ability to develop the underlying culture in problem solving to support growth and continuous improvement (HINES, 2004). In this context, the authors' judged very important to examine how the sustainability aspects are being applied in the healthcare environments. Table 24 shows that 71 (84.5 percent) of the empirical articles published about lean, six sigma and lean six sigma in healthcare environments even not mentioned any sustainability aspect of the improvement realized. Ten articles (11.9 percent) describe some sustainability aspect and try to show how is the situation of the organization between 1 and 12 months

after the improvement. Another three articles (3.6 percent) describe the improvement sustainability between 12 and 24 months. No article have described the situation after 24 months of the implementation phase. It is also important to say that no article have described how they create a continuous improvement culture. Again, the articles that described sustainability aspects stayed only in the field of tools. These are such good opportunities for future empirical works to explore.

Table 24 - Time after implementation

Time after implementation	Number of articles	Percentage
Between 1 and 12 months	10	11,9%
Between 12 and 24 months	3	3,6%
Not Mentioned	71	84,5%
Total Geral	**84**	**100,0%**

Source: Elaborated by the author

2.6 Summary of the results and conclusions

The authors of this paper do not know until now the existence of an empirical systematic review of the literature on the implementation of Lean, Six Sigma and Lean Six Sigma in healthcare. There is, accordingly, a need for thorough review of the empirical literature in this field to find their present situation and propose future directions consistent with the needs of professionals and academics. The authors have included a large sample size of the articles as well as the number of journals (84 articles selected in 58 journals) to compose the final list of works considered in the literature review. The field of continuous improvement in healthcare is growing very fast and regularly new articles are coming up on the subject.

The systematic literature review conducted resulted in several key findings that suggest there are still certain dark and unexplored themes. There is an immediate need for empirical research in this field that not only describe what tools were applied and what were the results obtained, but also to elucidate how the implementations were conducted.

The empirical research is on increasing trend in the field of lean, lean six sigma and lean six sigma in healthcare. There is evidence that approximately the number of empirical research articles published between 2010 and 2016 represent 85 percent of the amount of articles considered in this paper, while only 15 percent are articles published between 2004 and 2010. Both theory building and

theory verification are popular among researchers. One of the significant finding is that theory building and theory verification are having similar number of articles and both are advancing promisingly in the field of empirical research. In general, 60 percent of the total selected articles for this paper are theory verification, while 40 percent are theory building.

According to the present study, it is observed that the most popular research design was the Single Case Study with 42 publications, corresponding to 50 percent of the 84 selected articles. Jasti and Kodali, (2014) has also observed the Single Case Study as the most popular empirical research design in the lean manufacturing field. This paper also indicates that the single case study research design is equally distributed between theory building and theory verification articles, with 22 publications on each (50 percent).

The second most popular research design in this field is the Action Research design, which contains 27.4 percent (23 articles) of the total empirical articles (84 articles). Jasti and Kodali (2014), for example, not even cites this research design in his empirical review of the literature about lean manufacturing. Action research reveals to have some preponderance in theory verification articles with 17 of the 23 total of articles (74 percent). Therefore, there is a need of developing theory through the process of action research design instead of conceptual nature.

Many of the researchers were getting information in different forms instead of depending on single source of data collection. It is observed that the combination between Participant Observation and Historical Archive Analysis (HPO) is the most widely used data collection methods (33.3 percent), different of the research of Jasti and Kodali (2014) that found that the majority of data in lean manufacturing empirical researches were collected using questionnaire method, which is the tool mostly used in survey research designs.

Only 15 countries published 100.0 percent of the empirical researches analysed in this paper. It is interesting to observe that important countries like Australia, China, Germany and France, for example, not appeared in this research, what is a great opportunity for future researches in these countries as well. The contributions of empirical articles from developing countries are significantly smaller than from the developed ones. The USA, the Netherlands, Sweden and United Kingdom, together, represent 75 percent of the 84 empirical articles analysed in this paper. So, there is a need to bring the researchers across the globe on a single platform to get better results.

The sample sizes were generally very small. The actual scenario is highlighted by the fact that 71 percent of the researches articles were based on samples sizes smaller than a hundred. It shows the tendency of researches to collect data from smaller samples sizes. Malhotra and Grover (1998) reported that around 30 percent of the operations management survey studies suffered from statistical conclusion errors due to small sample sizes. Accordingly, it would be better if researchers tried to get

more responses from respondents. It is another opportunity for be explored in future empirical researches in this field.

In general, the studies are tending to be cross-sectional data instead of longitudinal data collection, with 63.1 percent of publications. It is possible to observe that action research design brings up the longitudinal data, with 17 of the total 31 longitudinal data publications (54.8 percent). In all others researches designs, the cross-sectional data is prominent. According to Bhasin and Burcher (2006), continuous improvement methodologies requires long-term commitment to achieve better results. Therefore, others researches designs should give equal priority to the longitudinal data collection method. According to Jasti and Kodali (2014), the longitudinal data could provide better analysis of the system than cross-sectional data study because it has a longer period of research.

The triangulation was the most common type of data collection (45.2 percent), what is a good surprise, since many authors like Hussey (1997) emphasis the importance of triangulated data to overcome potential bias of single method approaches in data collection methods.

Qualitative analysis techniques is the most chosen data analysis technique. Analysing only the quantitative data analysis techniques, the most popular is the statistical descriptive of parameters. As an opportunity for future works, researchers could perform more complex quantitative data analysis.

Lean initiatives represent 86.0 percent of the total articles and they tend to have a rather narrow scope, which contradicts the holistic view defended for many authors in the literature, like Rich and Piercy (2013), Souza (2009), Radnor et al. (2012) and Graban (2011). Future works on lean healthcare could explore the holistic view of the institution, instead of focusing on particular areas.

Some hospital areas have very few publications, like the Intensive Care Unit (ICU), Purchasing, and the Central of Material and Sterilization. Some areas are not even mentioned, like the Billing area, the Nutrition area and the Hospitality area, which are great opportunities of future empirical studies.

The most used continuous improvement techniques were the Value Stream Mapping (VSM), Standardization of Work and Visual Management. Re-layout, Cell, Single Minute Exchange of Die (SMED) and Poka-Yoke were the less cited, what is a good opportunity to be explored in future empirical researches in this field.

VSM was many times cited, but any article described a framework or a set of steps for constructing the future situation. There is a clear opportunity here to verify if there is any framework describing the steps for constructing the future situation in a healthcare value stream and to test the framework in the practice trough an empirical research.

Despite the fact that Visual Management has been cited many times, there is no single empirical study that explore the details and how the Visual Management was projected, the aspect of the boards and their effects in creating a continuous improvement culture.

Kanban, another known lean technique has been cited only four times, but not a single empirical study have described how was the implementation and the differences between the calculations for dimensioning a hospital inventory levels against a manufacturing one.

The majority (66.7 percent) of the works have not cited any continuous improvement methodology to conduct their implementations, and lean is the continuous improvement approach with the largest number of articles without any methodology of conducting, which is another good opportunity to be explored in future lean healthcare works. DMAIC is significantly larger applied than PDCA. The four PDCA articles are specifically on lean. DMAIC naturally is concentred in Six Sigma and Lean Six Sigma articles.

A very few papers have described barriers or lessons learned in the pre-implementation phase, implementation phase and post implementation phase. Furthermore, any article has focused on describe in detail the specific barriers for improvement efforts in the healthcare sector, which are not found in other sectors/segments. It is a great opportunity for future researches to explore this gap.

The great majority of the empirical articles published about lean, six sigma and lean six sigma in healthcare environments has even not mentioned any sustainability aspect of the improvement realized. The few articles that describe some sustainability aspect not described the situation after 24 months of the improvement implementation. It is a very interesting opportunity for future works to describe the differences between improvement efforts that failure and the ones that have success after 24 months of implementation and the key success factors.

Any empirical article studied in this paper have described how a healthcare organization can create a continuous improvement culture. The few articles that described sustainability aspects stayed only in the field of tools. It is a good opportunity for future empirical works to describe how the continuous improvement culture can be create in the practice.

Other opportunity, in terms of sustainability, is to verify if there is any framework that englobes the main tools and steps for its application in healthcare environments, as well as the steps for construct a continuous improvement culture in the organization.

This study is the first attempt to review the articles in this explicating field and provided an in-depth and integrated review of articles. Through this present study many issues are addressed which have not been covered properly in the past such as unexploited areas of empirical research in continuous improvement in healthcare. It is hoped that the study will set an impulse to promote further research and exploration in empirical research in this field. Overall, the study shows that there is substantial advancement in this field, however, there is further need to carry out research in this direction and to throw light on certain dark and unexplored themes.

This review, however, has certain limitations that should be considered. This study sought only lean and six sigma related work, considered as the main methods of continuous improvement. However, future research can be more comprehensive and bring a wider range of publications. This research shows that there seems to be a consensus about the potential and the results of continuous improvement techniques in healthcare. It is surprising, however, that any empirical paper points out failures or negative results of its implementation. For this reason, it remains a challenge for academics and practitioners to evaluate lean and six sigma under a more critical perspective. Another limitation of this study is that only two data-basis were searched for article collection.

It is hoped that the study will set an impulse to promote further research and exploration in empirical research in this field. The result of the present study will help researchers to direct their efforts toward a systematic approach for carrying out empirical research in continuous improvement in healthcare.

Chapter 3

A COMPARATIVE CASE STUDY OF SUSTAINING LEAN THINKING IN HEALTHCARE

Abstract

Many hospitals have achieved high levels of lean performance only to lose it later on. These hospitals, which often achieved excellent results, neglected some specific aspects of sustaining lean improvements in their environments, and failed to maintain what was implemented. This research develops a theoretical understanding of how organizations can sustain lean in healthcare. Through the analysis of the literature, it was possible to compile 22 main success factors of lean sustainability in hospitals through three main pillars: people, method and tools. A comparative case study provides evidence to confirm these 22 theoretical propositions, and also to add other 5 new propositions to the framework. The proposed framework allows hospitals to conduct a structured process of change, with all the foundation needed to succeed and sustain the lean journey in the long-term. It differs from previous studies by integrating literature streams that have been previously disconnected and by specifying the components of lean healthcare sustainability. These new insights are revealed by studying hospitals after minimum 18 months of lean implementation and comparing the ones that have achieved a high level of lean sustainability with those that do not. To the best of our knowledge, this article is the first to attempt to bring together the key factors that influence hospitals to sustain lean improvements in the long term.

This research found evidence that external factors to the three pillars may also interfere to facilitate or difficult hospitals to achieve sustainability in their lean implementations. They are called “success variables moderators” and they are intrinsically linked to the organizational characteristics of each hospital. The variables “type of administration and financial objective” and “accreditation” have proved to influence the hospital to achieve success in its lean implementations in the long term.

Another interesting conclusion that can be drawn is that although it is notorious knowledge, several points brought by the theoretical framework proved to be difficult to implement and the hospitals are failing to implement the basics.

Keywords: Lean Healthcare, Lean Hospital, Lean Sustainability, Continuous improvement, Case Study.

3.1 Introduction

The essence of an operation is to add value during the transformation of a product or service (STEVENSON, 2011). Still according to Stevenson (2011), operations management is the same as “managing the system or processes that produce goods or services".

A key aspect of operations management is the management of processes that do add value. In this context, Lean has a very important role, precisely because it has a set of principles, techniques and tools that help companies to eliminate wastes in their processes, in such a way to deliver the greatest possible value to their clients.

Rother and Shook (2003) define Lean as "a set of practices aimed in eliminating waste and creating value”, always looking for reduce costs, improve performance, increase productivity and profitability to organizations. Over the past few decades, scholars have extensively studied how organizations can obtain a competitive advantage through a better operations performance linked to lean initiatives (BHASIN, 2011a; HINES et al., 2008; LIKER, 2004; ShOOK, 2010; WOMACK et al., 2005).

During the past 15 years, a growing interest has been given in the healthcare sector to the methods used in the industrial sector, in terms of process reorganization to improve efficiency. In this context, Seidl and Newhouse (2012) state that Lean has been the most popular method of Continuous Improvement implemented in the healthcare sector in the last 10 years. According to a survey conducted by the American Society for Quality in 2009, 53 percent of the US hospitals apply some type of lean management initiative (HENKE, 2009). The application of lean production concepts in hospitals seeks to increase the quality of assistance to patients, optimization of information and materials flows, supporting the collaborators and physicians to eliminate wastes and allow them to focus on providing care (GRABAN, 2011). Lean projects in healthcare have become widespread. Brandao de Souza (2009) show the majority applications have occurred in the USA (57%), with the UK growing at a fast pace (29%), followed by Australia at 4%. Cases such as the Virginia Mason Medical Center in Seattle (USA), the Flinders Hospital in Australia and the Royal Bolton NHS Foundation Trust in the UK have become celebrated examples of Lean implementation in healthcare settings over the world. In these and in other cases, there is growing evidence of the potential impact on quality, cost, time, and satisfaction of both staff and customers. Recently, in their Lean healthcare literature review, Costa et al. (2015) indicate that reducing patient lead times, reducing costs, and making financial improvements were the primary factors that motivated lean healthcare implementation.

The application of lean in healthcare has been broadly reported in the modern literature (see for example NABELSI and GAGNON, 2016; LI, PAPADOPOULOS and ZHANG, 2016; CARDOEN, BELIËN and VANHOUCKE, 2015; HICKS et al., 2015). On the other hand, however, very little is known about how to sustain the quality of the lean implementations in the long term (BHASIN, 2012a, HINES et al., 2008). In the past few years, product recalls from the well-known quality leader Toyota reflect the difficulty of sustaining quality performance (OHNSMAN et al., 2010; VALASIC, 2010). Some authors estimate that less than 10 percent of the Lean implementations in all kinds of industries were successful in England (HINES et al., 2008, SIM and RODGERS, 2009, ATKINSON, 2010, BHASIN, 2011b; BHASIN, 2012a). In the literature, there is a consistent agreement among authors that at least two-thirds of change initiatives continue to fail (GRAHAM, 1991, ATKINSON 2010, SIRKIN et al., 2005, BHASIN, 2011b, BHASIN, 2012a). Because of the complexity of healthcare environments, the application of continuous improvement approaches as lean thinking in this sector may encounter unique challenges in comparison with others industries. In this context, as seen in the systematic review of this thesis, 84.5 percent of the empirical articles published about lean, six sigma and lean six sigma in healthcare environments even not mentioned any sustainability aspect of the improvement realized and any of them have described the situation after 24 months of the beginning of the program. For D'Andreamatteo et al. (2015), when analysing lean healthcare, the implementation process itself and the sustainability remain key and under investigated issues. Indeed, many researchers assert that the literature in lean healthcare is specifically built on positive cases (see HOLDEN, 2011, MAZZOCATO et al., 2012). Dickson et al. (2009) claim that a few cases in the literature demonstrated impacts other than positive. These authors also agree that it would be important to learn from unsuccessful initiatives and, generally, to apply a more critical view to evaluate Lean in healthcare. After this analysis, it is possible to conclude that a realistic framework with strategies to sustain lean in healthcare is necessary to guide both practitioners and academics.

This paper looks for filling this gap by examining the following research question: how do hospitals sustain lean initiatives in their operations? To investigate this question, we conduct a comparative case analysis that iterates between the literature and the case data to develop a theory on lean healthcare sustainability. The analysis draws on literature from experiences in: i) lean sustainability (LIKER, 2004; BATEMAN, 2005; RENTES, 2000; BHASIN, 2012b; KOVACHEVA, 2010; DOMBROWSKI and MIELKA, 2013) and ii) lean sustainability in healthcare (Hung et al., 2015; NIEMEIJER et al., 2011; GLASGOW, 2010; BRANDAO DE SOUZA and PIDD, 2011; GRABAN, 2011; POKSINSKA et al., 2013; TOUSSAINT and BERRY, 2013; MURPHREE and DAIGLE, 2011; BRANDAO DE SOUZA and PIDD, 2008a).

This study contributes to the literature by organizing concepts previously disconnected in a theoretical framework to sustain lean initiatives in the healthcare sector, testing these concepts in the practice and complementing it with new propositions. The comparative case analysis centralized literature streams that have been previously disconnected. What we offer is an evolutionary dynamic perspective of sustaining lean in healthcare, which has not been fully considered in the past. The rest of the paper has the following organization: Section 2 gives the conceptual background for the literature streams related to this research. Section 3 describes the case study research methodology, Section 4 presents the findings and the proposed framework. Finally, Section 5 discusses the implications and conclusions.

3.2 Conceptual background

Concepts from several different theories help to build the theoretical framework. Each theory comes from a different literature stream and offers a unique perspective on how to sustain lean implementations. In addition, prior research has not integrated these theories. The following sections give an overview of each theoretical perspective.

3.2.1 Lean Sustainability

Although many companies in several industries have achieved significant benefits from the adoption of the Lean Thinking concepts, many others have been unsuccessful in implementing isolated parts of a lean system without understanding the whole (WOMACK et al., 1990). According to different authors (KAYE and ANDERSON, 1999; BATEMAN and DAVID, 2002), sustaining the gains obtained proved to be a difficult task and, eventually, the initial improvements may be affected and reverted back to their original level. The failure rate of initiatives implementing Lean programs varies from 66% to 90% of cases (GRAHAM, 1991, Walker, 1992, SIRKIN et al., 2005, BICHENO and HOLWEG, 2009, ATKINSON, 2010 BHASIN, 2011b; SAURIN et al., 2011; BHASIN, 2012a).

According to Liker (2004), a lean production system is much more than a continuous flow, a Just in Time or a production pulled through a kanban system. For many times, the implementation was totally focused on tools, neglecting the human aspects of the lean approach. Process improvement tools are important, but their ultimate effectiveness depends on the ability to develop the underlying culture in support growth and continuous improvement. "*If were not the people who understand the culture*

behind this system, there would be no operational excellence and continuous improvement culture at Toyota" (HOLWEG, p.12, 2001). Understand the lean thinking as more than a set of mechanistic tools and techniques means considering the dimensions motivation, empowerment and respect for people. Indeed, these elements are essential for the long-term sustainability of any lean program, independently of the sector (HINES, HOLWEG and RICH 2004).

3.2.1.1 Critical barriers to failure

Although the failure of continuous improvement programs can be attributed to several factors, several authors consider that some fundamental causes are evident. As examples, we can see i) lack of a continuous improvement culture; ii) lack of knowledge of change management lessons; and iii) lack of a well-structured Method of project conducting (BICHENO and HOLWEG, 2009; ATKINSON, 2010; BHASIN, 2011-a; BHASIN, 2011-b; SAURIN et al., 2011; BHASIN, 2012).

Veiga (2009) complemented these authors, describing in details some of these failure possible causes:

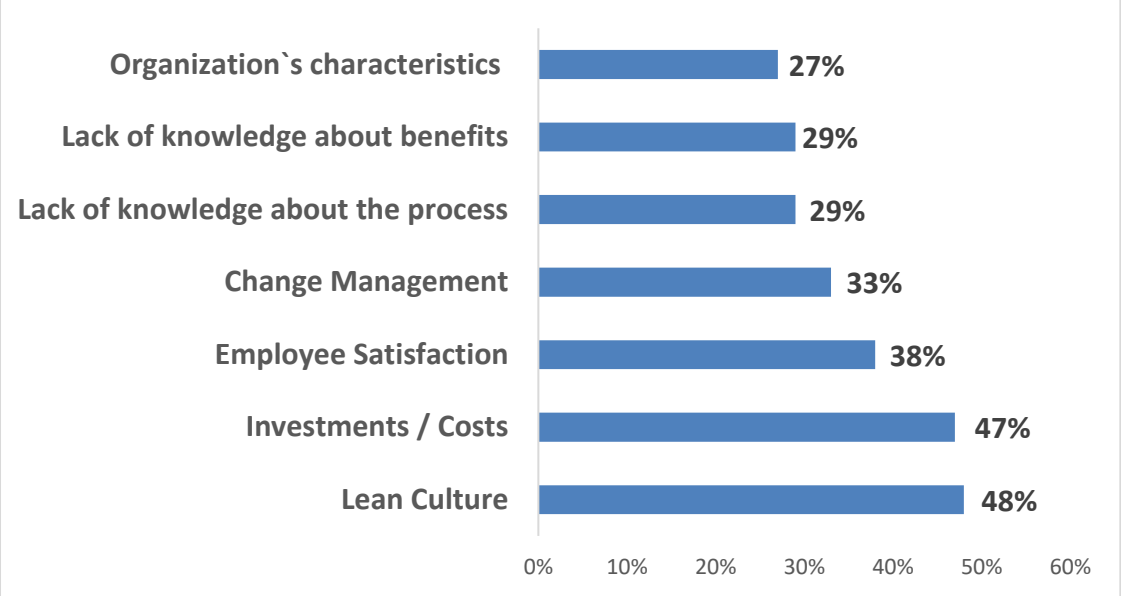
- There is no formal statement from who the improvement team is;
- There is no well-defined scope of improvements to be implemented;
- In many cases, there is no method to follow;
- The team is not properly trained;
- There is no systematization of monitoring the progress of the project; and
- The key people involved cannot focus on the project because of the extensive routine work and daily problems.

Deloitte and Touche (2002) applied a survey to 100 organizations, and obtained the results presented in Figure 8 on the main barriers to successful lean implementation. Similar to Deloitte and Touche (2002) survey, the Lean Institute Enterprise also conducted two surveys to assess the obstacles to organizational transformation through lean implementation. The results of both surveys are illustrated in Figure 9 and are similar. They bring as the main barriers to the success of lean implementations aspects such as: i) abandoning old habits of work; (ii) fails to create a lean culture; iii) lack of knowledge about lean concepts, with little training; iv) necessary financial investment; v) resistance of the middle management; and vi) employees' dissatisfaction with another activity incorporated into their routine.

It is possible to perceive that many of the barriers to lean implantation observed in these surveys are directly related to people. The people are who interpret and apply the aspects of the organizational culture, people are who resist to change, and people are who is capable to be engaged and committed

to transform the old ways of doing. To avoid that people become the main cause of failure, the lean program should provide a method that is able to guide people at all stages of implementation, involving them, capacitating them, empowering them, and directing them toward results that motivate them. In the same way, Heller et al. (1998) and Gravenhorst et al. (2003) suggested that among the many barriers to organizational change, if not all, the vast majority of barriers are directly or indirectly related to aspects of the people in the organization. According to Rentes (2000), the success of a lean transformation depends on the people involved in the change process because people will be motivated and will make more efforts as the results of the process appear, and they can also become discouraged if the results are not positive.

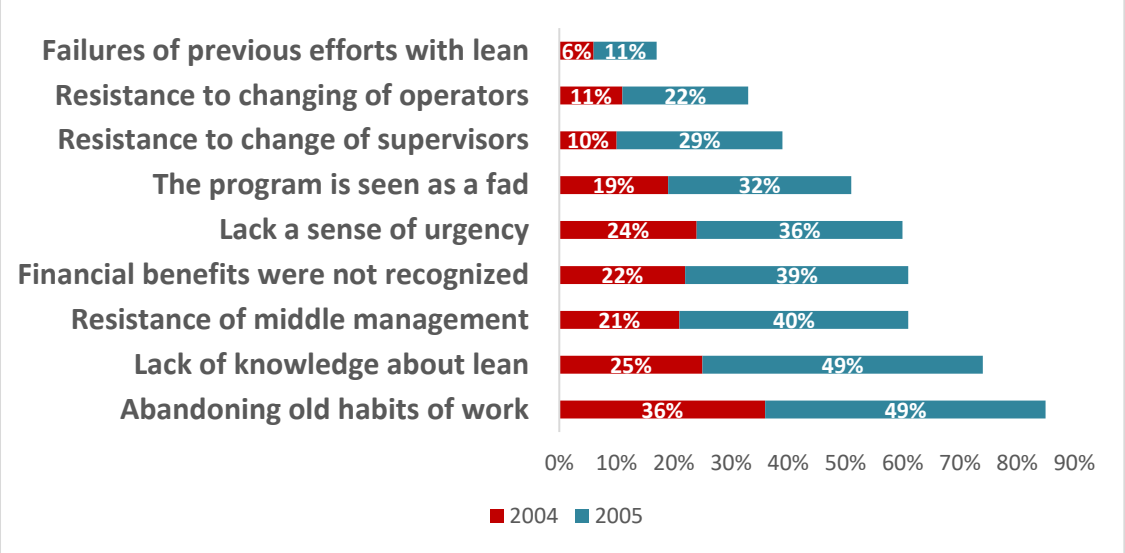
Figure 8 - Barriers to successful lean implementation



Source: Adapted from Delloite and Touche (2002)

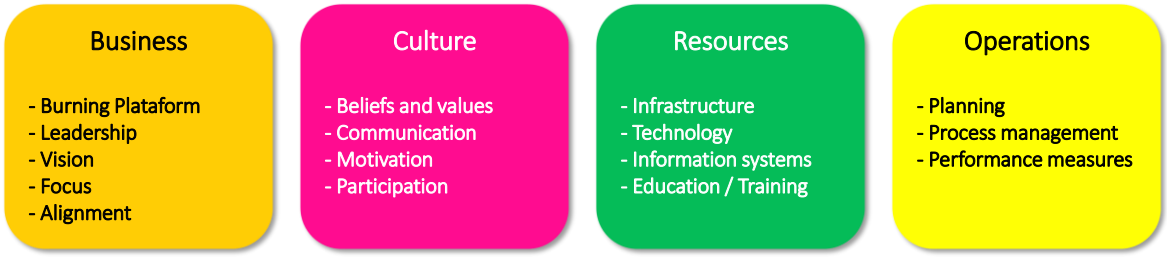
Rentes (2000) makes an accurate compilation of the main barriers that occur in the process of organizational transformation. This compilation is based on the conceptual framework of Sink et al. (1995), including fronts such as training, planning, performance measures, culture, motivation, infrastructure, communication, politics and technology, with the addition of seven fronts: burning platform, vision, focus, alignment, participation, process management and information systems. This author also organizes these “barriers fronts” of the change process in four dimensions, as shown in Figure 10. Table 25, in turn, compiles the 38 barriers listed in these four dimensions.

Figure 9 - Main obstacles to the success of the lean journey



Source: Adapted from the Lean Enterprise Institute Survey (2004 - 2005)

Figure 10 - Dimensions and analysis fronts barriers to organizational change.



Source: adapted from Rentes (2000)

The current challenge for the lean movement in the world, as Womack and Jones (2010) shows, is to move beyond the vision of lean tools to the era of lean management. In this context, that would be a grateful contribution for the literature a framework to guide researchers and professionals in applying lean with a systematic method which provides the boundary conditions necessary to avoid the barriers already known.

3.2.1.2 Critical factors of success

Among the 50 companies audited in the UK, Bhasin (2012b) identified five companies that had the best sustainability results on lean programs. The author was able to determine common characteristics only for these five companies. These common features can be differential to success in lean implementation and reveal the fact that a well-structured method can drive people in direction to create a lean culture and in consequence to have success in a lean journey. Interestingly, while tools

and techniques are vital to the success of Lean Manufacturing, the correlation of tools and techniques with success in Lean Journey was not particularly significant (BHASIN, 2012b). When comparing different organizational units executing the same projects, Matthiesen and Johansen (2008) also identified the strong influence of the organizational culture on the results of a continuous improvement project.

Table 25 - Barriers to the Change Process.

Dimension	Front	# Barriers
Business	Burnig Plataform	1 Not clear identification of a burning platform
		2 Excessive complacency
	Leadership	3 Fail to create leadership for the process
	Vision	4 Lack of a clear vision for the process of change
	Focus	5 Failure to identify the focus processes and the root problems
		6 Guidance / focus failure on customer needs
		7 Declare victory too early
	Alignmrnent	8 Fail to align goals
		9 Fail to create short-term goals
Culture	Beliefs and values	10 Underestimate current beliefs and values
		11 Overvalue existing beliefs and values
		12 Neglecting the anchoring of changes in culture
	Communication	13 Vision and Burning Platform Communication Failure
		14 Neglecting communication in the process of change
		15 Do not reap 360 degree feedback
		16 Failure to communicate the results
	Motivation	17 Absence of a clear reward system
		18 Allow obstacles to block vision
		19 Lack of empowerment to change agents and staff
	Participation	20 Driving the transformation only topdown
		21 Ignore the fears of the people involved in the process
Resources	Infrastructure	22 Confusion between the transformation and organizational structure
		23 Failure to adapt the organizational structure to change
		24 Do not create time availability on people's agenda
		25 Failure to allocate people to the transformation team
	Technology	26 Underestimating the importance of new technologies
		27 Failure to match need and technology
	Information systems	28 Failure to obtain relevant data to analyse the current situation
	Education / Training	29 Lack of process knowledge and tools
		30 Failure to share knowledge
		31 Training failure on new technologies
Operations	Planning	32 No transfer schedule with target conditions and milestones
		33 Failure to choose the time to start the change
		34 Drive the process slowly
	Process management	35 Failure to create a clear and consensual vision
		36 Fragmentation of processes between subgroups
	Performance measures	37 Failure to establish evaluation criteria
		38 Failure to maintain groups' adherence to evaluation measures

Source: Compiled and adapted from Rentes (2000)

Many authors also cite as the main success factor for lean implementations the adoption of a well-structured method of change management (TAPPING, LUYSTER and SHULZER, 2003; MANN, 2005; PEPPER and SPEDDING, 2010). In this context, DMAIC and PDCA are the continuous improvement methods most used by companies (SALAH, RAHIM, and CARRETERO,

2010; NICOLAY et al., 2012; ASSARLIND, GREMYR, and BÄCKMAN, 2013). To succeed and have a long-term sustainability, the lean programs must have a method that can order the entire implementation, with a well-defined sequence of steps, involving key people, defining the right tools for each moment, structuring a scientific way of thinking and solving problems with priority (SHAH, CHANDRASEKARAN, and LINDERMAN, 2008; COTTYN et al., 2011). In the end, the method and the routines will guide people to the expected lean culture (MANN, 2005).

Some expected behaviors in a lean culture are: long-term decisions, managers focused on daily activities at the front, operators focused on opportunities to improve the production system, managers working to solve system problems with open dialogue between all levels of the organization (DREW, MCCALLUM and ROGGENHOFFER, 2004). Toyota has successfully developed lean manufacturing in its culture, and for this reason, organizations around the world have created their lean production systems based on the Toyota Production System (AHMAD, 2013). For several authors (DREW, MCCALLUM and ROGGENHOFFER, 2004; LIKER, 2004; LIKER and HOSEUS, 2008; AHMAD, 2013), Toyota Culture is the basis of an ideal Lean Culture. A solid executive summary of the culture that supports the Toyota System is the 14 Toyota Model Principles (LIKER, 2004; FULLERTON and WEMPE, 2009). These principles should be the goal of a balanced plan focused on continuous improvement of the organization, capable of improving operational efficiency, promoting teamwork and, above all, promoting an Organizational Culture in which Lean initiatives are lasting and permanent (FULLERTON and WEMPE, 2009). In this context, Liker and Hoseus (2008) briefly define Toyota Culture as “the most successful lean implementation ever”. They divided some aspects of the Toyota Culture in three perspectives, as follow:

a) Visible artifacts and creations

Problem-solving methodology, 5-Why analysis to agile problem solving, 5S (organization and cleaning places), Job rotation (modifications of job functions to promote and stimulate employees learning), Daily meetings in Gemba (place where things happen), Kiosks (visual management to promote communication and consensus between people).

b) Beliefs and values

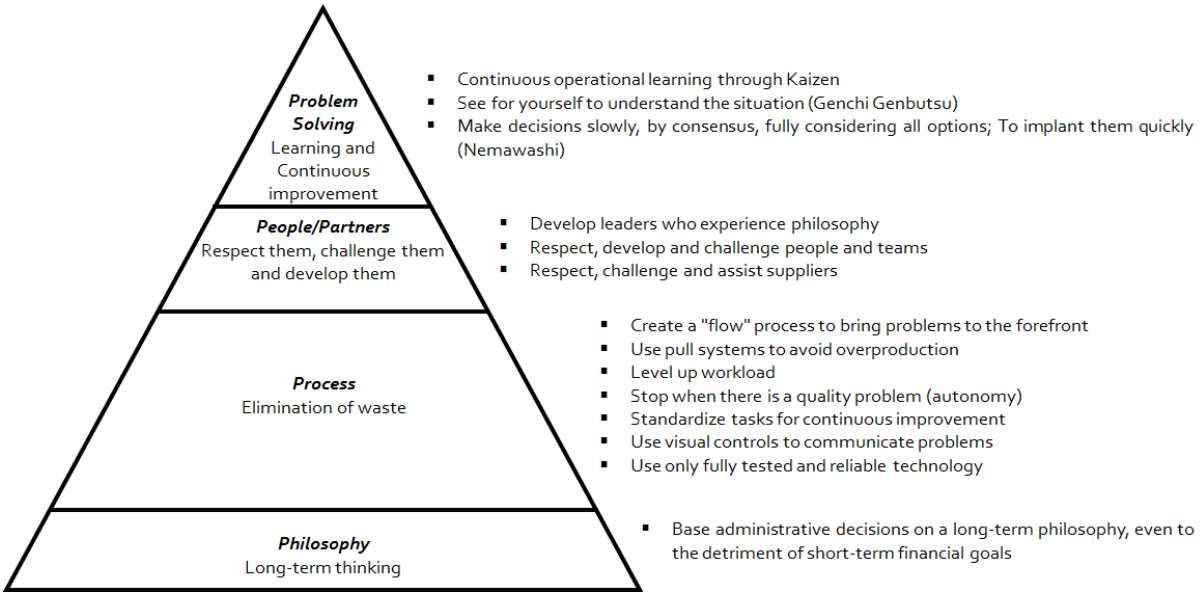
Mutual support teams, clearly defined work standards; the opportunity for employees to propose, develop and implement improvements; concern for the physical and psychological safety of employees; focus on solving problems and not on pointing people out as "culprits" (problems are in the process flow system, not in the people performing the activities).

C) Basic assumptions

Leaders are teachers and coaches; operations planning involves taking into account strategic planning; the commitment to the safety of people is continuous.

The 14 Toyota Model Principles are illustrated in Figure 11. These principles, proposed by Liker (2005), can be described as: basing administrative decisions on a long-term philosophy, even to the detriment of short-term financial goals (Principle 1, or P.1); Create a continuous flow to bring problems to the forefront (P.2); Use pulled systems to avoid overproduction (P.3); Leveling the workload (P.4); Building a culture of stopping and solving problems (P.5); Standardized tasks are the basis for continuous improvement (P.6); Use visual control so that no problem is hidden (P.7); Use only reliable and tested technology (P.8); Develop leaders who experience the philosophy (P.9); Develop exceptional people and teams (P.10); Respect your network of partners (P.11); See for yourself to understand the situation (P.12); Take decisions slowly by consensus, implement them quickly (P.13); Become a continuous learning organization through untiring reflection (P.14).

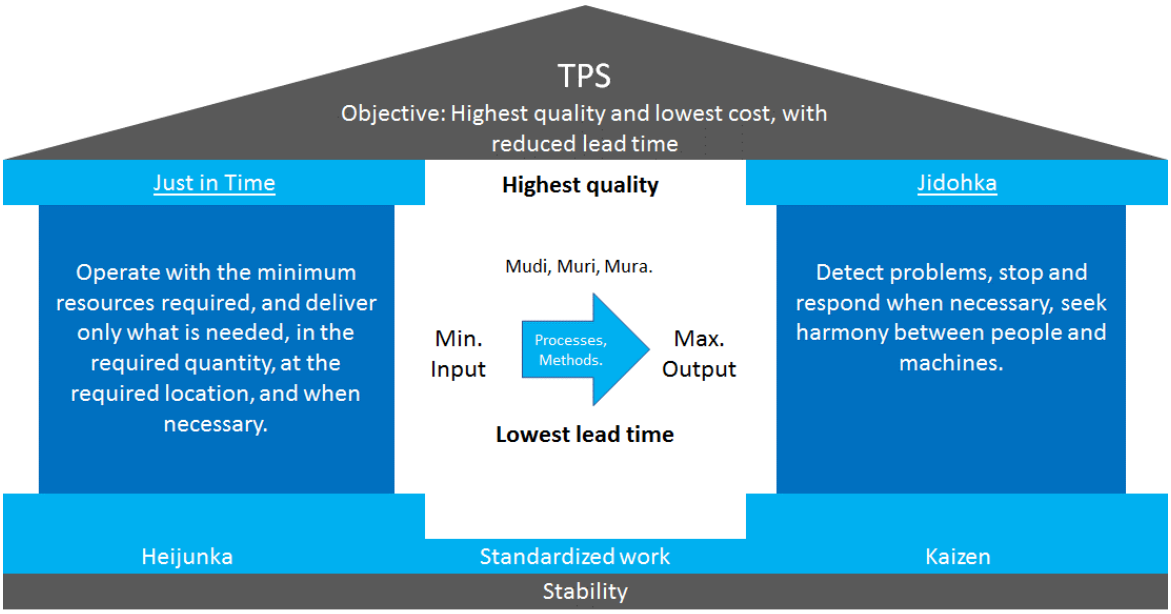
Figure 11 - The 14 Principles of the Toyota Model



Source: Adapted from Liker (2005)

Within the Toyota Production System (TPS), illustrated in Figure 12, one of the most famous concepts is Just in Time (JIT), which can be defined as a philosophy that seeks to systematically reduce total manufacturing costs and produce only what is needed, and when it is needed (Power and Sohal, 1997). It is interesting to note that the “Toyota House” already brings a number of insights and recommendations towards the sustainability of lean implementations, since stability and standardization of activities are at the base of its foundation.

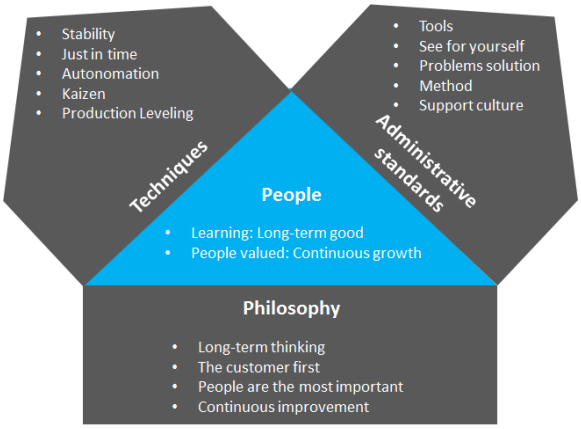
Figure 12 - The Toyota Production System (TPS)



Source: Adapted from Liker (2005)

For Gary Convis, former president of Toyota Motor Manufacturing of Kentucky, USA, all technical issues behind TPS (Stability, Just in Time, Autonomation, Kaizen, Production Leveling) will only be effective if people live the Philosophy. The basis of the whole productive system are people and their respective organizational culture (LIKER 2005). Figure 13 illustrates Gary Convis's vision of the Toyota Production System (TPS), when he was president of Toyota Kentucky (US). For Gary, the productive system was a combination of techniques, with administrative standards and philosophy, with people as the central and referential point of the system (LIKER, 2005).

Figure 13 - Gary Convis's Vision on the Toyota Production System



Source: Adapted from Liker (2005)

In order to create a lean culture and succeed in lean programs, Mann (2010) also raises four main elements of the lean management system, and ten other support elements, as follow:

a) Main elements of the Lean Management System: (1) Leadership standard work; (2) Visual controls; (3) Daily Accountability Process; (4) Discipline.

b) Lean Management System support elements: (1) Leadership work is a "continuous operation"; (2) Continuous learning; (3) Root cause analysis of problems; (4) Promote discipline throughout the environment (internal and external); (5) Develop a rapid response system; (6) Continuous improvement culture; (7) Develop Automation; (8) Work plan control; (9) Human Resources Policies; (10) Evaluate the development of the management system.

The literature also suggests the need to initiate a specific and realistic project at a time rather than initiating various global efforts without proper control of the process improvement as a whole (HINES et al., 2008; BHASIN, 2011a; BHASIN, 2012a).

For Cameron and Quinn (2009), in many cases, the introduction of a foreign element (result of an external or internal source) into the organizational system can be a good way to make changes. In agreement, Liker (2004) points the importance of a "Sensei" in this process of cultural change.

Within the improvement projects, fear and anxiety must be removed to achieve the necessary confidence. For this reason, Bhasin (2012a) suggests that in a lean implementation, it is necessary to reach specific short-term goals.

Drew et al. (2004) also have studied the lessons learned for a successful lean implementation, listed below:

1. The Lean starts at the top of the organization.
2. Set ambitious goals for the organization.
3. Rapid results are important.
4. Listen to the organization's employees.
5. Seek expert help.
6. "It takes time!”

Garcia-Sabater and Marin-Garcia (2009) agree that a lean transformation requires total commitment of the board of the company.

According to Smalley (2005), to develop a sustainable lean transformation, the company needs to develop the employees. Most companies have set up a special group known as "lean change agents" in charge of lean production. The author agrees that it is necessary to have such dedicated resources in order to start a program and sustain it. The author also says that the long-term success and sustainable improvements only occur when the medium management and the operational workers who are responsible for the current process are the people who drive the improvements. In addition to Liker

(2004), other authors, such as Porter (1996) cite the importance of people's behavior to the maximum performance of the most varied concepts of operations management. According to Lee (2007), the engagement and training of the organization's employees are absolutely vital to the successful implementation of the most diverse concepts of operations management. For the success of these concepts, it should be reinforced to everyone in the organization that the process of organizational change and improvement is not just about tools and techniques, but also about the behavior, attitude and commitment of all people in the organization (OHNO, 1988; BHASIN, 2011a; BHASIN, 2011b; BHASIN, 2012a).

Although Bhasin (2012b) found in his study that lean tools are not critical success factors in lean implementations, several other authors cite the importance of certain tools for long-term success and sustainability of improvements (RENTES, 2000; MANN, 2005; SNEE, 2010; PEPPER and SPEDDING, 2010; HINES et al., 2011).

The first factor related to the maintenance of the new procedures is the existence of work standards and standard procedures that are easily interpreted by those who need to know about them (LIKER and HOSEUS, 2008; MOTWANI, 2003; SHAH and WARD, 2003). According to Perin (2005), the process when standardized can achieve higher levels of quality and productivity, since the final result is the systematic reproduction of a "best practice" for the activity.

More important than having a standardized work is having a visual management in an easily accessible location. For Liker (2004), visual management is the best way to tell us quickly about how the work should be performed and whether there is any standard deviation. Keeping all of the information in visual management boards enables people to communicate and share information to to achieve faster and more accurate decision making and create an important sense of integration and consensus.

The third factor related to the maintenance of the new procedures is the formulation of a routine of audits of the new procedures, since there is a need for a constant monitoring the new work standards so that deviations from the planned ones are identified. Thus, to place this frequent monitoring of activities according to the new standards, it is important to systematize audits of the work routine (SISSON and ELSHENNAWY, 2015). Upton (1996) describes the practice of auditing as "structures to prevent setbacks". This means the removal of methods that typify "the old way of doing things". Araújo and Rentes (2006) agree that, in the post implementation phase, there should be a concern with the anchoring of the improvement through audits, in the form of management by rounds. To do this, they suggest that a verification checklist should be developed. As a result, audits work as a way to prevent setbacks and maintain improvement.

Another widely quoted tool as essential to the success of a lean implementation is the Kaizen event. The Kaizen event is a way of learning by doing. During Kaizen events, participants who always include frontline workers, managers, and often customers use Lean tools to evaluate processes, identify waste, test new solutions, and increase the value of the product or service produced. The idea is that once indoctrinated into the Lean philosophy by participating in a Kaizen event, participants will adopt the core value of continuous improvement and work endlessly to transform waste into value from the customer's perspective (VAN AKEN, 2010; CHEN and SHADY, 2010).

Another important way to maintain the sustainability of the implemented improvements is to follow the key performance indicators of the value stream in question (PARRY and TURNER, 2006; VINODH et al., 2013). The ultimate goal of continuous improvement is the improvement of indicators, whether productive, quality or customer satisfaction. These indicators should show the effectiveness of the interventions to improve the system, and they should be able to be translated into financial indicators whenever possible. This should happen because often the motivation for starting a lean project is financial and that is the concern of many boards (GARCIA-SABATER and MARIN-GARCIA, 2011). The goals and target conditions defined to evaluate continuous improvement evolution is identified by most authors as a facilitator for the sustainability of the system (BESSANT et al., 1994; UPTON 1996; DALE et al., 1997; KAYE and ANDERSON 1999). These goals should be consistent with the company's overall objectives and it is recommended that their definition should be in agreement with team leaders (KAYE and ANDERSON, 1999). Esposto (2008) reinforce that a well-structured performance management system for lean implementations should monitor three dimensions: i) performance ii) improvements and; iii) sustainability.

To achieve a structured way of sustaining lean improvements, Ferro (2010) concludes that one of the most important tasks of top management is to define the strategy (vision, true north, goals and strategic objectives) and ensure that it is implemented at the various levels and departments of the organization. In this context, the use of the A3 method is a powerful way to deploy the strategy, once the strategic A3 gives rise to the tactics A3, which in turn give rise to the operationals A3. For the author, the A3 is vital, since it aligns, communicates, involves those responsible from the beginning of the planning process, thus compromising all that are involved in the search of results and processes improvement. It also requires a clear explanation of data, hypotheses, causes and countermeasures, allowing a horizontal and vertical questioning, improving the quality of the established guidelines and mainly increasing the commitment to reach them. By generating this foundation from the outset, it allows for scientifically "check" and "act" over the period, avoiding sudden changes without explanation (FERRO, 2010; RENTES, 2000).

In the same manner, as pointed out by Tapping et al. (2002) all direct and indirect responsible for the change project must be present on the shop floor, encouraging employees to make improvements. Part of practicing lean is to walk and head out to the floor, accessing how well the results are going. The "Gemba Walk" is essential to maintain and continue to improve the system, as it is part of the "Check" in the Plan-Do-Check-Action continuous improvement cycle (MANN, 2005; TYAGI, 2015). Walking in the "Gemba" allows the team to identify problems, finding their causes, and working into solving them (RAHANI and AL-ASHRAF, 2012).

3.2.2 Lean Healthcare sustainability

Although Winch and Henderson (2009) have not done a systematic review of the literature, they critically questioned the theoretical basis from which the implementation of lean healthcare is derived, emphasizing the need for evidence of long-term benefits related to patient results. The systematic and critical review made by Brandao de Souza (2009) in lean healthcare suggests a taxonomy to classify the literature, and one of the gaps identified was the need of researches bringing the sustainability aspect of lean implementations in hospitals. The review of Poksinska et al. (2013) reveals that the vast majority of interventions in lean healthcare are limited to the first three principles of Lean Thinking (from the five), and proposes that future research should focus on two main areas: in the long-term performance of the health care system and in the influence of human resources and work environment in implementations of processes improvement. Another realist lean healthcare systematic review of the literature is presented by Mazzocato et al. (2012), reinforcing the successful appliance of lean thinking in healthcare and its influence in patient care. In this review, however, Mazzocato et al. (2012) cite no cases of failure, and no long-term sustainability question was addressed. Recently, in their systematic review of the literature exploring the state of the art in lean healthcare, Costa et al. (2015) analyse that a gap in the literature is about exploring better the barriers and lessons learned to sustain the process changes through a lean journey in healthcare. In this context, the systematic review of this thesis brought the state of the art in empirical researches related to lean, six sigma and lean six sigma implementations in healthcare. It was possible to observe that 84.5 percent of the empirical articles published even not mentioned any sustainability aspect of the improvement realized and any of them have described the situation after 24 months of the beginning of the program. For D'Andreamatteo et al. (2015), when analysing lean healthcare, the implementation process itself and sustainability remain key and under investigated issues. The application of lean in healthcare are being several reported in the modern literature and the fact that there is a gap of more in-depth studies on how to sustain lean improvements in the long term in hospitals seems to be a consensus (see

NABELSI and GAGNON, 2016; Li, PAPADOPOULOS and ZHANG, 2016; CARDOEN, BELIËN and VANHOUCKE, 2015; HICKS et al., 2015).

Healthcare is a highly political and complex organizational setting characterized by powerful professional groups and regulatory systems, which complicate the transfer and application of management techniques developed and successfully employed in other industries (MCNULTY & FERLIE, 2002; PETTIGREW et al., 1992).

In their study, Eriksson et al. (2016) found that to have a long-term sustainable change, hospitals depend on the degree of responsiveness and mutual adaptation of motives and strategies between different stakeholders, including the top managers, middle managers, change agents, and physicians. Overall, participatory approaches of change management have been described for enhancing both productivity and employee well-being (VINK et al. 2008). Winkel et al. (2015) studied the implementation of the lean tool value stream mapping in hospitals in three Nordic countries and they conclude that implementation processes pushed from top-down in general did not seem to work well for involving employees in change processes. Vink et al. (2008) argue that both the top and the middle management need to be involved to ensure improvement goals in line with the selected strategies in the early steps of the planning change processes.

Although cited by Langabeer et al. (2009) as the professional most resistant to changes, only few authors like Ben-Tovim (2008), McGrath et al. (2008), Godinho Filho et al. (2014) and Eriksson et al. (2016) cite specifically the involvement of physicians in the development of improvements. Eriksson et al. (2016) cite that it is recommended to involve the physicians since the beginning of the project for obtaining sustainable participation over time and less resistance. Godinho Filho et al. (2015) reinforces that in many cases, the board of a hospital is composed of physicians, and their participation in all stages of a lean implementation is essential to help breaking barriers to change in this environment. Physicians, nurses and other medical staff are not typically educated in quality initiatives (except accreditation), but when trained, they can benefit healthcare better than an external quality expert (CARMAN et al., 2010).

Hung et al. (2015) identified some barriers in lean healthcare implementations: i) Lack of visibility of progress; ii) Physician resistance to work standardization; iii) Difficulty to transfer responsibilities to medical assistant as “Value Stream Manager”; iiii) cross-coverage of patient care during lean improvement events.

Hence, both cultural and practical barriers will have to overcome before lean techniques can enjoy widespread use. On the cultural front, it will be necessary to overcome the most likely arguments against the applicability of lean concepts to the health care sector such as “people are not automobiles” and “each patient is unique” (KIM et al., 2006).

Many barriers and challenges include specific critical features that affect the lean journey in the healthcare setting, such as the receptivity of staff, the complexity of the adoption a culture of continuous improvement processes, the high process variability, the lack of understanding of lean, problems in defining waste and a poorly defined focus (BRANDAO DE SOUZA, 2009; GROVE et al. 2010).

Authors like Niemeijer et al. (2011), Glasgow (2010) and Brandao de Souza (2011) cite relevant factors that contributes to have a successful lean implementation in healthcare: i) engaging healthcare professionals in redesigning, implementing, and managing their new processes; ii) opening new lines of communication through the hospital hierarchy; iii) having a visual display of daily progress on performance metrics; iiii) Division of responsibilities between physicians and medical assistants; iiiii) rapid training sessions to minimize time away from patient care; and iiiiii) Gemba walks meetings with participation of the top and middle management, healthcare professionals and operational workers.

The project prioritization and specially the selection of the first value stream to be redesign in a lean program is another critical success factor in pursuing improvements in healthcare delivery, once gains related to patient safety, patient satisfaction, and financial are commonly the most appreciate in the healthcare environment (NIEMEIJER et al., 2010).

Another challenge is the definition of who is the client in a hospital environment, once there may be several clients. Some typical examples are the patient, the patient's family, physicians, hospital staff, the hospital itself, or even the health plan operators (MCGRATH et al, 2008). A well-defined value for a given customer group prevents conflicts and reduces resistance to change (WOMACK and JONES, 2003; YOUNG and MCCLEAN, 2009). The issue of assigning a value that serves the wrong customer group is a major failing of lean initiatives in healthcare (FILLINGHAM, 2007; FERLIE et al., 2010). Filingham (2007) and McGrath et al. (2008) argue that it is extremely important that the value should be determined by the main client: the patient. This definition can be extremely important for sustainability, once the first principle of lean thinking is exactly to define what is value from the perspective of the client.

Most hospitals are designed around specialized functions or departments. These departments have their own physical space, their own budgets, their own employees and their own management structures. Each department has its own work to do, but also plays a direct or indirect role in patient care. (GRABAN, 2011). Still according to the author, many unsuccessful lean healthcare implementations are conditioned to departmentalized projects, without focus on the patient flow as a whole.

As one of the major components of a lean redesign, standardizing work processes to promote a higher level of care quality was difficult for physicians to accept. For a profession that has historically valued the practice of medicine as an art form, lean was perceived as decreasing physicians' abilities to adapt their practices to the needs of patients (GUIMARÃES and DE CARVALHO, 2012).

Visual displays to manage improvements exist in numerous locations within a lean hospital or clinic. They have a series of proposes: to present key performance data (for example patient satisfaction, cost, and productivity metrics); to provide a dedicated place for any staff member to communicate a problem or to post an improvement idea; to organize all relevant improvement information in one place (including the actual projects focus, the backlog and the schedule progress); to provide a discussion local for staff meetings (TOUSSAINT and BERRY, 2013). These visual displays are in every department and units throughout Theda Care, for example (POKSINSKA et al., 2013).

In lean healthcare organizations, the top and middle managers support the operational workers by regularly visiting the worksites (or "Gemba") to see closely the work problems and barriers to improvement. They have in mind that they must make special efforts to create a safe environment for improvements to happen, such as attacking processes rather than people so that staff members do not fear reporting problems (TOUSSAINT and BERRY, 2013).

Sobek and Jimmerson (2004) suggest the Toyota's A3 report as a powerful lean tool for problem-solving efforts into healthcare practice. For the authors, the A3 proved to be a differential factor of success in healthcare environments, once the tool provides an easy understanding of the project by all organization.

Murphree and Daigle (2011) suggest that the application of lean tools such as the audit checklist to control the adherence to the new standards implemented are more than essential for the process not come back to the initial state. For the authors, close follow-up on recent Kaizen events should occur day-to-day after the implementation, especially in a healthcare environment where practitioners are not used to major changes in their routines.

The application of process improvement techniques has increased in popularity especially for healthcare, and to implement these techniques, researchers in generally apply some type of conducting methodology (DELLIFRAINE et al., 2010). Young and McClean (2008), Brandao de Souza and Pidd (2008) and Spear (2004) describe the importance of a structured method for the success of lean implementations in hospitals. According to these authors, the method, whatever it is, should guide the people involved in each step, making clear which reasoning process should be followed for problem-solving. The most known method are the Define, Measure, Analyse, Improve and Control (DMAIC) and the Plan Do Check and Act (PDCA). As verified in the systematic review of this thesis, around

66.7 percent of the empirical works studied about lean, six sigma and lean six sigma in healthcare have not cited any continuous improvement method to conduct their implementations. In addition to simply serving as a step-by-step guide to implementing an improvement process, a method able to orient the improvement team with the critical success factors in each of the implementation phases would be a great contribution for the lean sustainability in healthcare.

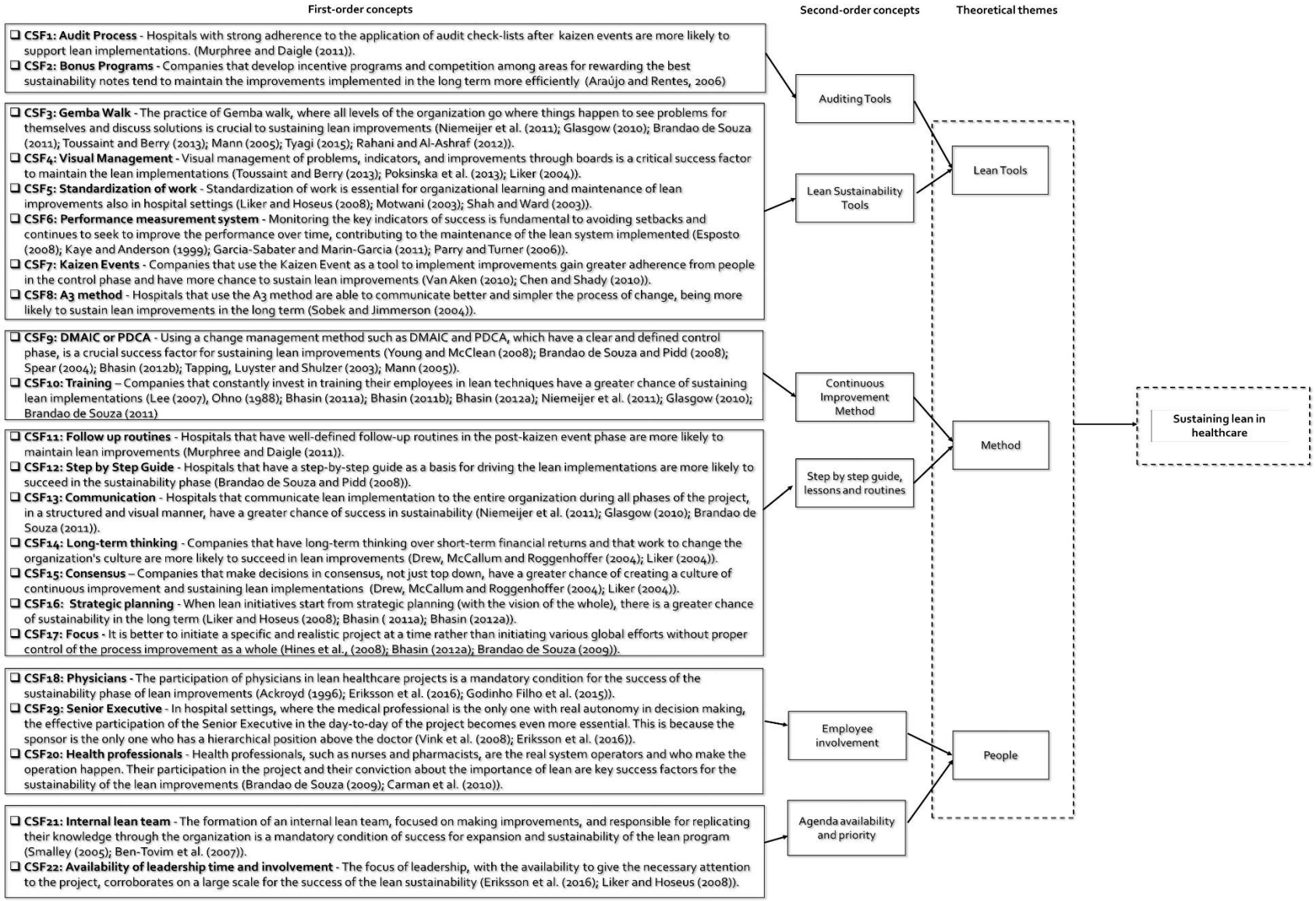
All these authors seem to be correct, however, the opinions and views seem isolated from the whole. In the same way, the lessons learned to achieve sustainability in lean implementations in healthcare appear disconnected in the literature.

In general, the same success factors cited as essential for the sustainability of lean implementations in manufacturing were also cited in healthcare, with some particularities.

From the concepts that emerged from this literature review, it was possible to identify 22 critical success factors (CSF) that indicate facilitating lean sustainability in hospital settings. We call them as first order concepts. To better organize them, it was possible to identify, also from the literature, that they fit into 6 second order concepts: 1) Auditing Tools, 2) Lean Sustainability Tools, 3) Continuous Improvement Method, 4) Step by Step guide, 5) Employee involvement, 6) Agenda Availability and priority. The second order concepts, in turn, fall into three pillars: People, Method and Tools. These pillars will be called as theoretical themes.

From the literature review, we have a theoretical framework bringing together previously disconnected concepts in the literature that can now be better tested in this and future research, as shown by Figure 14.

Figure 14 - Theoretical framework



Source: Elaborated by the author

3.3 Methods

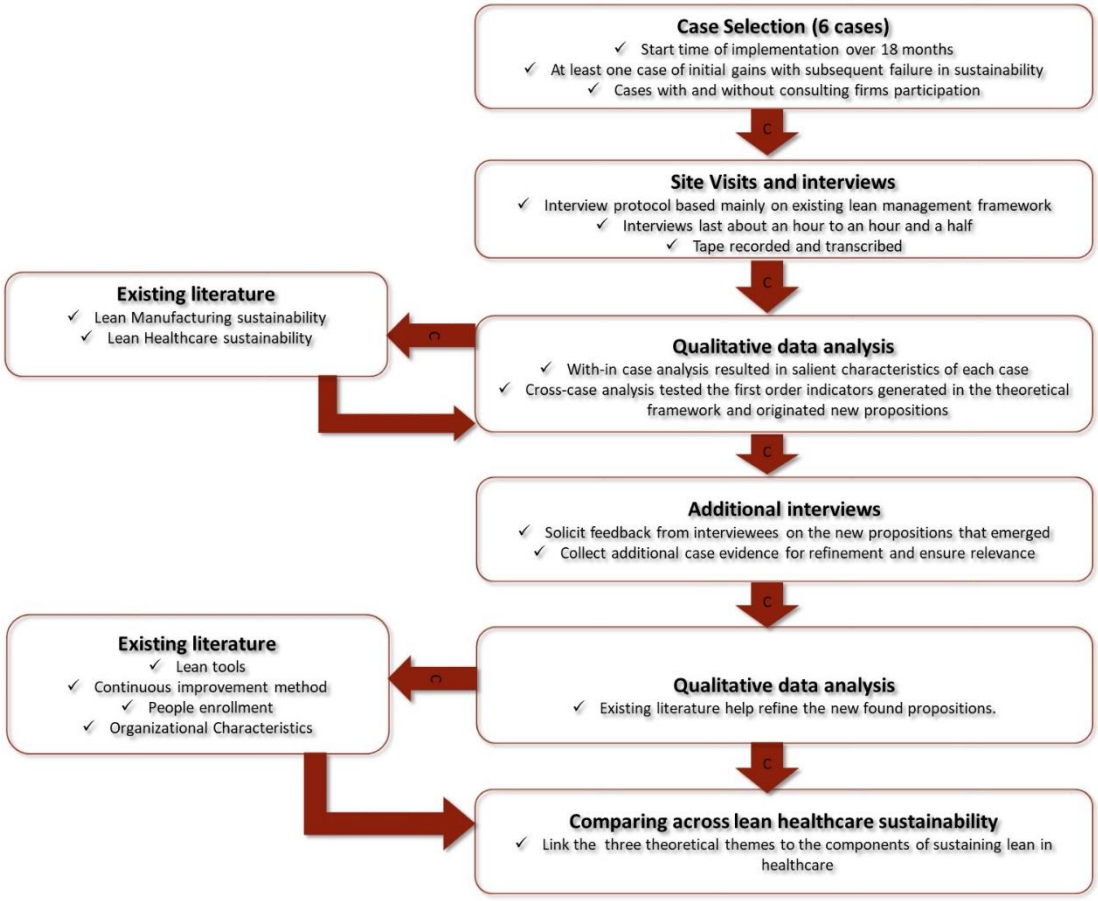
3.3.1 Data collection and research methods

This research conducts a comparative case study following the inductive theory-building approach (EISENHARDT, 1989; YIN, 2003). Since sustaining lean healthcare implementations in the long term has not been well studied, the inductive case study approach helps generate valuable insights. The qualitative data comes from six different hospitals in Brazil. Data collection involved multiple rounds of interviews over a two years' period. The research question focuses on designing a solution and describing the outcomes of the solution in use, so a longitudinal study of the case is appropriate (STUART et al., 2002). This approach allows us to study the experiences of managers in a real-life context and thus increases the practical relevance of the findings (YIN, 2013). The case analysis triangulates the qualitative data with the literature to establish a connection between concepts in different literature streams. Fig. 15 gives the overview of the research method.

3.3.2 Case selection

This study uses a purposive sampling strategy to include cases that span different hospital settings, which increases generalizability (PATTON, 1990). Still few hospitals in Brazil have already begun their lean journey (MAZZOCATO et al., 2012). The six hospitals chosen for the case study in question were selected from references obtained by the authors. Some of the criteria for this selection involved: i) Start time of implementation over 18 months; ii) At least one case of initial gains with subsequent failure in sustainability; iii) Cases with and without participation of different consulting firms. Following the principles of purposive sampling, the sample includes hospitals with varying degrees of lean sustainability. Table 26 summarizes the case profiles. Appendix A provides detail descriptions of each hospital.

Figure 15 - Overview of the research method



Source: Elaborated by the author

3.3.3 Site visits

The researchers designed the initial interview protocol based on the literature. A separate interview protocol was designed for each managerial function. The initial interview protocol consisted of a series of open-ended questions about existing lean practices from the lean management literature and additional questions that solicit informant's opinion on sustaining lean performance (see Appendix B). The study used lessons from lean management sustainability in several industries (e.g. LIKER, 2004; BATEMAN, 2005; BHASIN, 2012b; HUNG et al., 2015; BRANDAO DE SOUZA and PIDD, 2011; GRABAN, 2011; BRANDAO DE SOUZA and PIDD, 2008) as a starting point, and then investigated any additions, enhancements or deviations from the literature which could contribute to sustaining lean performance in healthcare. This served as a starting point in differentiating the sustaining from the non-sustaining hospitals. The visits were previously scheduled with the interviewees. In addition to the interviews, during the visits, the researchers were able to walk through the hospitals, make observations, talk with employees, and analyze documents related to lean projects.

Table 26 - Summary of the six hospital units

Hospital	H1	H2	H3	H4	H5	H6
Service features	Privaty oncology clinic with chemotherapy and drug infusion applications	Philanthropic Institution, essentially public service (medium and high complexity)	Philanthropic Institution, Oncology Care	Private hospital, carries out procedures of high complexity	Philanthropic Institution, Oncology Care	Private hospital, carries out procedures of medim and high complexity
Number of beds	0	273	166	187	76	88
Number of of employees	320	1400	1300	1100	600	500
Number of informants and position	2 (Nurse Director and Quality Manager)	3 (CEO, Physician and Quality Manager)	3 (CEO, Quality Manager, Administrative Manager)	4 (President, Nurse Manager, Quality Manager, Lean Consultant)	3 (Clinical Director, Administrative Director and General Manager)	3 (Quality Manager, Nurse Manager, IT Manager)
Period of implementation	Beginning in May 2014	Beginning in September 2014	Beginning in January 2014	Beginning in February 2012	Beginning in March 2011	Beginning in March 2015
Participation of consulting firm	No	Yes	Yes	Yes	Yes	Yes
Motivational factor for lean implementation	Possibility to produce more with less effort	Dissemination of the continuous improvement culture throughout the Institution - a strong desire for employees to absorb the culture of combating waste and promoting continuous improvement	Search for financial equilibrium. Fixed revenue over the years due to the frozen government table and rising expenses (wage settlements, high dollar prices on imported materials, inflation of materials and medicines) caused a major financial imbalance	The reasons for implementing Lean Healthcare in the hospital were the opportunities to become more competitive and effective, considering that the company's business model is a model of operational competitive advantage.	The institution was in financial trouble and needed help to leverage operational gains.	Big problem of excess of materials and medicines in the hospital. Constant shortages, loans with other hospitals, lack of control at points of use. This is what motivated hospital leaders to look for a solution in lean.
Initial focus	Information flow: Authorization and Scheduling	Material flow: Stock reduction	Patient flow: Chemotherapy	Material flow: Sterile Processing Department	Patient flow: Chemotherapy	Material flow: Stock reduction
Main results of the lean implementation	• Patient rescheduling rate: 2015 (14%) - 2016 (8%) • Mat / Med dispensation compliance rate: 2015 (81%) - 2016 (98%) • Authorization fee in the expected period: 2014 (85%) - 2016 (96%) • Early drug handling rate: 2014 (47%) - 2016 (70%) • Rate of bills delivered on time: 2014 (83%) - 2016 (97%) • Infusion room occupation time: 2014 (2.3 hours) - 2016 (1.7 hours)	• Reduction of U$ 300.000,00 in general costs of the Institution • Reduction of 50% in total inventory (U$ 250.000,00) • Increase of U$ 200.000,00 in revenue • Reduction of 60% in nursing movement	• Reduction of 66% in medication delivery delays • Reduction of 45% of Lead Time delivery of Anatomopathological exams (from 11 days to 6 days) • Increase of 30% of the storage capacity of Medical Records in the Medical File • Increase of 20% in the turnover of the Chemotherapy sector • Reduction of 53% (U$ 215.000,00) of the global stock of drugs and antineoplastics	• Reduction of U$ 450.000,00 per year in general costs • Reduction of 10% in the average time spent in the hospital • Reduction of 40% in the stock of materials and medicines • 60% reduction in billing gloss levels • Reduction of hospital infection levels to near zero • Increase of the capacity of the Autoclaves in the Central of Materials sterilized in 65%	• Chemotherapy billing increase + 35% • Increased number of patients seen on chemotherapy + 28% • Reduction of waiting times for onset of chemotherapy - 84% • Increase in radiotherapy billing + 23% • Reduction of waiting time for radiotherapy treatment - 28%	• Reduction of 42% in the stock of materials and medicines • 10% increase hospitalization capacity

Source: Elaborated by the author

3.3.4 Interviews

The first round of interviews typically included two activities in parallel by the researchers: lead the discussion and take notes, asking additional questions. During the interview, the researchers probed informants with questions and encouraged them to discuss additional managerial practices or concepts that might affect the sustainability of lean in their hospitals. The interviews included the strategic level (CEO or director) and operational level (managers). All interviews lasted between one hour to one hour and a half, and specific questions were targeted to the informant's expertise. They were tape recorded, transcribed, and assembled into manuscripts that contain details of each of the six hospitals for the qualitative data analysis (ANDRIOPOULOS and LEWIS, 2009; GIOIA and THOMAS, 1996; MILES and HUBERMAN, 1994). Additional archival data such as internal audit reports of lean performance ratings, value stream maps, kaizen events presentations and historical key performance indicators were also collected to help minimize the retrospective bias (LANGLEY, 1999). In the first round of interviews, a total of 18 interviews were completed in 2016.

3.3.5 Qualitative data analysis

The qualitative data analysis began with a within-case analysis followed by a cross-case analysis (MILES and HUBERMAN, 1994). The researchers familiarized themselves with over 100 pages of transcribed interviews and had multiple meetings after the interviews to compare and contrast hospital units. The qualitative analysis started with a within-case analysis of each hospital unit to understand how they did or did not sustain the lean implementations. The researchers first read the interview transcripts closely and independently provided ideas of possible sustainability indicators. Case summary reports were prepared and reviewed by the researchers to improve validity (YIN, 2003). The researchers then conducted a cross-case analysis of hospital units to compare units with higher and lower levels of sustaining lean healthcare. The cross-case comparisons helped rule out hospital unit specific characteristics and extract the common indicators. This resulted in validating the first-order concepts of sustaining lean in healthcare found previously in the literature and originated new propositions. This analysis came from comments, views made by informants, observations made by the researchers and materials analyzed. The relevant literature was incorporated at this stage to conceptually understand the emerging concepts, which also provided an additional source of validation (Eisenhardt, 1989). The lean manufacturing sustainability and lean healthcare sustainability literature streams provided a useful conceptual lens to interpret the qualitative data.

3.3.6 Additional interviews and data analysis

During the second-round interviews, the researchers gave interviewees an overview of the concepts that emerged from the first round of qualitative analysis and solicited their feedback about the emerging concepts. The second-round interviews focused also on gathering additional data that would help verify or shape the new propositions that emerged from the first round of interviews. These interviews provided additional information about changes in hospital unit's lean practices and performance. Multiple contacts with the informants also provided relevancy to the concepts and theory that emerged from this study (EMDEN et al., 2006; MADHAVAN and GROVER, 1998). The second round of interviews resulted in another 18 interviews performed in 2017. The researchers then went back and forth between the concepts, second round interview data, and existing literature to better refine the new propositions (EISENHARDT, 1989; YIN, 2003). Additional literature was brought in at this stage. This iteration process resulted in the proposal framework that emerged from the comparative case study and the existing literature.

3.4 Findings and the proposed framework

During the interviews, we asked the informants in each hospital to describe several factors that influence the sustainability of the improvements over the time. These questions included "In your opinion, after the implementation of the lean program, the continuous improvement culture became part of the company? In positive case, cite the main aspects that influenced in bringing this new culture to the company? In negative case, cite the main aspects that contribute to failure" and "What were the main barriers faced during the pre-implementation, the implementation and post implementation phase?" and "Any ups and downs?" and "What were the main critical factors that ensured the success of lean implementation and maintenance? All questions are listed in the Appendix B.

In general, to evaluate the levels of sustainability of the hospitals studied, all 22 critical success factors placed in the Theoretical Framework were analyzed. For the evaluation of each of these CSF, we focused on quantitative and qualitative indicators of sustainability performance over time. Some quantitative examples are: sustainability audit ratings, adherence to the routines implemented, data on the amount of training on lean principles, number of persons involved, performance indicators evolution in the value streams worked such as average time spent in beds, inventory levels, total

treatment lead time, patient satisfaction and patient safety. Performance data from archival sources also helped to verify the lean sustainability performance in the hospitals. For example, H1, H2, H4, H5 and H6 provided the research team with internal audit reports of their lean performance ratings. The own quality team of the hospitals performed the ratings. The archival data sources from the hospitals in some cases exceeded four years. In the qualitative form, we evaluated issues such as people involvement, level of knowledge and application of lean tools, people's ability to apply a continuous improvement method and others. All the qualitative evaluations were done by the researchers who could analyze the interviews, the data provided by the hospitals and also through the face-to-face visits. Based on all this, we classified the hospitals as high level, medium level or low level of sustaining. The final evaluation took into account the following criteria:

- High level of sustainability: Hospitals that on average had more than 90% adherence in adopting the theoretical concepts and to maintaining them over time.
- Medium level of sustainability: Hospitals that on average had between 50% and 90% adherence in adopting the theoretical concepts and to maintaining them over time.
- Low level of sustainability: Hospitals that on average had less than 50% adherence in adopting the theoretical concepts and to maintaining them over time.

As a result, H1 and H4 were categorized as high level of sustaining, H2 and H6 as medium level, H3 and H5 as low level of sustaining. Table 27 shows the respective sustainability level of the six hospital units.

Table 27 - Cross-case comparisons across three main theoretical themes and sustainability aspects

		H1	H2	H3	H4	H5	H6
Lean Tools	Percentage of theoretical propositions involving "Lean Tools"that are applied after 18 months	100%	50%	13%	88%	13%	63%
	Sustainability level of "Lean Tools" theoretical propositions initially implemented after 18 months	100%	80%	25%	100%	20%	71%
Method	Percentage of theoretical propositions involving "Method"that are applied after 18 months	100%	44%	11%	100%	0%	67%
	Sustainability level of "Method" theoretical propositions initially implemented after 18 months	100%	67%	25%	100%	0%	83%
People	Percentage of theoretical propositions involving "People"that are applied after 18 months	100%	80%	20%	100%	20%	80%
	Sustainability level of "People" theoretical propositions initially implemented after 18 months	100%	67%	50%	100%	50%	67%
	Average rating on ratings	100%	65%	24%	98%	17%	72%
	Level of lean sustainability	High	Medium	Low	High	Low	Medium

Source: Elaborated by the author

In order to explain the results of this evaluation, the next sections will detail the evidences found in the cases, and also present and discuss the new propositions observed.

3.4.1 Lean Tools and high level of lean healthcare sustainability

By definition, sustaining improvements in hospital environments requires a large capacity´s organization to properly and efficiently apply some lean tools. Although Bhasin (2012b) found in his study that lean tools are not critical success factors in lean implementations, several other authors cite the importance of certain lean tools for long-term success and sustainability of improvements (RENTES, 2000; MANN, 2005; PEPPER and SPEDDING, 2010; HINES et al., 2011). To achieve a high level of lean healthcare sustainability, hospitals need to invest in training whether on theoretical or on the job trainings, with the support of a sensei for example. Specifically, for the improvements sustainability in hospital environments, lean tools are divided into two groups: i) audit tools of the implemented new standards and ii) tools for the development of a continuous improvement system.

Several hospital units in our sample expressed an ongoing concern about looking for ways to improve their know-how of applying the lean tools correctly. For instance, one physician who is clinical director of one of the hospitals studied indicated: "*We still have an enormous difficulty in correctly applying the lean tools we have been learning. I always say to the operation that if we do not apply the tools properly, it is like if we physicians do not use our scalpel or any other working tool properly. This will not bring the desired results and we will get frustrated and get someone to blame*." Comparing the hospital units that sustain high level of lean improvements (H1 and H4) with those that had difficulties (H2, H3, H5, H6), the sustaining hospital units encouraged organizational members to reflect on how to enhance both audit lean tools and improvement lean tools on a regular basis. They reflected on their current learning processes and frequently raised questions such as: how can we learn to enhance the improvement practices? Are we really learning how to apply the right tools in the right moments? Are we developing routines that stimulate people in the organization to apply the lean tools? Are we really auditing the right points of our new processes in a rigorous and disciplined manner? In a sense, sustaining hospital units constantly reexamine their processes or to improve it or to sustain it. This indicates the relevance of applying lean tools to enhance sustainability. It distinguished the hospital units that sustained lean improvements in a high level (H1 and H4) from the others that did not. We now examine lean tools more deeply by comparing the case findings and the literature.

3.4.1.1 Lean audit tools

Lean improvement systems refine and improve existing products and processes. A crucial factor related to the maintenance of the new lean procedures implemented is the formulation of a routine of audits of the new processes, since there is a need of a constant monitoring of the new work standards to identify possible deviations (SISSON and ELSHENNAWY, 2015). Upton (1996) describes the practice of auditing as "structures to prevent setbacks". Araújo and Rentes (2006) agree that, in the post implementation phase, there should be a concern with the anchoring of the improvement through audits, in the form of management by rounds. To do this, they suggest that a verification checklist should be developed. As a result, audits work as a way to prevent setbacks and maintain the quality of the improvements.

The ongoing audit and update of the improvement system is one factor that differentiates the hospital units that sustained lean improvements at a high level (H1, H4) to those units that had difficulties to sustaining it (H2, H6) and those that lost it (H3, H5). As one quality manager at H4 (high level) noted: "*If it were not for sustainability audits, especially at the very beginning of the project, we would certainly have returned to the state before the improvements. People are accustomed to doing their jobs in one way and do not want to leave the comfort zone. The application of audit checklists shortly after the changes that occurred during kaizen events were fundamental for everyone to follow if the new standards were being applied. These routines went on for a long time, until the new process was really rooted in the organization.*" The nurse director of the H1 (high level) also suggests the importance of the lean audit tools for having success in sustaining lean efforts: "*We have the process audit, which is carried out periodically through check list, generating a note for the sector responsible for the process. Audits should be performed by external members and always accompanied by the quality team or the lean team. The hospital directors conduct surprises audits in a lower frequency. In addition to the audits, we set up bonus programs for sectors with a higher compliance rate. This entire monitoring structure made the difference to the commitment of the entire operation, especially those responsible for these indicators. It is important to say that long before lean arrived at the hospital, we had already lost many improvements, and in my opinion these losses occurred precisely because we had not properly monitored the new processes.*"

The general manager at H5 (Lost) pointed out that "*a big failure was not to devote too much time to post-implementation monitoring. When the consulting firm was still helping us, the audit process worked well and the new processes were in order. With the exit of the consultancy, the audits ceased to happen and much was lost. I think the big failure was not having invested in building a*

continuous improvement team internally, and having become so reliant on consulting." The CEO at H3 (Lost) indicated that they did not reflect on their existing improvement practices and believed that they should have given greater attention to monitoring lean tools: "*We care too much about short-term financial returns, and we care very little about creating a culture of continuous improvement with solid foundations. We made the improvements and pressed our managers to the maximum to generate the results, but we did not exile to know if the processes that went through the changes were solidified.*"

The quality manager at H6 (medium level) also expressed the need to audit the new routines. According to him: "*At first, we had difficulty keeping up with the auditing routine, mainly due to the number of parallel projects that were happening in the hospital. After we start to expose the sustainability ratings in the organization's visual management boards, we noted a higher commitment from leaders to achieve higher levels of performance.*" One physician interviewed in H2 (medium level) also reported the importance of performing lean audits: "*I can speak from my own experience that only after audits I become more committed to the changes that have taken place. I realized that this is essential because we are human, and we tend to resist to change.*"

It is clear from the analysis of the cases that the use of lean audit tools of the new processes was a differential between the hospitals that in fact were able to maintain the implemented improvements and the hospitals that did not succeed.

3.4.1.2 Lean improvement tools

Some lean tools were widely cited by our respondents as key success factors in maintaining lean improvements. When we talk about the application of such tools to the sustainability of lean efforts in hospital settings, several authors such as Guimarães and De Carvalho (2012), Toussaint and Berry (2013), Poksinska et al. (2013), Fillingham (2007), Henrique et al. (2015), Sobek and Jimmerson (2004), Murphree and Daigle (2011) cite work standardization, A3 method, key performance indicators, kaizen events, visual management boards, among others, as tools that if well used become fundamental factors for the maintenance of the lean improvements in healthcare.

The quality manager of the H1 (high level) suggests the importance of some lean tools for having success in sustaining lean efforts: "*Although people are the main factor for sustainability, if they do not know how to apply lean tools in the right way, the sustainability of the improvements implemented would certainly be at risk. I will mention only those that I consider really fundamental in this process: Standardization of activities, follow-up indicators and visual management (Gemba Boards)*". The president at H4 (high level) noted: "*I used to run the hospital in my own room. Meetings were in my office, performance indicators were in my office, everything was happening in my office.*

From the moment I started doing the Gemba walk and going to the operation, where things really happen, the team's involvement changed and I realized the adherence to the standards has increased a lot."

The Clinical Director at H5 (Lost) indicated once again that the main goal of short-term financial returns made him not worry about training his operation: "*I remember that working patterns were drawn, but we did not have a follow-up routine to see if the operation had managed to keep them*." The H3 (Lost) quality manager said that lean was top down and did not come as a philosophy of continuous improvement. "*We have not actually been trained to apply lean tools. The few lean sustainability tools we see in the hospital are some visual management boards that have not been filled for some time.*"

Having a trained operation in correctly applying some lean tools seems to have a great influence on the sustainability results among the hospitals studied. The H2 quality manager emphasized the relevance of the Kaizen event. "*For me what makes the most difference in sustainability is the adherence of people to what was implemented, and this adherence could only be achieved through a implementation made by the operation itself through Kaizen events.*" The nurse manager at H6 (medium) agrees that some lean tools have helped her a lot in breaking down some internal resistance in the sustainability phase. "*I only got the operating team support after demonstrating our improvement project in a structured and simple way through the A3 method. Our A3 started to be visually exposed in the boards and the team came to give us suggestions for improvement*".

Table 28 summarizes the comparisons across hospital units over the application of lean tools for sustainability. It is clear from the analysis of the cases that the use of lean tools was a differential between the hospitals that did succeed in the long term from the hospitals that did not succeed and it was possible to validate the 8 critical success factors (1 to 8) from the theoretical framework related to the Lean Tools pillar.

3.4.1.3 New findings about lean tools and high level of lean healthcare sustainability

In addition to the tools cited in the theoretical framework, the Value Stream Map (VSM), which is largely cited in the literature as the most important lean tool to improve operations in healthcare (see HENRIQUE et al., 2015; SERRANO LASA, 2009), is not mentioned as a critical success factor specifically in the control phase. However, it proved to be a decisive tool to achieve long term sustainability in the hospitals studied.

Table 28 - Cross-case comparisons of Lean Tools application

Propositions related to lean tools	H1		H2		H3		H4		H5		H6	
	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months
CSF1: **Audit Process** - Hospitals with strong adherence to the application of audit check-lists after kaizen events are more likely to support lean implementations. (Murphree and Daigle (2011)).	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓
CSF2: **Bonus Programs** - Companies that develop incentive programs and competition among areas for rewarding the best sustainability notes tend to maintain the improvements implemented in the long term more efficiently (Araújo and Rentes, 2006)	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
CSF3: **Gemba Walk** - The practice of Gemba walk, where all levels of the organization go where things happen to see problems for themselves and discuss solutions is crucial to sustaining lean improvements (Niemeijer et al. (2011); Glasgow (2010); Brandao de Souza (2011); Toussaint and Berry (2013); Mann (2005); Tyagi (2015); Rahani and Al-Ashraf (2012)).	✓	✓	✗	✗	✓	✗	✓	✓	✗	✗	✓	✗
CSF4: **Visual Management** - Visual management of problems, indicators, and improvements through boards is a critical success factor to maintain the lean implementations (Toussaint and Berry (2013); Poksinska et al. (2013); Liker (2004)).	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓
CSF5: **Standardization of work** - Standardization of work is essential for organizational learning and maintenance of lean improvements also in hospital settings (Liker and Hoseus (2008); Motwani (2003); Shah and Ward (2003)).	✓	✓	✓	✗	✗	✗	✓	✓	✓	✗	✓	✗
CSF6: **Performance measurement system** - Monitoring the key indicators of success is fundamental to avoiding setbacks and continues to seek to improve the performance over time, contributing to the maintenance of the lean system implemented (Esposto (2008); Kaye and Anderson (1999); Garcia-Sabater and Marin-Garcia (2011); Parry and Turner (2006)).	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓
CSF7: **Kaizen Events** - Companies that use the Kaizen Event as a tool to implement improvements gain greater adherence from people in the control phase and have more chance to sustain lean improvements (Van Aken (2010); Chen and Shady (2010)).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓
CSF8: **A3 method** - Hospitals that use the A3 method are able to communicate better and simpler the process of change, being more likely to sustain lean improvements in the long term (Sobek and Jimmerson (2004)).	✓	✓	✗	✗	✗	✗	✓	✓	✗	✗	✓	✓
Percentage of theoretical propositions involving "lean tools" that are applied after 18 months	**100%**		**50%**		**13%**		**88%**		**13%**		**63%**	
Sustainability level of "lean tools" theoretical propositions initially implemented after 18 months	**100%**		**80%**		**25%**		**100%**		**20%**		**71%**	

Source: Elaborated by the author

Jasti and Sharma (2014) mention that the VSM should be constantly updated, since the future situation after being implemented becomes the current situation and this cycle should never end. Fillingham (2007) cites the importance of the VSM for the success of a lean implementation in healthcare environments. The author cites that in some cases a multidisciplinary team of physicians, nurses, therapists, managers and patients, spent a week removed from their routines focusing just on the mapping Event. They are trained and then they map together, in detail, the progress of the patient's journey from the arrival to the discharge, through all process such as radiology, the wards, operation theatres, back to the wards and so. After analyzing all the positive and negative points of all the value steam mapping models applied in hospital environments, Henrique et al. (2015) presented a specific value stream mapping approach for healthcare. In this approach, it is possible to see the patient flow, the information flow and materials and drugs flow in a single map.

It is interesting to observe some interviews collected in the cases, suggesting the importance of the VSM specifically to control and sustain the lean implementations. The president at H4 (high level), for example, noted: "*For me, the lean tool that made the most difference during the entire process was the value stream mapping. The VSM was important in the waste identification phase, in the future state construction phase, and especially in the sustainability phase, since whenever we had a problem, we used the value stream analysis to identify the best way of solving it.*" In the same way, the quality manager of the H1 (high level) suggests the importance of the VSM to sustain lean in the hospital: *"What caught my attention in the methodology we used was to perform both current and future value stream mapping in a Workshop format, involving all key people. This mapping process brought a ownership feeling to those involved, and in my opinion it was what made the most difference for us to succeed in sustaining".*

Through the analysis of comparative data among the hospitals studied, it is possible to say that hospitals that continued to use VSM for discussions and continuous improvement specifically in the Control phase were the most successful hospitals in long-term sustainability (H1 and H4). Another evidence is that in hospitals with lower sustainability (H3 and H5), VSM was used only in the design phase and only by the consulting company, without the involvement of the key people.

Thus, it is possible to add to the theoretical framework the following hypothesis or proposition, which should be better explored and tested in future works:

P1: VSM is an essential tool for the sustainability of lean implementations in hospitals, which should be used both in the design phase and, specifically, in the control phase.

3.4.2 Method and high level of lean healthcare sustainability

To achieve a high level of lean healthcare sustainability, hospitals should follow a well-structured method which: i) structure a scientific way of thinking and solving problems with priority and ii) order the entire implementation, with a well-defined sequence of steps, involving key people, defining the right tools for each moment, inserting leadership routines and following the lessons learned in the literature and in other experiences (SHAH, CHANDRASEKARAN and LINDERMAN, 2008; COTTYN et al., 2011). Because of this, we will evaluate the hospital units studied in two characteristics: i) Continuous improvement method and ii) step by step guide, lessons and routines. In the end, the method and the routines will guide people to the expected lean culture (MANN, 2005).

Comparing the hospital units that sustain high level of lean improvements (H1 and H4) with those that had difficulties (H2, H3, H5, H6), the sustaining hospital units encouraged organizational members to apply the continuous improvement method in their routines on a regular basis. In addition, the method works as a true guide, detailing what should be done at each stage of the project. For example, in these hospitals with the highest level of sustainability, the method indicates that one project must be done at a time, with focus, and not try to transform the hospital at once. The method also indicates that there should be well-defined meeting routines in the Gemba (place where things happen) with the presence of the sponsor and long-term thinking should be adopted in detriment of short-term financial returns. The method makes the lean leader reflect all the time about questions such as: What initial scope should be chosen? How should I involve people so that decisions are made consensually and not just top down? Which people should be involved? How should I communicate the results to the organization? What routines should I implement in the hospital so that I can maintain the engagement of everyone involved? Are all lean initiatives in line with the hospital's strategic planning? This indicates the relevance of applying a well-structured method to enhance sustainability. It distinguished the hospital units that sustained lean improvements in a high level (H2 and H4) from the others that did not. We now examine the method more deeply by comparing the case findings and the literature.

All hospital units studied use some kind of continuous improvement method as a scientific standard of reasoning for problem solving and structuring of improvement projects. The big question, however, is how they apply the method in their day-to-day routines and how this method can be really a good guide to implementing lean healthcare. For instance, one of the hospitals directors indicated: "*We know what method of continuous improvement we adopted, we know what it means, but what we do not know is how to incorporate it into our routines.*"

3.4.2.1 Continuous improvement method

DMAIC and PDCA are the continuous improvement methods most used by companies (SALAH, RAHIM, and CARRETERO, 2010; NICOLAY et al., 2012; ASSARLIND, GREMYR, and BÄCKMAN, 2013). As verified in the systematic review of this thesis, around 66.7 percent of the works studied have not cited any continuous improvement method to conduct their implementations in hospitals. In the six case studies performed in this work, however, all hospitals apply some form of continuous improvement method. From the six hospitals studied, five use DMAIC and only one use PDCA. The PDCA and the DMAIC are very similar methods, with the same objective: to structure a scientific process of reasoning to solve problems and to lead improvement projects (NICOLAY et al., 2012). What will differentiate the hospitals studied in terms of lean sustainability in this regard is how the method is applied.

The ongoing continuous improvement method appliance and adherence is one factor that differentiates the hospital units that sustained lean improvements at a high level (H1, H4) to those units that had difficulties to sustaining it (H2, H6) and those that lost it (H3, H5). As the quality manager at H1 (high level) noted: "*We apply the PDCA every time we have the need to solve a more complex problem in our hospital. It is rooted in the culture of the organization so that the operation applies it in its day to day to structure new improvement projects. This has greatly helped to create a culture of continuous improvement in the hospital and thereby ensure the sustainability of the improvements.*" The nurse manager at H4 (high level) also notes, "*Since we started using DMAIC in absolutely every open improvement project, the hospital has made a leap in quality. We used the reasoning process in our day-to-day discussions, and we were able to follow up every step of the project in a much simpler way. And being able to do this follow up helped us a lot to ensure the maintenance of all the activities of the control phase.*"

The clinical director at H5 (Lost) indicated that even though they have adopted DMAIC as a method for conducting the lean project, if they ask someone else about how to apply it, no one will know its meaning. "*Unfortunately, we did not structure ourselves to learn how to apply the method while we still had the presence of the consultancy firm here. The professionals' turnover also removed the rest of the method knowledge of the operation*". The quality manager at H3 (Lost) also said, "*The DMAIC was adopted by the consulting firm, not by operation or leadership*".

The fact of having the operation trained and routines for the application of the continuous improvement method seems to be a differential factor for lean sustainability. The CEO at H2 emphasized the relevance of the DMAIC method. "*Before Lean arrives at the hospital, we have missed many improvements we have made in recent years precisely because we did not use a method like*

DMAIC to conduct our projects. Just to think that the DMAIC has a phase (C) just reserved for sustainability makes clear that the method does not let us neglect the control of everything we implement. Despite this, we still have a lot of difficulty in making the operation use the method on a daily basis. Today, basically our lean team and few nurses' leaders uses properly and constantly." The IT manager at H6 (medium) agrees that the method helped a lot in the sustainability, "*Lean arrived at the hospital at a stage that we were doing a series of other projects and everything was very tumultuous. If it were not for the DMAIC control phase to be very clear, we would certainly have jumped from one implementation to another without careful pay attention to the strict control of the new processes. Unfortunately, however, I cannot say that using DMAIC is part of our culture. We do invest in training the operation after the first year of lean implementation, so just a few people know how to use it properly in the operation."*

It is clear from the analysis of the cases that hospitals that apply a continuous improvement method in their day-to-day routines differentiated in sustaining improvements from the hospitals that did not.

3.4.2.2 Step by step guide, lessons and routines

In addition to the method itself, one of the things that seems to make a difference in the sustainability of the hospitals studied is to have a template with the step by step to be followed within each of the phases of the method before starting the implantation. Taking the DMAIC as an example, the hospital unit H4, before the beginning of the lean journey, already had a list with several lessons and activities required in each of the phases. In the phase "D", they should select a short scope that would bring quick results to break initial resistances. In the phase "M" they should map the value stream, raising the main waste. To carry out the mapping, they should hold a Workshop involving all health professionals. In the phase "A", they should design the future situation through a Workshop with the involvement of all. In the phase "I", they should follow the implementation template through a kaizen event, with opening and closing Event with the presence of the hospital board, and then, general communication of the results. In the phase "C", visual management displays and boards should be implemented (Gemba Boards) containing the operational indicators, the improvement focus A3 at that time and the sustainability audit notes, as well as the current and future value stream maps. Still in the phase "C", Gemba meetings and routines should be structured at a predefined frequency, again with the involvement of the hospital's sponsor and board. We understand that this detailed structuring of the steps as part of the method being applied contributes significantly to the success of the lean project both for obtaining results and for sustaining them. Bhasin (2012b) determine common

characteristics that can be differential to success in lean implementation and reveal the fact that a well-structured method can drive people in direction to create a lean culture and in consequence to have success in a lean journey. Many other authors also indicated that a set of structured steps within the methodology could be a decisive factor for the success of a lean implementation (SHAH, CHANDRASEKARAN, and LINDERMAN, 2008; DREW, MCCALLUM and ROGGENHOFFER, 2004; LIKER and HOSEUS, 2008).

The quality manager at H1 (high level) noted: "*One thing that made a big difference for us was having set up a very detailed schedule until the beginning of the lean program. In this schedule, we put everything we have already learned in courses and in lean healthcare literature. It served as a guide throughout the implementation and so we did not neglect any steps or lessons learned from other experiences. In the post-implementation phase, for example, we already had in this schedule all the routines that should be implemented to keep the new standards set and to guide our people towards a lean culture.*" The nurse manager at H4 (high level) also notes, "*When we started lean in the hospital, I did not even know what that meant. I speak for myself, but I believe that almost 100% of the other professionals were unaware of it. Therefore, the templates brought in by the consulting firm with the step-by-step and list of all the activities that should be developed at each stage of the implementation was crucial to our success. All of our projects were carefully selected according to the hospital's macro strategy, and the decisions on the following paths were taken in consensus between top management (always present at Gemba) and the operation.*"

The administrative director at H5 (Lost) indicated: "*We had excellent initial results, both financial and medical. To give you an idea, we have reduced the time between getting the patient to the hospital, being diagnosed with cancer and receiving chemotherapy in 84%. Was not it fantastic? This was achieved through a well-structured project conducted by the consulting firm. I remember well that every week I was following up the schedule with the step by step of each phase of the DMAIC and we not neglect any stage. The big problem was that this knowledge went away together with the consultancy and with our high turnover of personnel. Today I do not even know if we have any of these templates that were used.*" The CEO at H3 (Lost) said: "*To be very sincere, I know there is a methodology with a step by step only because I thought it was important at the time of hiring the consultancy. I have not learned these steps myself. Decisions have always been taken top down, and this may have been a problem as well.*"

Having a detailed implementation planning seems to have made the difference to the lean sustainability in the hospitals studied. The H2 quality manager emphasized the relevance of the follow up routines. "*For me, the great integrator between people, lean tools, and the DMAIC method was the implementation of follow ups routines in the post implementation phase in front of the visual*

management boards, which are part of the methodology we have learned". The nurse manager at H6 (medium) agrees that some lessons learned in other experiences with lean healthcare have helped her a lot in the sustainability phase. "*A great example was having a well-structured communication process during all phases of the project. Never in my professional life before I had worried about it. As the endomarketing was part of the project and embedded in our methodology, this communication was executed with rigor. In the control phase, many people came to me saying that they would like to collaborate with the project because they were fully aligned with the expectations of the project in terms of results for all: patients, employees and hospital. This comes from people with whom the project still had no direct interface. It was very gratifying*."

Table 29 summarizes the comparisons across hospital units over the application of a well-structured method for continuous improvement. It is clear from the analysis of the cases that the application of a step by step guide, lessons and routines by the hospital team were a differential between the hospitals that did succeed in the long term from the hospitals that did not succeed. In this section, it was possible to validate the critical success factors 9 to 17 from the theoretical framework related to the Method pillar.

3.4.2.3 New findings about Method and high level of lean healthcare sustainability

In addition to the critical success factors already inserted in the theoretical framework, it was verified through the results of each case studied and in the comparison between the cases that hospitals which started their lean initiatives through "support" flows, other than patient flow, such as information flow or materials flow were more likely to sustain the improvements in the long term.

In the literature, it is possible to observe three major workflows in hospitals: i) patient flow; ii) information flow, and; iii) materials flow (HENRIQUE et al., 2015). In the cases studied, it is possible to see lean implementations in these three different flows. Lean implementations that involve patient flow are related to bed management, operating room optimization, emergency room improvements, etc. Lean implementations that involve the materials flow are related to stock reduction, sterilization and distribution of surgical instruments and dispensing of drugs in the Pharmacy, etc. Lean implementations that involve the information flow are related to authorization, billing, information technology, and purchasing, etc.

Table 29 - Cross-case comparisons of Method application

Propositions related to Method	H1		H2		H3		H4		H5		H6	
	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months
CSF9: **DMAIC or PDCA** - Using a change management method such as DMAIC and PDCA, which have a clear and defined control phase, is a crucial success factor for sustaining lean improvements (Young and McClean (2008); Brandao de Souza and Pidd (2008); Spear (2004); Bhasin (2012b); Tapping, Luyster and Shulzer (2003); Mann (2005)).	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓
CSF10: **Training** – Companies that constantly invest in training their employees in lean techniques have a greater chance of sustaining lean implementations (Lee (2007), Ohno (1988); Bhasin (2011a); Bhasin (2011b); Bhasin (2012a); Niemeijer et al. (2011); Glasgow (2010); Brandao de Souza (2011).	✓	✓	✗	✗	✗	✗	✓	✓	✓	✗	✓	✗
CSF11: **Follow up routines** - Hospitals that have well-defined follow-up routines in the post-kaizen event phase are more likely to maintain lean improvements (Murphree and Daigle (2011)).	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓
CSF12: **Step by Step Guide** - Hospitals that have a step-by-step guide as a basis for driving the lean implementations are more likely to succeed in the sustainability phase (Brandao de Souza and Pidd (2008)).	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗	✓	✓
CSF13: **Communication** - Hospitals that communicate lean implementation to the entire organization during all phases of the project, in a structured and visual manner, have a greater chance of success in sustainability (Niemeijer et al. (2011); Glasgow (2010); Brandao de Souza (2011)).	✗	✓	✓	✗	✗	✗	✓	✓	✗	✗	✓	✓
CSF14: **Long-term thinking** - Companies that have long-term thinking over short-term financial returns and that work to change the organization's culture are more likely to succeed in lean improvements (Drew, McCallum and Roggenhoffer (2004); Liker (2004)).	✓	✓	✓	✗	✗	✗	✓	✓	✗	✗	✗	✗
CSF15: **Consensus** – Companies that make decisions in consensus, not just top down, have a greater chance of creating a culture of continuous improvement and sustaining lean implementations (Drew, McCallum and Roggenhoffer (2004); Liker (2004)).	✓	✓	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓
CSF16: **Strategic planning** - When lean initiatives start from strategic planning (with the vision of the whole), there is a greater chance of sustainability in the long term (Liker and Hoseus (2008); Bhasin (2011a); Bhasin (2012a)).	✓	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	✗
CSF17: **Focus** - It is better to initiate a specific and realistic project at a time rather than initiating various global efforts without proper control of the process improvement as a whole (Hines et al., (2008); Bhasin (2012a); Brandao de Souza (2009)).	✓	✓	✗	✗	✗	✗	✓	✓	✗	✗	✗	✓
Percentage of theoretical propositions involving "Method" that are applied after 18 months	**100%**		**44%**		**11%**		**100%**		**0%**		**67%**	
Sustainability level of "Method" theoretical propositions initially implemented after 18 months	**100%**		**67%**		**25%**		**100%**		**0%**		**83%**	

Source: Elaborated by the author

Several authors cite the physician as the professional in the hospital most resistant to change (see LANGABEER et al., 2009; ERIKSSON et al., 2016; CARMAN et al., 2010). The professional environment of healthcare is based on a hierarchy of professional achievement, with healthcare setting executives above physicians and physicians out-ranking nurses in a very controlled environment which negatively contributes to the culture of flexibility and encouragement of individual initiatives required by a truly lean organization (JOOSTEN et al., 2009; WARING and BISHOP, 2010; BRANDAO DE SOUZA and PIDD, 2011). In this context, physicians tend to be the only traditional profession in healthcare regarding autonomy, collegiality, professional dominance, etc. (ACKROYD, 1996). This lack of autonomy by non-medical professionals within the hospital environment also can difficult the success of lean implementations initially in areas that directly involve the patient. The cases studied demonstrated that hospitals which started the lean project by areas focused on improving flows with less interface with the physicians achieved better results in the long term. Starting lean initiatives through flows with less medical interface does not mean not involving them, but engaging them in a more subtle way, showing the results and breaking the initial resistances. Eriksson et al. (2016) cite that it is recommended to involve the physicians since the beginning of the project for obtaining sustainable participation over time and less resistance. Godinho Filho et al. (2015) reinforces that in many cases, the board of a hospital is composed of physicians, and their participation in all stages of a lean implementation is essential to help breaking barriers to change in this environment.

The President of H4 (High Level) commented on evidence that the initial focus of the project may have contributed to long-term sustainability: "*We purposely started by the sterilized materials flow, since the medical staff did not believe in lean and were resistant. This strategy worked very well, since we achieved expressive results that even impacted the life of the physician, such as eliminating the delays of sterilized surgical instruments for performing surgeries and reducing the level of hospital infection in clean surgeries to zero. These results caught the attention of the clinical staff, and some physicians asked me to start doing lean in the patient flow as soon as possible, with necessary improvements in the operating room, in bed management, and in the emergency room.*"

The H5 (Low-Level) Clinical Director pointed out: "*We found resistance from the physicians when we started the project by the chemotherapeutic patient flow. Since the patients were often in a critical condition, the clinical staff did not want us to change any procedure, even the administrative ones. This posture influenced the other professionals involved, such as nurses and pharmacists, since the physician has hierarchical power over them."*

It is also possible to notice, from the data and evaluations, that hospitals that obtained the highest sustainability index (H1 and H4) started with administrative flows (information and materials, respectively), while the worst evaluated hospitals (H3 and H5) started their lean journeys through the

patient flow. Despite this, it is realized that it is not only the initial focus of the project that will define the success of the lean journey in the long term, but rather a series of variables together that can make it easier to achieve the expected results in terms of sustainability. Since it is a very small sample, these results need to be better studied and tested in future researches, such as surveys for example.

In general, we believe there are evidences to suggest the following hypothesis, or proposition, that should be tested in future works:

P2: In hospitals where there is initial resistance from physicians, the initial focus of lean implementation should be the information or material flow, instead of the patient flow.

3.4.3 People involvement and high level of lean healthcare sustainability

Process improvement tools and method are important, but their ultimate effectiveness depends on the ability to develop the underlying culture in support growth and continuous improvement. If were not the people who understand the culture behind this system, there would be no operational excellence and organizational performance at Toyota (HOLWEG, 2001). They manage the system, define the true north, use the tools, verify and solve problems, present questions and concepts to other employees, manage projects and form the culture of support. It is also the people who support the philosophical aspect of the system: it is the people who put the client first, check the issues to be solved, do the Gemba Walk, and think about efficiency and operational excellence. Understand the lean thinking as more than a set of mechanistic tools and techniques means considering the dimension's motivation, empowerment and respect for people. Indeed, these elements are essential for the long-term sustainability of any lean program, independently of the sector (HINES, HOLWEG and RICH 2004).

To achieve a high level of lean healthcare sustainability, hospitals should involve people at all stages of implementation. For this, it is important to invest in training, in releasing people time to focus on lean, and in an unrestricted support from the hospital's top management.

Several hospital units in our sample expressed an ongoing concern about looking for ways to involve their staff in the lean project. Hospitals that lost the improvements implemented were just the hospitals that did not invest in building internal lean teams and training the operation. These same hospitals have not worried to engage their professionals, focusing much more on the financial return of the improvement actions. On the other hand, the hospitals that are now in a structured lean sustainability situation were precisely the hospitals that had the top management participating since the beginning at all stages, involving physicians, nurses, pharmacists and other health professionals. These highly sustainable hospitals were the ones that invested most in training and in internal team

formation. Given special regards to the hierarchical structure of healthcare settings, top management should be ready and willing to demonstrate their support for any lean projects whenever issues arise (BEN-TOVIM et al., 2007; CARPENTER, 2011; STEED, 2011). Case studies in the literature findings that physicians and nurses have the most trouble to accepting the cultural changes required for lean when persons of different educational or professional designation make suggestions that change the way their work is carried out (BEN-TOVIM et al., 2007; FILLINGHAM, 2007; CARPENTER, 2011; PAPADOPOULOS et al., 2011). Physicians are considered key contributors to successful change implementation in healthcare and they are not typical employees. Therefore, their attention and involvement is essential. (CARMAN et al., 2010), For instance, one physician of one of the hospitals studied indicated: "*We did not want to be involved and we did not believe in anything that was happening. All the physicians thought this was just another fad where the hospital was losing money. However, the board of the hospital was very emphatic and pulled us hard to participate since the beginning of the program. Today I see that our participation (clinical body) was fundamental to obtain several results and to maintain them.*" Comparing the hospital units that sustain high level of lean improvements (H1 and H4) with those that had difficulties (H2, H3, H5, H6), the sustaining hospitals units encouraged the agents of change in reflecting about questions such as: Who should be invited to participate in the opening of this project? Who should attend this mapping workshop? Who should participate as member of the kaizen team? Who should participate of the Gemba walk meetings? In the same way, these hospitals encourage the operation to be motivated to participate in all stages of the project. This indicates the relevance of involving people to enhance sustainability. It distinguished the hospital units that sustained lean improvements in a high level (H1 and H4) from the others that did not. We now examine the involvement of people more deeply by comparing the case findings and the literature.

3.4.3.1 Employee involvement

Many authors cite the full relevance of involving people to succeed in the lean journey in different segments, including healthcare (SMALLEY, 2005; PORTER, 1996; LEE, 2007; OHNO, 1988; BHASIN, 2011a; BHASIN, 2011b; BHASIN, 2012a; TAPPING et al., 2002; ERIKSSON et al., 2016; GODINHO FILHO et al., 2014).

In this context, the quality manager of the H1 (high level) suggests the importance of involving the top management for having success in sustaining lean efforts: "*The most critical factor for success*

is senior management support in conducting the program. Since the beginning, it was the board that stimulated the involvement and engagement of all employees, from all levels, from physicians to nursing assistants. The board participates today for at least one Gemba walk daily, which consequently causes the involvement of all. Until now, this factor is critical to the continuity of the process." The president at H4 (high level) noted: "*For us, people are the key to any change. So, from the time we started implementing lean in the hospital, I make clear to all physicians and employees that without their involvement and support, we would not achieve our goals. From there, we adopted the strategy of engaging professionals at every stage of the DMAIC so that they felt they were the owners of the whole process of change. That was fundamental! Today, if we walk around the hospital, you will notice the concern they have in keeping everything that has been implemented as organized as possible*."

The administrative director at H5 (Lost) indicated once again that the main goal of short-term financial returns made him not worry about training his operation: "*We have even involved people, but in a very punctual way. People did not feel owner of the changes. Some professionals, especially physicians, have been away almost all the time*". The quality manager at H3 (Lost) indicated once again that lean was top down and did not come as a philosophy of continuous improvement and people involvement: "*the improvements occurred top down, and without reaching a consensus with the operation. Therefore, we often cannot get the commitment to sustain what has been implemented.*"

The quality manager at H2 emphasized the relevance of involving the key people in the change process. "*We seek to involve people as we go through the value streams that they are involved. For a long time we did not want to involve the physicians, because we did not want problems with this professional. Recently, with the clinical director support, we are trying to improve this aspect and some physicians are getting more involved.*" The nurse manager at H6 (medium) agrees that some professionals are even more important than others to make things happen. "*We noticed a lot of difference in the engagement of nurses after the involvement of the physicians. In our hospital, involving them is even more difficult because all of them are partners of the hospital (medical work cooperative)*".

3.4.3.2 Agenda availability and priority

According to Smalley (2005), to develop a sustainable lean transformation, the company needs to develop the employees. Many companies have set up a special group known as "lean change agents" in charge of lean production. The same author agrees that it is necessary to have such dedicated resources in order to start a program and keep up the momentum. In this study, this seems to be correct.

The two hospitals that have not invested in creating an internal lean team with people focused on the project development are the hospitals with the lowest level of sustainability.

The literature also suggests the need to initiate a specific and realistic project at a time rather than initiating various global efforts without proper control of the process improvement as a whole (HINES et al., 2008; BHASIN, 2011a; BHASIN, 2012a). This has a lot to do with the availability of time for hospital professionals to devote themselves to the lean efforts in which they are involved. The manager of a hospital illustrated this conclusion: "*Lean has begun in the middle of numerous other projects and has been not a priority for a long time. We began improving the results and maintaining the processes changes only when we were able to finalize the other issues and focus more on lean*."

According to Lee (2007), the engagement and training of the organization's employees are absolutely vital to the successful implementation of the most diverse concepts of operations management. This also seems to be true, once the hospitals studied that have more invested in training are the hospitals that achieved the higher levels of lean sustainability.

The nurse director at H1 (high level) said: "*Our priority was to structure a team of continuous improvement in the hospital. In the beginning, we started with 2 people, and today this team has merged with the quality team and there are already 8 professionals involved. Speaking about availability, our methodology tells us that we must always open a single A3 per area to not overload the people involved and focus*". The president at H4 (high level) also notes: "*One great difficulty is getting people to take time to think about improvement. Before lean, managers spent most of their time putting out fires and did not have time to think about improvement. Creating a dedicated team for lean has helped us a lot in this early phase*".

The clinical director at H5 (Lost) revealed that the biggest mistake was not having created a team dedicated to lean that could pass on the knowledge acquired for the operation. The quality manager at H3 (Lost) also said, "*It was decided not to invest in an internal improvement structure, since this would depend on more hospital investments. As we all have our routines and many problems to solve, we are very dependent on the consulting*".

The quality manager at H2 emphasized that top management support is really vital for lean sustainability. "*We oscillate much in terms of priority. In the beginning lean was a priority, but when there was a small departure from the board, it was no longer. Little by little, the board returned to be very present in the project and we return to have priority. I believe the availability of everyone here in the hospital is shaped from what the board demonstrates*". The IT manager at H6 (medium) agrees that focus is the success secret: "*A major problem we have is the competition for resources to run the projects. When lean arrived at the hospital, we were implementing ONA certification, an electronic*

medical record system, and changing our entire operating system. We had no time for anything. What secured the project was the creation of a lean team (even if small with one employee)".

Table 30 summarizes the comparisons across hospital units over people involvement and availability. In this section, it was possible to validate the critical success factors 18 to 22 from the theoretical framework related to the People pillar.

3.4.3.3 New findings about People involvement and high level of lean healthcare sustainability

In addition to the critical success factors already inserted in the theoretical framework, it was verified through the results of each case studied and in the comparison between the cases that the information technology (IT) professional, although not once cited in the literature review on lean healthcare, has proven to be a highly important professional to participate in lean improvements in hospitals.

Several authors, including Eriksson et al. (2016), Vink et al. (2008), Langabeer et al. (2009), McGrath et al. (2008), Godinho Filho et al. (2014) and Carman et al. (2010) cite the importance of engaging senior management, physicians, nurses, pharmacists, and other health professionals as essential to increasing the chances of success in lean implementations in hospitals. However, although it did not appear in the literature review, the IT professional demonstrated to have important and differentiated skills to assist in the implementation and sustainability of lean healthcare. According to Herring (1992), who studied the role of IT professional in the National Health Service (NHS) in England, these professionals are information providers to senior managers; information analysts dealing with the needs of clinicians; information gatherers for collecting certain kinds of data; and systems evaluators and developers. Still according to the author, IT professionals in a hospital have a systemic view and can see the whole. Thus, they have a major paper linking people in the information flow.

Over the last decade, information technology has increasingly been seen as a critical lever for improving the quality, safety and efficiency of health systems (CHAUDHRY et al., 2006). Once processes by which new technologies in healthcare are adopted and implemented between various relevant actors and networks, IT professionals can create a better interface with all players, from physicians to analysts (WEBSTER and WYATT, 2007).

Table 30 - Cross-case comparisons of People involvement

Propositions related to People	H1		H2		H3		H4		H5		H6	
	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months	First year	After 18 months
CSF18: **Physicians** - The participation of physicians in lean healthcare projects is a mandatory condition for the success of the sustainability phase of lean improvements (Ackroyd (1996); Eriksson et al. (2016); Godinho Filho et al. (2015)).	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗	✗	✓
CSF19: **Senior Executive** - In hospital settings, where the medical professional is the only one with real autonomy in decision making, the effective participation of the Senior Executive in the day-to-day of the project becomes even more essential. This is because the sponsor is the only one who has a hierarchical position above the doctor (Vink et al. (2008); Eriksson et al. (2016)).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✗
CSF20: **Health professionals** - Health professionals, such as nurses and pharmacists, are the real system operators and who make the operation happen. Their participation in the project and their conviction about the importance of lean are key success factors for the sustainability of the lean improvements (Brandao de Souza (2009); Carman et al. (2010)).	✓	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓
CSF21: **Internal lean team** - The formation of an internal lean team, focused on making improvements, and responsible for replicating their knowledge through the organization is a mandatory condition of success for expansion and sustainability of the lean program (Smalley (2005); Ben-Tovim et al. (2007)).	✓	✓	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓
CSF22: **Availability of leadership time and involvement** - The focus of leadership, with the availability to give the necessary attention to the project, corroborates on a large scale for the success of the lean sustainability (Eriksson et al. (2016); Liker and Hoseus (2008)).	✗	✓	✗	✓	✗	✗	✗	✓	✗	✗	✗	✓
Percentage of theoretical propositions involving "People"that are applied after 18 months	**100%**		**80%**		**20%**		**100%**		**20%**		**80%**	
Sustainability level of "People" theoretical propositions initially implemented after 18 months	**100%**		**67%**		**50%**		**100%**		**50%**		**67%**	

Source: Elaborated by the author

The case studies of this paper also point in this direction and have shown that the IT professional can play a key role in the implementation and sustainability of lean in hospitals. The President of H4 (High Level) commented on evidence that the participation of the IT professional in the lean team may have contributed to long-term sustainability: "*Among the members of our lean team, a professional who caught my attention was the IT professional. Despite being a professional outside the health area, his integration into the team provided a much broader systemic vision, and greater ease of searching for data and information. I see that his participation was even more important in the sustainability phase, because all the changes that occurred in the system were mapped and easily managed.*"

Hospitals H1 (high level) and H6 (middle level) also had active participation of IT professionals in their lean implementations. The clinical director of H1 after being specifically questioned about the role of the IT professional in the hospital, emphasized: "*It is not enough to have just the medical care vision. We need to involve professionals who have a vision from outside and the IT professional was essential for this*." The H6 quality manager told us: "*Nowadays everything in the hospital is computerized. All processes are also digital. How could we make process improvements without the active participation of an IT professional?"*

In our sample, hospitals H3, H5 (low level) and H2 (middle level) did not have the active participation of IT professionals during the lean implementation and sustainability period.

Since it is a very small sample, these results need to be better studied and tested in future researches, such as surveys for example.

In general, we believe there are evidences to suggest the following hypothesis, or proposition, that should be tested in future works:

P3: The active participation of the IT professional in lean implementations in hospitals can increase the chances of success and sustainability in the long term.

3.4.4 Organizational Characteristics as success variables moderators

After confirming, through the cases, the 22 critical success factors (first order concepts) and obtaining new findings on the three pillars elucidated in the theoretical framework (people, method and tools), the authors found evidence that external factors to these pillars may also interfere to facilitate or difficult hospitals to achieve sustainability in their lean implementations. We call them “success variables moderators” and they are intrinsically linked to the organizational characteristics of each hospital.

Previous studies refer to the classification of hospitals by type of administration and financial objective, by geographical areas, by types of services, by accreditation and by size (LOUX et al., 2005). This study will analyze the influence of these organizational characteristics on lean sustainability in hospitals, as described in the sections below.

3.4.4.1 Type of administration and financial objective

Regarding the type of administration, in Brazil, according to Cherubin (1997), hospitals can be identified as: i) Public: administered by a municipal, state or federal governmental entity; or (ii) private: belonging to a person or group of persons governed by private law.

Regarding the financial objective, it can be classified as: i) Philanthropic: a private and non-profit entity, which allocates a percentage of its income to free care to patients without resources or health coverage; ii) Beneficent: private and non-profit association focused on the assistance of specific groups and seek for contributions from associates and users; iii) Medical work cooperative: a form of private business that is democratically owned and controlled by physicians who have common needs, and who in turn work for the non-profit business and receive benefits in proportion to their share; or iv) Ordinary private hospitals: private organizations that objective profit and offsets the employment of its capital with dividend distribution. The authors also differentiate the hospitals concerning the purpose of the hospital itself in terms of being an educational or non-educational hospital.

All the hospitals in this study are private and non-educational, but with different financial objectives. Three hospitals are philanthropic, one of them is a medical work cooperative, and two of them are ordinary private hospitals. It was observed in this study that the two ordinary private hospitals (H1 and H4) were the ones that obtained the best results in terms of sustainability, while the philanthropic ones (H3 and H5) obtained the worst results. Likewise, the hospital that is a medical work cooperative (H6) also did not achieve so good results as the ordinary private ones.

The authors were able to observe in their visits and interviews that the ordinary private hospitals and the medical work cooperative were the ones with more financial resources to make investments. This can be a differential, since investments in team building and training have proved to be essential to the success of lean implementations in the long-term.

On the other hand, despite having financial resources, the medical work cooperative bureaucratese decision-making (many associates) and has short-term thinking (new board elections every 3 years). Since achieving consensus and long-term thinking were also identified as key success factors for lean sustainability in hospitals, this organizational feature may have affected the hospital's performance in terms of lean sustainability.

These factors lead to the follow hypothesis or proposition:

P4: A ordinary private hospital is more likely to succeed in its long-term lean implementations when comparing to other types of Brazilian hospitals, such as the philanthropic and the work medical cooperative ones.

Because it is a small sample, this hypothesis should be proved in future works of greater extension.

3.4.4.2 Geographical areas

Studies related to the geographic location of hospitals are almost always related to aspects of access (GUAGLIARDO, 2004; GRAVES, 2009). The fundamental principle of health geography is that healthcare services should be easily accessed by the population (SURAGE et al., 2017). In the present study, however, the geographic location of each hospital could influence in some way the quality and availability of the workforce, which could consequently affect the sustainability aspects of lean implementations.

When we compare the results among the hospitals studied, although they are located in different regions within Brazil, this factor has not been shown to be a moderator of success. The hospitals that obtained the worst evaluations (H3 and H5) are located in two different capitals of Brazil, both known to have a large workforce supply. The most successful hospitals (H1 and H4) are located respectively in a capital and in an interior city in Brazil. Thus, it is not possible, through this study, to establish a correlation between the sustainability success of lean implementations in hospitals with their geographic location.

3.4.4.3 Type of services

There are two main types of services in hospitals - they can be general or specialized. General hospitals provide care for various types of care. On the other hand, specialized hospitals provide care to specific populations of patients. Some common types of specialized hospitals are: Oncologic Hospital, Cardiologic Hospital, Maternity Hospital, Pediatric Hospital, Psychiatric Hospital, among others (VOELKER, 2003; CASALINO et al., 2003).

In our study, we had 3 oncological hospitals (H1, H3 and H5) and 3 general hospitals (H2, H4 and H6). It is not possible, however, to identify any correlation between the type of service of each hospital and the success in lean sustainability, since hospitals with high and low evaluation (H1 and H5 for example) provide the same type of assistance, but achieved different levels of lean sustainability.

3.4.4.4 Accreditation

Healthcare accreditation standards are broadly known as an important way of improving clinical practice and organizational performance (GREENFIELD et al., 2012).

The transition to lean requires a significant investment of time (WOMACK and JONES, 1996). For example, the actual Toyota Production System has been improved since 1945. This sense of long-term and need for continuous learning has not existed in healthcare (YOUNG and MCCLEAN, 2009). In our study, poor understanding of lean principles by the hospital's staff was identified as a barrier to success. There is evidence of this in the following excerpt from the H3 CEO's interview: *"Our staff had never had contact with any other quality improvement initiatives. I believe that lean was very innovative for them, and in general they had difficulties to understand lean principles and consequently more resistance, mainly at the beginning."*

The high-level hospitals (H1 and H4) and the medium level (H6) were previously certified by the National Accreditation Organization, a non-governmental and non-profit entity that certifies healthcare services quality in Brazil with a focus on patient safety. The other hospitals from our sample were not certified. The fact that these hospitals performed an accreditation process meant that they had formed a quality team previously and made numerous improvements in their processes. This may have facilitated the implementation of lean, since people in these hospitals had a better prior knowledge of process improvement and greater maturity in implementing changes. This does not mean that lean cannot come before accreditation, but rather that these hospitals were better structured to receive lean. Likewise, the tendency is that hospitals that implement lean before going through an accreditation would be much more prepared for the accreditation process. The H4 (high level) quality manager said: "*The fact that we had previously accredited made us more prepared for lean's challenges. We already had a good understanding of process improvement and quality management, which made it easier to understand the lean principles and reduced the resistance by a good part of the assistance team."*

It is important to make it clear that lean and accreditation are not mutually exclusive and that there is no conclusion in this study about what should come first. The hypothesis formulated in this study, however, is:

P5: Hospitals that made the process of accreditation are more prepared to implement lean in their operations and succeed in the long term.

3.4.4.5 Size

Most of the classifications used to identify the hospital size are based on the number of beds. Hospital bed capacity is the number of beds which a hospital has been designed (AL-HYARI et al., 2016).

Regarding the size, according to Loux et al. (2005), the institution can be denominated as follows. Small: it has capacity less than or equal to 50 beds; Medium: has 51 to 100 beds; Large: offers 101 up to 500 beds; and Extra or Special: has more than 500 beds.

In the literature, it is possible to find studies that try to identify if there is influence of size in relation to the success or not of lean implementations, in manufacturing and even in hospitals. Many researchers have assumed that size does not affect a firm's ability to implement lean system, and that small and medium sized enterprises (SMEs) can implement such systems just as effectively as large business (AL-NAJEM et al., 2013; RAGHUNATH and JAYATHIRTHAV, 2014). In reality, large companies and SMEs are able to gain the benefits of lean system (RAGHUNATH and JAYATHIRTHAV, 2014). Rymaszewska (2014) emphasize the successful adoption of lean among SMEs. The author highlights the capability of lean to address the challenges that companies, regardless of their size, face. Strong leadership culture and committed management support the cornerstone for success in implementing any idea regardless of organization size (ACHANGA et al., 2006).

Differently, Bhasin (2012) found that large organizations that implemented lean manufacturing achieved higher improvements in their performance compared to SMEs. Hadid (2014) and Karim and Arif-Uz-zaman (2013) also found that the firm size has an impact on the adaptation of lean practices because large firms are argued to have more financial and human resources allowing more experimentation with new technologies and innovations that may improve their productivity and efficiency

On the other hand, according to Hu et al. (2015), SMEs have a better chance of adapting to change compared with large firms, as they are less hierarchical and less bureaucratic than large firms, and can therefore adopt and form the information across entire departments more efficiently than large one. In the same way, Shah and Ward (2003) found that large organizations suffer from structural inertial forces that negatively affect the implementation of lean manufacturing practices.

In their study to identify whether hospital size influences the success of lean implementations in these environments, Al-Hyari al. (2016) conclude in their sample that hospital performance could be improved significantly without significant differences depending on size.

The literature leaves doubts about the influence of size for the success of lean implementations, with different opinions among the authors.

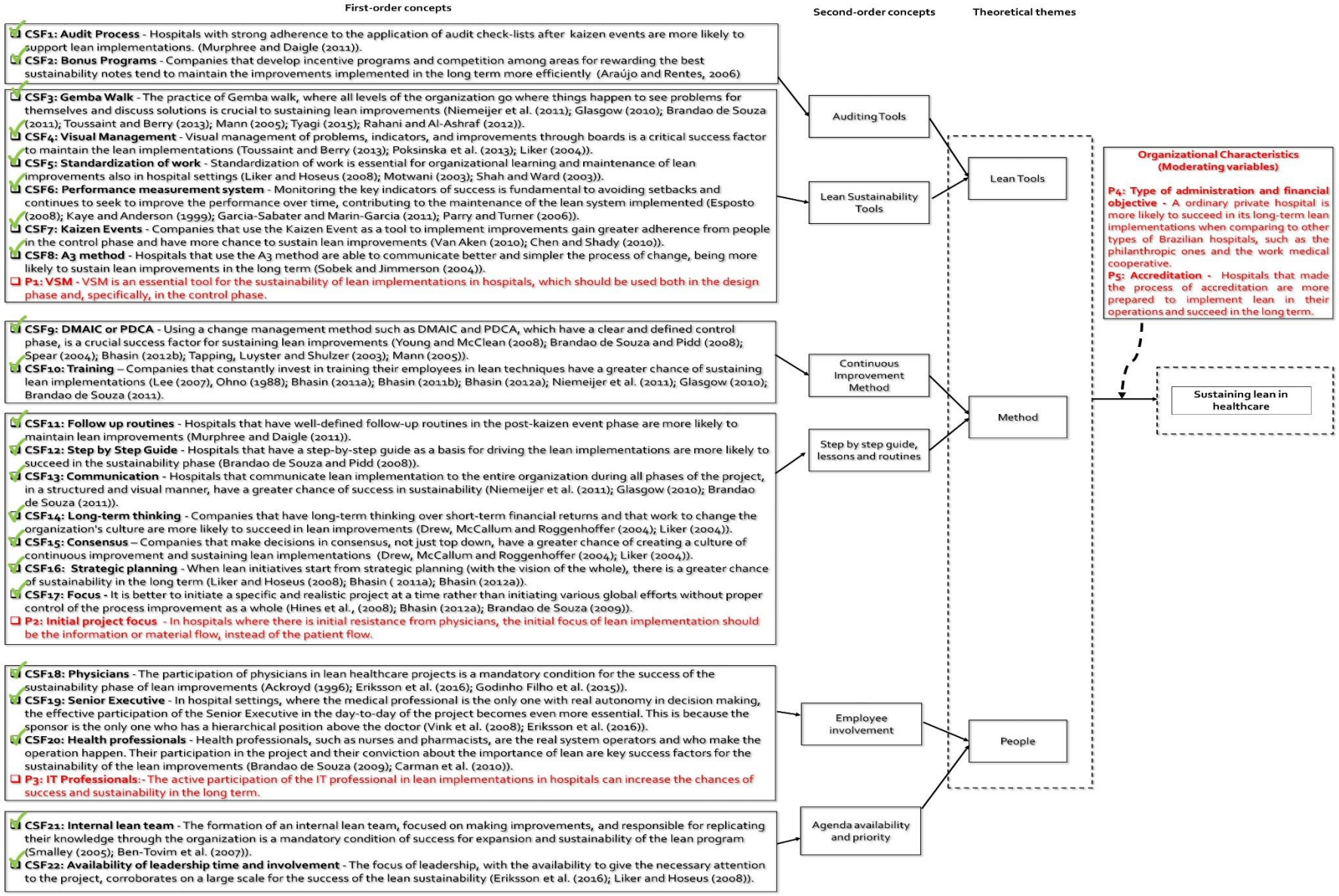
Similarly to Al-Hyari al. (2016), our sample did not point to significant differences between the sustainability of lean implementations and hospitals' size, since a small hospital (H1) and a large hospital (H4) were the hospitals with the highest degree of lean sustainability.

3.4.5 Final proposed Framework

Fig. 16 gives the proposal framework that emerged from the above analysis. Sustaining lean improvements in healthcare is reflected by maintaining the new operational standards implemented and by creating a culture of continuous improvement. All hospital units in our study implemented several lean management practices (e.g. Value stream mapping, visual management, continuous flow, kanban, work standardization, 5S, work cells, lean routines, etc.) to a certain level.

All the first order concepts consolidated during the literature review were analyzed and showed to be differential factors among the hospitals that achieved long-term lean sustainability over those which did not. In addition to the 22 critical success factors from the theoretical framework, other 5 new propositions were originated through the analysis of the cases. Three of these new propositions were organized within the 3 main pillars already emerged from the literature: People, Methods, and Tools. It was observed in the cases, in addition, that some organizational characteristics of the hospitals studied proved to be moderators of success for the sustainability of lean implementations and two new propositions were considered in the proposed final framework.

Figure 16 - First and second order concepts of each theoretical theme (Proposed Framework)



3.5 Conclusions

Through the analysis of the literature, it was possible to compile 22 main critical success factors of lean sustainability in hospitals through three main pillars: people, method and tools. With the analysis of the cases, it was possible to confirm the relevance of these 22 theoretical propositions, and also to add to the framework another 5 new propositions. Three of these propositions related to each described pillar and two other propositions that identify moderators of success directly linked to the organizational characteristics of each hospital.

As a first final result of this study, it was observed that hospital units with high sustainability invest since the beginning of the program to have a fully participative board in all phases of the project. Consequently, all health professionals are involved, trained, and encouraged to learn and apply lean in their daily activities. Physicians have proven to be the most important professionals to influence and make improvements sustainable. The formation of an internal lean team also proved to be a differential factor in maintaining sustainability among high-level and low-level sustainability hospitals. It was also identified that the involvement of the IT professional can be a differential factor to achieve success in lean sustainability.

Second, sustaining lean improvements in hospitals involves the application of a structured method of conducting process change. The hospitals units with a higher level in maintaining lean standards and with the greatest commitment to continue improving the processes were those that besides using the method as a structuring tool for scientific problem resolution, used it as a methodology for conducting the project, with a detailed step-by-step and lessons learned from other experiences. In addition to the propositions identified through the compilation of previously disconnected success factors (theoretical framework), the comparison between the cases showed that in hospitals where there is initial resistance from physicians, the initial focus of lean implementations should be the information or material flow, instead of the patient flow.

The correct application of lean tools at the right moments also proved decisive in the sustainability of lean in the hospitals studied. Lean audit tools, such as sustainability checklist, and audit notes for standards maintenance, as well as visual management boards, kaizen events, and standardization of activities were key factors in maintaining lean in hospitals that have succeed to maintain a high standard of lean sustainability. Another lean tool identified as a

differential factor among the hospitals that applied it during the control phase was the value stream map. VSM has proved to be essential both in the design phase and in the sustainability phase.

Another interesting conclusion that can be drawn is that although it is notorious knowledge, several points brought by the theoretical framework proved to be difficult to implement and the hospitals are failing to implement the basics.

After confirming, through the cases, the 22 critical success factors (first order concepts) and obtaining new findings on the three pillars elucidated in the theoretical framework (people, method and tools), the authors found evidence that external factors to these pillars may also interfere to facilitate or difficult hospitals to achieve sustainability in their lean implementations. They are called “success variables moderators” and they are intrinsically linked to the organizational characteristics of each hospital. In this sense, the authors investigated if there was influence in the sustainability success by the following hospital organizational characteristics, according to the classification previously proposed by Loux et al. (2005): i) type of administration and financial objective; ii) geographical areas; iii) types of services; iv) accreditation; and v) size of the hospitals. It was verified, in the hospitals studied, that characteristics such as “geographic area”, “type of service”, and “size” did not influence the success of sustainability. On the other hand, the “type of administration and financial objective” and “accreditation” have proved to be successful moderators and can influence the hospital to achieve success in its lean implementations in the long term. In sum, what the cases showed is that ordinary private hospitals and hospitals that have gone through the accreditation process prior to the implementation of lean have a greater chance of sustainability.

These new insights are revealed by studying hospitals after minimum 18 months of lean implementation and comparing the ones that have achieved a high level of lean sustainability with those that do not.

The comparative case analysis integrates several literature streams to develop a coherent framework that helps hospitals to sustain lean efforts. The case data helps identify concepts in different literature streams and connect them to an operations management context. It differs from previous studies by specifying the level and consistency components of lean healthcare sustainability.

It is important to say that the proposed framework aims to elucidate the factors that can make the difference in terms of lean sustainability in healthcare. These factors should be taken into consideration by healthcare organizations in their lean deployment planning, in order to have a greater chance of success.

The goal of the framework, therefore, is not to organize a step-by-step guidance with the sequence which these critical success factors should be implemented, nor even to demonstrate the interrelationship between these factors. These analyzes are great opportunities for future research that can make an immense contribution to literature and practice.

This research provides a conceptual model for sustaining lean in healthcare. The final framework proposed have important implications for practice and for the academia, bringing good opportunities for future research.

Like most studies, this research is not without limitations. The research is based on a purposive sample from six hospital units with the purpose of developing propositions and a theory for future testing. The qualitative research study only focuses on Brazilian hospitals, which could have a different reality from other hospitals in other countries. Studying a wider array of hospitals would improve the generalizability of the results. Future research should select a larger sample of hospitals in different countries for further investigation. We hope this model brings new ways of thinking about sustaining lean in healthcare.

Chapter 4

CONCLUSIONS

In this chapter, the final considerations of this thesis are presented. First, the results are discussed observing if the research objectives were achieved. Second, the final considerations about the contributions of the comparative case study in lean healthcare sustainability are elucidated. Finally, the limitations and suggestions for future researches are presented.

4.1 Attending to the research objectives

In the conclusion of a research it is necessary to evaluate the coherence between the objectives initially proposed in the research and the work actually carried out.

The development of this thesis was initiated with the follow research question: “How do hospitals sustain lean initiatives in their operations?” To answer this question, first, a theoretical framework with best practices in terms of lean sustainability was developed. This framework is composed of 22 critical success factors, organized in three pillars: People, Method and Tools. To develop it, a systematic literature review of empirical research in Lean, Six Sigma and Lean Six Sigma in Healthcare was conducted and combined with an exploratory review. After that, the authors conduct a comparative case study analysis that iterates between the literature and the case data to confirm the theory proposed by the theoretical framework and to propose new findings on lean healthcare sustainability. In addition to the 22 critical success factors from the theoretical framework, other 5 new propositions were originated through the analysis of the cases. Three of these new propositions were organized within the 3 main pillars already emerged from the literature: People, Methods, and Tools. It was observed in the cases, in addition, that some organizational characteristics of the hospitals studied proved to be moderators of success for the sustainability of lean implementations and two new propositions were considered in the proposed final framework.

This proposed final framework could also answer other initial research questions, elucidating the key points that differentiate successful hospitals in sustaining lean

improvements with the failing ones. The proposed framework also makes clear the main factors that hospitals cannot neglect to achieve long-term sustainability in lean initiatives. An interesting conclusion that can be drawn is that although it is notorious knowledge, several points brought by the theoretical framework proved to be difficult to implement and the hospitals are failing to implement the basics. These new insights were revealed by studying hospitals after minimum 18 months of lean implementation and comparing the ones that have achieved a high level of lean sustainability with those that do not.

It is also important to elucidate that the systematic literature review of empirical research in Lean, Six Sigma and Lean Six Sigma in Healthcare, conducted in this thesis, present the state of the art in this subject and propose future directions, consistent with the needs of professionals and academics.

The systematic literature review conducted resulted in several key findings that suggest there are still certain dark and unexplored themes in continuous improvement implementations in healthcare. There is an immediate need for empirical research in this field that not only describe what tools are applied and what are the results obtained, but also to elucidate how the implementations are conducted.

The entire content development of this thesis meets the initial objectives proposed in the research, to organize a framework that could guide practitioners and academics with the critical success factors for lean sustainability in hospital settings.

4.2 Final considerations and contributions

The authors of this thesis do not know until now the existence of an empirical systematic review of the literature on the implementation of Lean, Six Sigma and Lean Six Sigma in healthcare, and its development, by itself, is already a great contribution to the literature.

This systematic literature review resulted in several key findings that suggest there are still certain dark and unexplored themes in continuous improvement implementations in healthcare, and therefore, future researches are necessary. Some of these aspects are:

1. The great majority of the empirical articles published about lean, six sigma and lean six sigma in healthcare environments has even not mentioned any sustainability aspect of the improvement realized. The few articles that describe some sustainability aspect have not described the situation after 24 months of the improvement implementation.

2. Any revised article has focused on describing in detail the specific barriers for improvement efforts in the healthcare sector, which are not found in other sectors/segments.
3. It is still needed studies describing how to create a continuous improvement culture in practice and the main successful factors on how to sustain the improvements implemented.
4. The contributions of empirical articles from developing countries are significantly smaller than from the developed ones. The USA, the United Kingdom, the Netherlands and Sweden together, represent 75 percent of the 84 empirical articles analysed in the systematic literature review. So, there is a need to bring the researchers across the globe on a single platform to get better results.

The comparative case study developed in this thesis sought to respond to these specific gaps found in the systematic literature review by proposing a framework that allows hospitals to conduct a structured process of change, with all the foundation needed to succeed and sustain the lean journey in the long-term. It differs from previous studies by integrating literature streams that have been previously disconnected and by specifying the components of lean healthcare sustainability.

To the best of our knowledge, this thesis is the first to attempt to bring together the key factors that influence hospitals to sustain lean improvements in the long term.

The comparative case study resulted in a conceptual model for sustaining lean in healthcare. The final framework proposed have important implications for practitioners and academics, bringing good opportunities for future research. Some of the main contributions are:

1. Regarding the People Pillar, it was observed that hospital units with high sustainability invest since the beginning of the program to have a fully participative board in all phases of the project. Consequently, all health professionals are involved, trained, and encouraged to learn and apply lean in their daily activities. Physicians have proven to be the most important professionals to influence and make improvements sustainable. The formation of an internal lean team also proved to be a differential factor in maintaining sustainability among the hospitals. It was also identified that the involvement of the IT professional can be a differential factor to achieve success in lean sustainability.
2. Regarding the Method Pillar, it is possible to conclude that sustaining lean improvements in hospitals involves the application of a structured method of conducting process change. The hospitals units with a higher level in maintaining lean standards and with the greatest commitment to continue improving the processes were those that besides using the method as a structuring tool for scientific problem resolution, used it as a methodology for conducting the project, with a detailed step-by-step and lessons learned from other

experiences. In addition to the propositions identified through the compilation of previously disconnected success factors (theoretical framework), the comparison between the cases showed that in hospitals where there is initial resistance from physicians, the initial focus of lean implementation should be the information or material flow, instead of the patient flow.

3. Regarding the Tools Pillar, it is possible to conclude that the correct application of lean tools at the right moments proved to be decisive in the sustainability of lean in the hospitals studied. Lean audit tools, such as sustainability checklist, and audit notes for standards maintenance, as well as visual management boards, kaizen events, and standardization of activities were key factors in maintaining lean in hospitals that have succeed to maintain a high standard of lean sustainability. Another lean tool identified as a differential factor among the hospitals that applied it during the control phase was the value stream map. VSM has proved to be essential both in the design phase and in the sustainability phase.
4. The authors found evidence that external factors to these three pillars (people, method and tools) may also interfere to facilitate or difficult hospitals to achieve sustainability in their lean implementations. They are called “success variables moderators” and they are intrinsically linked to the organizational characteristics of each hospital. Between the variables studied, it was verified that characteristics such as “geographic area”, “type of service”, and “size” did not influence the success of sustainability. On the other hand, the “type of administration and financial objective” and “accreditation” have proved to be successful moderators and can influence the hospital to achieve success in its lean implementations in the long term. In sum, what the cases showed is that ordinary private hospitals and hospitals that have gone through the accreditation process prior to the implementation of lean have a greater chance of sustainability.

4.3 Research limitations and future research propositions

Despite the results and contributions presented in the two previous subsections, this research also has limitations.

This research involved only six hospitals and the generalization of the results is not possible, being an implicit limitation to the research method used. In this way, the results and propositions mentioned should be studied more broadly. As a suggestion of future work, in

order to mitigate this limitation, we suggest the use of quantitative methods like surveys, or also, triangular approaches, considered more robust by using different sources of information and forms of analysis (BARRAT, BARRAT, 2011).

Another limitation relates to the main technique of primary data collection used in this research: the interview. In total, 18 professionals were interviewed in different contexts. Some of them had a limitation of available time, being necessary to conduct the speech in a more punctual way and with a predetermined time available by the professional. With others, also due to the restriction of available time, it was necessary to conduct the interview in two different moments, thus compromising the line of reasoning of the discussion.

The qualitative research study only focuses on Brazilian hospitals, which could have a different reality from other hospitals in other countries. Studying a wider array of hospitals would also improve the generalizability of the results. Future research should select a larger sample of hospitals in different countries for further investigation.

As the main suggestions for future research, we emphasize the elaboration of surveys, which cover a significant number of hospitals to increase the chances of generalization of the new propositions observed in this work:

P1: VSM is an essential tool for the sustainability of lean implementations in hospitals, which should be used both in the design phase and, specifically, in the control phase.

P2: In hospitals where there is initial resistance from physicians, the initial focus of lean implementation should be the information or material flow, instead of the patient flow.

P3: The active participation of the IT professional in lean implementations in hospitals can increase the chances of success and sustainability in the long term.

P4: A ordinary private hospital is more likely to succeed in its long-term lean implementations when comparing to other types of Brazilian hospitals, such as the philanthropic and the work medical cooperative ones.

P5: Hospitals that made the process of accreditation are more prepared to implement lean in their operations and succeed in the long term.

Other studies could also seek to prove the generalization of the 22 first order concepts as critical success factors for lean sustainability in hospitals.

The possibilities for future research reinforce the relevance of the study topic addressed in this thesis. We hope this thesis brings new ways of thinking about sustaining lean in healthcare.

REFERENCES

ACHANGA, P.; SHEHAB, E.; ROY, R.; AND NELDER, G. Critical Success Factors for Lean Implementation within SMEs. **Journal of Manufacturing Technology Management**, Vol. 17 No. 4, pp. 460-471, 2006.

Adams, R.; Warner, P.; Hubbard, B.; Goulding, T. Decreasing turnaround time between general surgery cases. **JONA**, 34(3), 140-148, 2004.

AGUILAR-ESCOBAR, V. G.; BOURQUE, S.; GODINO-GALLEGO, N. Hospital kanban system implementation: Evaluating satisfaction of nursing personnel. **Investigaciones Europeas de Dirección y Economía de la Empresa**, 21(3), 101-110, 2015.

AHMAD, S. Culture and Lean Manufacturing – Towards a Holistic Framework. **Australian Journal of Basic and Applied Sciences**, v. 7, n. 1, p. 334-338, 2013.

AIJ, K. H., SIMONS, F. E.; WIDDERSHOVEN, G. A.; VISSE, M. Experiences of leaders in the implementation of Lean in a teaching hospital—barriers and facilitators in clinical practices: a qualitative study. **BMJ open**, 3(10), e003605, 2013.

AL-NAJEM, M.; DHAKAL, H.; LABIB, A.; BENNETT, N. Lean Readiness Level within Kuwaiti Manufacturing Industries. **International Journal of Lean Six Sigma**, Vol. 4 No. 3, pp. 280 – 320, 2013.

ANDALEEB, S.S. Service quality perceptions and patient satisfaction: a study of hospitals in a developing country. **Social Science and Medicine**, Vol. 52 No. 9, pp. 1359-70, 2001.

ANDERSEN, H.; RØVIK, K. A. Lost in translation: a case-study of the travel of lean thinking in a hospital. **BMC health services research**, 15(1), 401, 2015.

ANDRIOPOULOS, C.; LEWIS, M.W. Exploitation–exploration tensions and organizational ambidexterity: managing paradoxes of innovation. **Organ. Sci.** 20,696–717, 2009.

ANTONY, J.; KUMAR, M. Lean and Six Sigma methodologies in NHS Scotland: an empirical study and directions for future research. **Quality Innovation Prosperity**, 16(2), 19-34, 2012.

ARAÚJO, C.; RENTES, A. A Metodologia Kaizen na condução de Processos de Mudança em Sistemas de Produção Enxuta**. Revista Gestão Industrial** v. 02, n. 02: p. 133-142, 2006.

ARTHUR, J. Lean six sigma for hospitals: simple steps to fast, affordable, and flawless healthcare. New York, NY: McGraw-Hill, 2011.

ARUMUGAM, V.; ANTONY, J.; KUMAR, M. Linking learning and knowledge creation to project success in Six Sigma projects: An empirical investigation. **International Journal of Production Economics**, 141(1), 388-402, 2013.

Assarlind, M.; Gremyr, I.; Bäckman, K. Multi-faceted views on a Lean Six Sigma application. **International Journal of Quality & Reliability Management**, 30(4), 387-402, 2013.

ATKINSON, P. Lean is a cultural issue. **Management Services**, v. 54, p. 35-44, 2010.

BAHENSKY, J. A.; ROE, J.; BOLTON, R. Lean sigma—will it work for healthcare. **J Healthc Inf Manag**, 19(1), 39-44, 2005.

BAMFORD, D.; FORRESTER, P.; DEHE, B.; LEESE, R. G. Partial and iterative Lean implementation: two case studies. **International Journal of Operations & Production Management**, 35(5), 702-727, 2015.

BARIL, C.; GASCON, V.; MILLER, J.; CÔTÉ, N. Use of a discrete-event simulation in a Kaizen event: A case study in healthcare. **European Journal of Operational Research**, 249(1), 327-339, 2016.

BARRAT, M.; BARRAT, R. Exploring internal and external supply chain linkages: evidence from the field. **Journal of Operations Management**, v.29, p.514-528, 2011.

BASTIAN, N. D.; MUNOZ, D.; VENTURA, M. A mixed-methods research framework for healthcare process improvement. **Journal of pediatric nursing**, 31(1), e39-e51, 2016.

BATEMAN, N. Sustainability: the elusive element of process improvement. **International Journal of Operations and Production Management**, Vol.25, No.3, p.261-276, 2005.

BATEMAN, N.; DAVID, A. Process improvement programs: a model for assessing sustainability. **International Journal of Operations e Production Management**, Vol.22, No.5, p. 515-26, 2002.

BEGEN, M. A.; PUN, H.; YAN, X. Supply and demand uncertainty reduction efforts and cost comparison. **International Journal of Production Economics**, 180, 125-134, 2016.

BEN-TOVIM, D. I.; BASSHAM, J. E.; BENNETT, D. M.; DOUGHERTY, M. L.; MARTIN, M. A.; O'NEILL, S. J.; SZWARCBORD, M. G. Redesigning care at the Flinders Medical Centre: clinical process redesign using" lean thinking". **Medical Journal of Australia**, 188(6), S27, 2008.

BESSANT, J.; CAFFYN, S.; GILBERT, J. Mobilizing continuous improvement for strategic advantage, **Euroma,** Vol.1, p.175-80, 1994.

BHASIN, S. Performance of organizations treating Lean as an ideology. Department of Quality Assurance, NOMS Civil Service College, Rugby, UK. Business **Process Management**, Emerald Group Publishing Limited, 2011a.

BHASIN, S. Measuring the Leanness of an organization. NOMS College, Stretton-under-Fosse, UK. **International Journal of Lean Six Sigma**, Emerald Group Publishing Limited, 2011b.

BHASIN, S. An appropriate change strategy for Lean success. **Management Decision**, Emerald Group Publishing Limited, 2012a.

BHASIN, S. Prominent obstacles to Lean. **International Journal of Productivity and Performance Management**. Vol. 16, No. 4, 2012b.

BHASIN, S.; BURCHER, P. Lean viewed as a philosophy. **Journal of manufacturing technology management,** 17(1), 56-72, 2006.

BICHENO, J.; HOLWEG, M. The Lean Toolbox: the essential guide to Lean transformation. 4 th ed. **Buckingham**: Picsie, 290 p, 2009.

BISGAARD, S. Solutions to the healthcare quality crisis: Cases and examples of lean six sigma in healthcare. **ASQ Quality Press**, 2009.

BISGAARD, S.; DOES, R. J. Quality Quandaries*: Health CareQuality—Reducing the Lengthof Stay at a Hospital. **Quality Engineering**, 21(1), 117-131, 2008.

BISHU, R. R.; JONES, E. C.; THUMMALAPALLI, R. DEAPS-An alternative to DMAIC? A case study. **International Journal of Industrial Engineering**: Theory Applications and Practice, 16(3), 214-226, 2009.

BRANDAO DE SOUZA, L. Trends and approaches in lean healthcare. **Leadership in health services**, 22(2), 121-139, 2009.

BRANDAO DE SOUZA, L.; PIDD, M. Exploring the barriers to lean health care implementation. **Public Money & Management**, 31(1), 59-66, 2011.

BRANDAO DE SOUZA, L.; PIDD, M.; GUNAL, M. M. Lean healthcare and computer simulation: a soft-hard approach. In Proceedings of Operations Research Applied in Health Services Conference, Toronto, ON, 2008.

BRYMAN, A. Research methods and organization studies (Vol. 20). Routledge, 2003.

BURSTRÖM, L.; LETTERSTÅL, A.; ENGSTRÖM, M. L.; BERGLUND, A.; ENLUND, M. The patient safety culture as perceived by staff at two different emergency departments before and after introducing a flow-oriented working model with team triage and lean principles: a repeated cross-sectional study. **BMC health services research**, 14(1), 1, 2014.

BUTTLE, F. "SERVQUAL: review, critique and research agenda", **European Journal of Marketing**, Vol. 30 No. 1, pp. 8-32, 1996.

CAMERON, K. S.; QUINN, R. E. Diagnosing and Changing Organizational Culture: based on the competing values framework. San Francisco: Jossey Bass, pp. 242, 2009.

CARDOEN, B.; BELIËN, J.; VANHOUCKE, M. On the design of custom packs: grouping of medical disposable items for surgeries. **International Journal of Production Research**, 53(24), 7343-7359, 2015.

CASALINO, L. P.; DEVERS, K. J.; BREWSTER, L. R. Focused factories? Physician-owned specialty facilities. **Health Affairs**, 22(6), 56-67, 2003.

CASEY, J. J. W. A lean enterprise approach to process improvement in a health care organization (Doctoral dissertation, **Massachusetts Institute of Technology**), 2007.

CHAUDHRY, B.; WANG, J.; WU, S.; MAGLIONE, M.; MOJICA, W.; ROTH, E.; SHEKELLE, P. G. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. **Annals of internal medicine**, 144(10), 742-752, 2006.

CHEN, J. C.; LI, Y.; SHADY, B. D. From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study. International Journal of Production Research, 48(4), 1069-1086, 2010.

CHENG, C. Y.; CHANG, P. Y. Implementation of the Lean Six Sigma framework in non-profit organizations: A case study. **Total Quality Management & Business Excellence**, 23(3-4), 431-447, 2012.

CHENG, S. Y.; BAMFORD, D.; PAPALEXI, M.; DEHE, B. Improving access to health services–challenges in Lean application. **International Journal of Public Sector Management,** 28(2), 121-135, 2015.

CHERRY, J.; SESHADRI, S. Six Sigma: using statistics to reduce process variability and costs in radiology. **Radiology Management**, 22(6), 42-49, 2000.

CHERUBIN, N. A. Administração hospitalar: fundamentos. In Administração hospitalar: fundamentos. Cedas, 1997.

CHUNG, S. H.; KWON, C. Integrated supply chain management for perishable products: Dynamics and oligopolistic competition perspectives with application to pharmaceuticals. **International Journal of Production Economics**, 179, 117-129, 2016.

CIGOLINI, R.; FEDELE, L.; VILLA, A. N. Managing facilities under the multi-service result-oriented approach: some insights coming from the field in Italy. **Production Planning & Control**, 19(4), 312-326, 2008.

CIMA, R. R.; BROWN, M. J.; HEBL, J. R.; MOORE, R.; ROGERS, J. C.; KOLLENGODE, A.; TEAM, S. P. I. Use of lean and six sigma methodology to improve operating room efficiency in a high-volume tertiary-care academic medical center. **Journal of the American College of Surgeons**, 213(1), 83-92, 2011.

COSTA, L. B. M.; GODINHO FILHO, M.; RENTES, A. F.; BERTANI, T. M.; MARDEGAN, R. Lean healthcare in developing countries: evidence from Brazilian hospitals. **The International journal of health planning and management**, 2015.

COTTYN, J.; VAN LANDEGHEM, H.; STOCKMAN, K.; DERAMMELAERE, S. A method to align a manufacturing execution system with Lean objectives. **International Journal of Production Research**, 49(14), 4397-4413, 2011.

COUGHLAN, P.; COGHLAN, D. Action research for operations management. **International journal of operations & production management**, 22(2), 220-240, 2002.

CREMA, M.; VERBANO, C. How to combine lean and safety management in health care processes: A case from Spain. **Safety Science**, 79, 63-71, 2015.

D'ANDREAMATTEO, A.; IANNI, L.; LEGA, F.; SARGIACOMO, M. Lean in healthcare: A comprehensive review. **Health Policy**, 119(9), 1197-1209, 2015.

DALE, B. G.; BOADEN, R. J.; WILCOX, M.; MCQUATER, R. E. Sustaining Total Quality Management: What Are the Key Issues? **The TQM Magazine**, Vol.9, No.5, p.372-380, 1997.

DELLIFRAINE, J. L.; LANGABEER, J. R.; NEMBHARD, I. M. Assessing the evidence of Six Sigma and Lean in the health care industry. **Quality Management in Healthcare**, 19(3), 211-225, 2010.

DELOITTE; TOUCHE. The road to world class manufacturing, Deloitte and Touche, 2002.

DICKSON, E. W.; ANGUELOV, Z.; VETTERICK, D.; ELLER, A.; SINGH, S. Use of lean in the emergency department: a case series of 4 hospitals. Annals of emergency medicine, 54(4), 504-510, 2009.

DICKSON, E. W.; SINGH, S.; CHEUNG, D. S.; WYATT, C. C.; NUGENT, A. S. Application of lean manufacturing techniques in the emergency department. **The Journal of emergency medicine**, 37(2), 177-182, 2009.

DOBRZYKOWSKI, D. D.; MCFADDEN, K. L.; VONDEREMBSE, M. A. Examining pathways to safety and financial performance in hospitals: A study of lean in professional service operations. **Journal of Operations Management**, 42, 39-51, 2006.

DOMBROWSKI, U.; MIELKE, T. Lean leadership–fundamental principles and their application. **Procedia CIRP**, 7, 569-574, 2013.

DREW, J.; MCCALLUM, B.; ROGGENHOFER, S. The Essence of Lean. In Journey to Lean (pp. 15-24). Palgrave Macmillan UK, 2004.

DUSKA, L. R.; MUELLER, J.; LOTHAMER, H.; PELKOFSKI, E. B.; NOVICOFF, W. M. Lean methodology improves efficiency in outpatient academic Gynecologic Oncology clinics. **Gynecologic oncology**, 138(3), 707-711, 2015.

EISENHARDT, K. M. Building theories from case study research. **Academy of management review**, 14(4), 532-550, 1989.

EL-BANNA, M. Patient Discharge Time Improvement by Using the Six Sigma Approach: A Case Study. **Quality Engineering**, 25(4), 401-417, 2013.

EMDEN, Z.; CALANTONE, R.J.; DROGE, C. Collaborating for new product development: selecting the partner with maximum potential to create value. **J. Prod. Innov. Manage**. 23, 330–341, 2006.

ERIKSSON, A.; HOLDEN, R. J.; WILLIAMSSON, A.; DELLVE, L. A Case Study of Three Swedish Hospitals' Strategies for Implementing Lean Production. **Nordic Journal of Working Life Studies**, 6(1), 105, 2016.

ESPOSTO, K. F. Elementos estruturais para gestão de desempenho em ambientes de Produção Enxuta. 241 p. Tese (Doutorado em Engenharia de Produção) - **Escola de Engenharia de São Carlos,** Universidade de São Paulo, São Carlos, 2008.

FERLIE, E.; FITZGERALD, L.; MCGIVERN, G.; DOPSON, S.; EXWORTHY, M. Networks in health care: a comparative study of their management, impact and performance. **Book Networks in Health Care**, 2010.

FERRO, J. R. O Movimento Lean no Brasil e no mundo. **Lean Institute Brasil**. Avaiable in: http://www.lean.org.br/leanmail/19/o-movimento-lean-no-brasil-eno-mundo.aspx. Access in: 14 mar. 2016. 2008.

FILLINGHAM, D. Can lean save lives? **Leadership in health services**, 20(4), 231-241, 2007.

FLYNN, B. B.; SAKAKIBARA, S.; SCHROEDER, R. G.; BATES, K. A.; FLYNN, E. J. Empirical research methods in operations management. **Journal of operations management,** 9(2), 250-284, 1990.

FULLERTON, R. R.; WEMPE, W. F. Lean manufacturing, non-financial performance measures, and financial performance**. International Journal of Operations & Production Management**, 29(3), 214-240, 2009.

FURTERER, S. L. Applying lean Six Sigma to reduce linen loss in an acute care hospital. **International Journal of Engineering, Science and Technology**, 3(7), 39-55, 2011.

GARCIA-SABATER, J. J.; MARIN-GARCIA, J. A. Can we still talk about continuous improvement? Rethinking enablers and inhibitors for successful implementation**. International Journal of Technology Management**, 55(1/2), 28-42, 2011.

GIJO, E. V.; ANTONY, J. Reducing patient waiting time in outpatient department using lean six sigma methodology. **Quality and Reliability Engineering International**, 30(8), 1481-1491, 2014.

GILLESPIE, S. M.; OLSAN, T., LIEBEL, D.; CAI, X.; STEWART, R.; KATZ, P. R.; KARUZA, J. Pioneering a Nursing Home Quality Improvement Learning Collaborative: A Case Study of Method and Lessons Learned. **Journal of the American Medical Directors Association**, 17(2), 136-141, 2016.

GIOIA, D.A.; THOMAS, J.B. Identity, image, and issue interpretation: sense making during strategic change in academia. **Adm. Sci**. Q. 41, 370–403, 1996.

GLASGOW, J. M.; SCOTT-CAZIEWELL, J. R.; KABOLI, P. J. Guiding inpatient quality improvement: a systematic review of Lean and Six Sigma. **The Joint Commission Journal on Quality and Patient Safety,** 36(12), 533-540, 2010.

GLASGOW, J. M.; SCOTT-CAZIEWELL, J. R.; KABOLI, P. J. Guiding inpatient quality, 2010.

GODINHO FILHO, M.; BOSCHI, A.; RENTES, A. F.; THURER, M.; BERTANI, T. M. Improving Hospital Performance by Use of Lean Techniques: An Action Research Project in Brazil. **Quality Engineering**, 27(2), 196-211, 2015.

GOH, T. N. A strategic assessment of Six Sigma. **Quality and Reliability Engineering International**, 18(5), 403-410, 2002.

GRABAN, M. Lean hospitals: Improving quality, patient safety, and employee engagement. **CRC press**, 2011.

GRAHAM, I. Take your time to total quality success. **Works Management**, pp. 17-21, 1991.

GRAVENHORST, K. M. B.; WERKMAN, R. A.; BOONSTRA, J. J. The change capacity of organizations: general assessment and five configurations. **Applied Psychology: and international review**, Vol. 54, pp. 83-105, 2003.

GREENFIELD, D.; PAWSEY, M.; HINCHCLIFF, R.; MOLDOVAN, M.; BRAITHWAITE, J. The standard of healthcare accreditation standards: a review of empirical research underpinning their development and impact. **BMC health services research**, 12(1), 329, 2012.

GROVE, A. L.; MEREDITH, J. O.; MACINTYRE, M.; ANGELIS, J.; NEAILEY, K. UK health visiting: challenges faced during lean implementation. **Leadership in Health Services**, 23(3), 204-218, 2010.

GUAGLIARDO, M. F. Spatial accessibility of primary care: concepts, methods and challenges. **International journal of health geographics**, 3(1), 3, 2004.

GUIMARÃES, C. M.; DE CARVALHO, J. C. Lean healthcare across cultures: state-of-the-art. **American International Journal of Contemporary Research**, 2(6), 187-206, 2012.

GUVEN-USLU, P.; CHAN, H. K.; IJAZ, S.; BAK, O.; WHITLOW, B.; KUMAR, V. In-depth study of 'decoupling point'as a reference model: an application for health service supply chain. **Production Planning & Control**, 25(13-14), 1107-1117, 2014.

HADID, W.; MANSOURI, A. The Lean-Performance Relationship in Services: a Theoretical Model. **International Journal of Operations & Production Management**, Vol. 34 No. 6, pp. 750-785, 2014.

HAGAN, P. Waste not, want not: Leading the lean health-care journey at Seattle Children's Hospital. **Global Business and Organizational Excellence**, 30(3), 25-31, 2011.

HART, C. Doing a literature review: Releasing the social science research imagination. Sage, 1998.

HELLER, F.; PUSIC, E.; STRAUSS, G.; WILPERT, B. Organizational participation – myth and reality. **Oxford University Press**, 1998.

HENKE, C. ASQ study: healthcare catches on to lean, Six Sigma. **Quality Progress**, Vol. 42 No. 5, p. 17, 2009.

HENRIQUE, D. B.; RENTES, A. F.; GODINHO FILHO, M.; & ESPOSTO, K. F. A new value stream mapping approach for healthcare environments. **Production Planning & Control**, 27(1), 24-48, 2016.

HERRING, J. E. The role of the healthcare information officer. **In Aslib proceedings** (Vol. 44, No. 3, pp. 139-146). MCB UP Ltd, 1992.

HEYWORTH, L.; BITTON, A.; LIPSITZ, S. R.; SCHILLING, T.; SCHIFF, G. D.; BATES, D. W.; SIMON, S. R. Patient-centered medical home transformation with payment reform: patient experience outcomes. **The American journal of managed care**, 20(1), 26-33, 2013.

HICKS, C.; MCGOVERN, T.; PRIOR, G.; SMITH, I. Applying lean principles to the design of healthcare facilities. **International Journal of Production Economics,** 170, 677-686, 2015.

HINES, P.; FOUND, P.; GRIFFITHS, G.; HARRISON, R. Staying Lean: thriving, not just surviving. **CRC Press**, 2011.

HINES, P.; HOLWEG, M.; RICH, N. Learning to evolve: a review of contemporary lean thinking. **International journal of operations & production management**, 24(10), 994-1011, 2004.

HOLDEN, R. J. Lean thinking in emergency departments: a critical review. **Annals of Emergency Medicine**; 57(3):265–78, 2011.

HOLDEN, R. J.; ERIKSSON, A.; ANDREASSON, J.; WILLIAMSSON, A.; DELLVE, L. Healthcare workers' perceptions of lean: A context-sensitive, mixed methods study in three Swedish hospitals. **Applied ergonomics,** 47, 181-192, 2015.

HOLWEG, M. The genealogy of lean production. **Journal of operations management**, 25(2), 420-437, 2007.

HOLWEG, M.; PIL, F. Successful build-to-order strategies start with the customer. Sloan Management Review. Vol. 43, No. 1, p.74-83, 2001.

HSIEH, Y. J.; HUANG, L. Y.; WANG, C. T. A framework for the selection of Six Sigma projects in services: case studies of banking and health care services in Taiwan. *Service Business*, 6(2), 243-264, 2012.

HU, Q.; MASON, R.; WILLIAMS, S.; FOUND, P. Lean Implementation within SMEs: a Literature Review. Journal of Manufacturing Technology Management, Vol. 26 No. 7, 2015.

HUNG, D.; MARTINEZ, M.; YAKIR, M.; GRAY, C. Implementing a Lean Management System in primary care: Facilitators and barriers from the front lines. **Quality Management in Healthcare**, 24(3), 103-108, 2015.

IKUMA, L. H.; NAHMENS, I. Making safety an integral part of 5S in healthcare. Work, 47(2), 243-251, 2014.

IMPROTA, G.; BALATO, G.; ROMANO, M.; CARPENTIERI, F.; BIFULCO, P.; ALESSANDRO RUSSO, M.; CESARELLI, M. Lean Six Sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery. **Journal of evaluation in clinical practice**, 21(4), 662-672, 2105.

JASTI, N. V. K.; SHARMA, A. Lean manufacturing implementation using value stream mapping as a tool: a case study from auto components industry. **International Journal of Lean Six Sigma,** 5(1), 89-116, 2014.

JASTI, N.; KODALI, R. A literature review of empirical research methodology in lean manufacturing. **International Journal of Operations & Production Management**, 34(8), 1080-1122, 2014.

JAYASINHA, Y. Decreasing Turnaround Time and Increasing Patient Satisfaction in a Safety Net Hospital–Based Pediatrics Clinic Using Lean Six Sigma Methodologies. **Quality Management in Healthcare**, 25(1), 38-43, 2016.

JIMMERSON, C. Value stream mapping for healthcare made easy. **CRC Press**, 2009.

JOHNSON, B.; TURNER, L. A. Data collection strategies in mixed methods research. **Handbook of mixed methods in social and behavioral research**, 297-319, 2003.

JOOSTEN, T. C. M.; BONGERS, I. M. B.; JANSSEN, R. T. J. M. Redesigning mental healthcare delivery: is there an effect on organizational climate?. **International journal for quality in health care**, 26(1), 58-63, 2014.

JOOSTEN, T.; BONGERS, I.; JANSSEN, R. Application of lean thinking to health care: issues and observations. **International Journal for Quality in Health Care**, 21(5), 341-347, 2009.

KARIM, A.; ARIF-UZ-ZAMAN, K. A Methodology for Effective Implementation of Lean Strategies and its Performance Evaluation in Manufacturing Organizations. **Business Process Management Journal**, Vol. 19 No. 1, pp. 169-196, 2013.

KAYE, M.; ANDERSON, R. Continuous Improvement: the Ten Essential Criteria. **International Journal of Quality e Reliability Management**, Vol.16, No.5, p.485-509, 1999.

KEMPER, B. P.; KOOPMANS, M.; DOES, R. J. Quality Quandaries∗: The Availability of Infusion Pumps in a Hospital. **Quality Engineering**, 21(4), 471-477, 2009.

KER, J. I.; WANG, Y.; HAJLI, M. N., SONG, J.; KER, C. W. Deploying lean in healthcare: Evaluating information technology effectiveness in US hospital pharmacies. **International Journal of Information Management**, 34(4), 556-560, 2014.

KHODAMBASHI, S. Alignment of an intra-operating management process to a health information system: a Lean analysis approach. **Personal and Ubiquitous Computing,** 19(3-4), 689-698, 2015.

KIM, C. S.; SPAHLINGER, D. A.; KIN, J. M.; BILLI, J. E. Lean health care: what can hospitals learn from a world-class automaker? **Journal of Hospital Medicine**, 1(3), 191-199, 2006.

KING, D. L.; BEN-TOVIM, D. I.; BASSHAM, J. Redesigning emergency department patient flows: application of lean thinking to health care. **Emergency Medicine Australasia**, 18(4), 391-397, 2006.

KNAPP, S. Lean Six Sigma implementation and organizational culture. **International journal of health care quality assurance**, 28(8), 855-863, 2015.

KOVACH, J. V.; FREDENDALL, L. D. Learning During Design for Six Sigma Projects—A Preliminary Investigation in Behavioral Healthcare. **Engineering Management Journal**, 27(3), 109-123, 2015.

KOVACHEVA, A. V. Challenges in Lean implementation – Successful transformation towards Lean enterprise. Master Thesis in Strategy, Organization and Leadership. **Aarhus School of Business**, University of Aarhus, 2010.

KUMAR, S.; KWONG, A. M. Six sigma tools in integrating internal operations of a retail pharmacy: A case study. **Technology and Health Care**, 19(2), 115-133, 2011.

KUMAR, S.; DEGROOT, R. A.; CHOE, D. Rx for smart hospital purchasing decisions: The impact of package design within US hospital supply chain. **International Journal of Physical Distribution & Logistics Management**, 38(8), 601-615, 2008.

LAGANGA, L. R. Lean service operations: reflections and new directions for capacity expansion in outpatient clinics. **Journal of Operations Management**, 29(5), 422-433, 2011.

LANGABEER, J. R.; DELLIFRAINE, J. L.; HEINEKE, J.; ABBASS, I. Implementation of Lean and Six Sigma quality initiatives in hospitals: A goal theoretic perspective. **Operations Management Research**, 2(1-4), 13-27, 2009.

LANGLEY, A. Strategies for theorizing from process data. **Academy of Management review**, 24(4), 691-710, 1999.

LANGSTRAND, J.; DROTZ, E. The rhetoric and reality of Lean: a multiple case study. **Total Quality Management & Business Excellence,** 27(3-4), 398-412, 2016.

LAURSEN, M. L.; GERTSEN, F.; JOHANSEN, J. Applying lean thinking in hospitals-exploring implementation difficulties, 2003.

LEAN ENTERPRISE INSTITUTE. The State of Lean Survey. Available in: www.Lean.org, Access in 13/11/2015. 2004.

LEAN ENTERPRISE INSTITUTE. The Lean Survey. Available in: www.Lean.org, Access in 13/11/2015. 2005.

LEE, Q. Implementing Lean manufacturing. **Institute of Management Services Journal**, Vol. 51, No. 3, pp. 14-19, 2007.

LI, J.; PAPADOPOULOS, C. T.; ZHANG, L. Continuous improvement in manufacturing and service systems. **International Journal of Production Research**. 54(21), 2016.

LIFVERGREN, S.; GREMYR, I.; HELLSTRÖM, A.; CHAKHUNASHVILI, A.; BERGMAN, B. Lessons from Sweden's first large-scale implementation of Six Sigma in healthcare. **Operations Management Research,** 3(3-4), 117-128, 2010.

LIGHTER, D. Basics of health care performance improvement. **Jones & Bartlett Publishers,** 2011.

LIKER, J. K. The toyota way. **Esensi**, 2004.

LIKER, J.; HOSEUS, M. Toyota Culture: the heart and soul of the Toyota Way. India: McGraw-Hill, 2008.

Lokkerbol, J.; Molenaar, M. F.; & Does, R. J. Quality Quandaries*: An Efficient Public Sector. **Quality Engineering**, 24(3), 431-435, 2012.

LOUX, S. L.; PAYNE, S. M.; KNOTT, A. Comparing patient safety in rural hospitals by bed count, 2005.

LUMMUS, R. R.; VOKURKA, R. J.; RODEGHIERO, B. Improving quality through value stream mapping: A case study of a physician's clinic. **Total Quality Management**, 17(8), 1063-1075, 2006.

LYNHAM, S. A. Theory building in the human resource development profession. **Human Resource Development Quarterly**, 11(2), 159, 2000.

MADHAVAN, R.; GROVER, R. From embedded knowledge to embodied knowledge: New product development as knowledge management. **The Journal of marketing**, 1-12, 1998.

MALHOTRA, M. K.; GROVER, V. An assessment of survey research in POM: from constructs to theory. **Journal of operations management**, 16(4), 407-425, 1998.

MANN, D. Creating a lean culture. Volume I, 2005.

MARGERIE, V; JIANG, B. “How relevant is OM research to managerial practice?: an empirical study of top executives perceptions”, **International Journal of Operations and Production Management**, Vol. 31 No. 2, pp. 124-147, 2011.

MATTHIESEN, R.V.; JOHANSEN, J. Lean Transformation of multinational concerns. **Lean Business Systems and Beyond,** 2008.

MAZZOCATO, P.; HOLDEN, R. J.; BROMMELS, M.; ARONSSON, H.; BÄCKMAN, U.; ELG, M.; THOR, J. How does lean work in emergency care? A case study of a lean-inspired intervention at the Astrid Lindgren Children's hospital, Stockholm, Sweden. **BMC health services research**, 12(1), 28, 2012.

MAZZOCATO, P.; SAVAGE, C.; BROMMELS, M.; ARONSSON, H.; THOR, J. Lean thinking in healthcare: a realist review of the literature. **Quality and Safety in Health Care**, 19(5), 376-382, 2010.

MCDERMOTT, C. M.; VENDITTI, F. J. Implementing lean in knowledge work: Implications from a study of the hospital discharge planning process. **Operations Management Research**, 8(3-4), 118-130, 2015.

MCGRATH, K. M.; BENNETT, D. M.; BEN-TOVIM, D. I.; BOYAGES, S. C.; LYONS, N. J.; O'CONNELL, T. J. Implementing and sustaining transformational change in health care: lessons learnt about clinical process redesign. **Medical Journal of Australia**, 188(6), S32, 2008.

MCNULTY, T.; FERLIE, E. Reengineering health care: the complexities of organizational transformation. **OUP Oxford**, 2002.

MEREDITH, J. Building operations management theory through case and field research. **Journal of operations management**, 16(4), 441-454, 1998.

MILES, M. B.; HUBERMAN, A. M. Qualitative data analysis: **A sourcebook**. Beverly Hills: Sage Publications, 1994.

MILLER, R.; CHALAPATI, N. Utilizing lean tools to improve value and reduce outpatient wait times in an Indian hospital. *Leadership in Health Services*, 28(1), 57-69, 2015.

MONTOYA-WEISS, M. M.; CALANTONE, R. Determinants of new product performance: a review and meta-analysis. **Journal of product innovation management**, 11(5), 397-417, 1994.

MOTWANI, J. A business process change framework for examining lean manufacturing: a case study. **Industrial Management & Data Systems**, 103(5), 339-346, 2003.

MURPHREE, P.; DAIGLE, L. Sustaining Lean Six Sigma projects in health care. **Physician executive**, 37(1), 44, 2011.

NABELSI, V.; GAGNON, S. Information technology strategy for a patient-oriented, lean, and agile integration of hospital pharmacy and medical equipment supply chains. **International Journal of Production Research**, 1-17, 2016.

NAYAR, P.; OJHA, D.; FETRICK, A.; NGUYEN, A. T. Applying Lean Six Sigma to improve medication management. **International journal of health care quality assurance**, 29(1), 16-23, 2016.

NICOLAY, C. R.; PURKAYASTHA, S., GREENHALGH, A.; BENN, J.; CHATURVEDI, S.; PHILLIPS, N.; DARZI, A. Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare. **British Journal of Surgery**, 99(3), 324-335, 2012.

NIEMEIJER, G. C.; DOES, R. J.; DE MAST, J.; TRIP, A.; VAN DEN HEUVEL, J. Generic project definitions for improvement of health care delivery: a case-based approach. **Quality Management in Healthcare**, 20(2), 152-164, 2011.

NONTHALEERAK, P.; HENDRY, L. C. Six Sigma action research in Thailand: a comparative study. **International Journal of Services Technology and Management**, 8(6), 491-511, 2007.

OHNO, T. Toyota Production System – beyond large-scale production. **Portland,** 1988.

OHNSMAN, A.; GREEN, J., INOUE, K.; WELCH, D.; FISK, M.C.; LEVIN, D.; ROWLEY, I.; KITAMURA,M.; HAGIWARA, Y. The humbling fof Toyota. **Bus. Week**, 32–36, 2010.

OLSSON, O.; ARONSSON, H. Managing a variable acute patient flow–categorising the strategies. **Supply Chain Management: An International Journal**, 20(2), 113-127, 2015.

ORTÍZ, M. A.; FELIZZOLA, H. A.; ISAZA, S. N. A contrast between DEMATEL-ANP and ANP methods for six sigma project selection: a case study in healthcare industry. **BMC medical informatics and decision making**, 15(3), 1, 2015.

PAPADOPOULOS, T.; RADNOR, Z.; MERALI, Y. The role of actor associations in understanding the implementation of Lean thinking in healthcare. **International Journal of Operations & Production Management**, 31(2), 167-191, 2011.

PARRY, G. C.; TURNER, C. E. Application of lean visual process management tools. **Production Planning & Control**, 17(1), 77-86, 2006.

PATTON, M. Qualitative Data Analysis, 2nd ed. **Sage Publications**, ThousandOaks, CA, 1990.

PEPPER, M. P. J.; SPEDDING, T. A. The evolution of lean Six Sigma. **International Journal of Quality & Reliability Management**, 27(2), 138-155, 2010.

PERIN, P. C. Metodologia de padronização de uma célula de fabricação e de montagem, integrando ferramentas de Produção Enxuta. Dissertação (Mestrado em Engenharia de Produção) – **Escola de Engenharia de São Carlos**, Universidade de São Paulo, São Carlos, 2005.

PETTIGREW, A.; FERLIE, E.; MCKEE, L. Shaping strategic change - The case of the NHS in the 1980s. **Public Money & Management**, 12(3), 27-31, 1992.

POKSINSKA, B.; SWARTLING, D.; DROTZ, E. The daily work of Lean leaders–lessons from manufacturing and healthcare. **Total Quality Management & Business Excellence**, 24(7-8), 886-898, 2013.

PORTER, M. E. What is strategy? Published November, 1996.

PORTER, M. E.; LEE, T. H. The strategy that will fix health care. **Harvard Business Review,** 91(12), 24, 2013.

POWER, D. J.; SOHAL, A. S. An examination of the literature relating to issues affecting the human variable in just-in-time environments. **Technovation**, 17(11), 649-666, 1997.

PRABHUSHANKAR, G. V.; DEVADASAN, S. R.; SHALIJ, P. R.; THIRUNAVUKKARASU, V. The origin, history and definition of Six Sigma: a literature review. **International Journal of Six Sigma and Competitive Advantage**, 4(2), 133-150, 2008.

PROUDLOVE, N.; MOXHAM, C.; BOADEN, R. Lessons for lean in healthcare from using six sigma in the NHS. **Public Money and Management**, 28(1), 27-34, 2008.

RADNOR, Z. J.; HOLWEG, M.; WARING, J. Lean in healthcare: the unfilled promise?. **Social science & medicine**, 74(3), 364-371, 2012.

RADNOR, Z.; WALLEY, P.; STEPHENS, A.; BUCCI, G. Evaluation of the lean approach to business management and its use in the public sector. **Scottish executive social research**, 2006.

RAGHUNATH, A.; JAYATHIRTHA, R.V. 'Six Sigma Implementation by Indian Manufacturing SMEs - an Empirical Study', **Academy of Strategic Management Journal**, Vol. 13 No. 1, pp. 35-55, 2014.

RAHANI, A. R.; AL-ASHRAF, M. Production flow analysis through value stream mapping: a lean manufacturing process case study. **Procedia Engineering**, 41, 1727-1734, 2012.

RAISINGHANI, M. S.; ETTE, H.; PIERCE, R.; CANNON, G.; DARIPALY, P. Six Sigma: concepts, tools, and applications. **Industrial management & Data systems**, 105(4), 491-505, 2005.

RECHEL, B.; WRIGHT, S.; EDWARDS, N.; DOWDESWELL, B; MCKEE, M. Introduction: hospitals within a changing context. Investing in Hospitals of the Future, **World Health Organisation**, Geneva, 2009.

RENTES, A. F. TransMeth - Proposta de uma Metodologia para Condução de Processos de Transformação de Empresas. Tese de Livre Docência, **Escola de Engenharia de São** Carlos, Universidade de São Paulo, 2000.

REVERE, L.; BLACK, K. Integrating Six Sigma with total quality management: a case example for measuring medication errors. **Journal of healthcare management**, 48(6), 377, 2003.

RICH, N.; PIERCY, N. Losing patients: a systems view on healthcare improvement. **Production Planning & Control,** 24(10-11), 962-975, 2013.

RICKARD, T. Lean Principles in Laboratory: Inpatient Phlebotomy. EUA: **Mayo Clinic**, 2007.

RINDFLEISCH, A.; MALTER, A. J.; GANESAN, S.; MOORMAN, C. Cross-sectional versus longitudinal survey research: Concepts, findings, and guidelines. **Journal of Marketing Research**, 45(3), 261-279, 2008.

ROBINSON, S.; RADNOR, Z. J.; BURGESS, N.; WORTHINGTON, C. SimLean: Utilising simulation in the implementation of lean in healthcare. **European Journal of Operational Research**, 219(1), 188-197, 2012.

ROTH, A. V. Applications of empirical science in manufacturing and service operations. **Manufacturing & Service Operations Management**, 9(4), 353-367, 2007.

ROTHER, M.; SHOOK, J. Learning to see: value stream mapping to add value and eliminate muda. **Lean Enterprise Institute**, 2003.

RYMASZEWSKA, A. The Challenges of Lean Manufacturing Implementation in SMEs. **Benchmarking: An International Journal,** Vol. 21 No. 6, pp. 987-1002, 2014.

SALAH, S.; RAHIM, A.; CARRETERO, J. A. The integration of Six Sigma and lean management. **International Journal of Lean Six Sigma**, 1(3), 249-274, 2010.

SANDERS, J. H.; KARR, T. Improving ED specimen TAT using lean six sigma. **International journal of health care quality assurance**, 28(5), 428-440, 2015.

SAREMI, A., JULA, P.; ELMEKKAWY, T.; WANG, G. G. Appointment scheduling of outpatient surgical services in a multistage operating room department. **International Journal of Production Economics**, 141(2), 646-658, 2013.

SAURIN, T.; MARODIN, G.; RIBEIRO, J. A framework for assessing the use of Lean production practices in manufacturing cells. **International Journal of Production Research**, v. 46, n. 23, p. 32-51, 2011, 2011.

SEIDL, K. L.; NEWHOUSE, R. P. The intersection of evidence-based practice with 5 quality improvement methodologies. **Journal of Nursing Administration**, 42(6), 299-304, 2012.

SERRANO LASA, I.; CASTRO, R. D.; LABURU, C. O. Extent of the use of Lean concepts proposed for a value stream mapping application. **Production Planning & Control,** 20(1), 82-98, 2009.

SHAH, R.; WARD, T. Lean manufacturing: context, practice bundles, and performance. **Journal of operations management**, 21(2), 129-149, 2003.

SHAH, R.; WARD, T. Defining and Developing Measures of Lean Production. **Journal of Operations Management**, Vol. 25 No. 4, pp. 785-805, 2007.

SHAH, R.; CHANDRASEKARAN, A.; LINDERMAN, K. In pursuit of implementation patterns: the context of Lean and Six Sigma. **International Journal of Production Research**, 46(23), 6679-6699, 2008.

SHAH, R.; GOLDSTEIN, S. M.; UNGER, B. T.; HENRY, T. D. Explaining anomalous high performance in a health care supply chain. **Decision Sciences**, 39(4), 759-789, 2008.

SHAW, J. A schema approach to the formal literature review in engineering theses. **System**, 23(3), 325-335, 1995.

SHOOK, J. How to Change a Culture: Lessons from NUMMI. **MIT Sloan Management Review**, 2010.

SIM, K. AND RODGERS, J. "Implementing lean production systems: barriers to change", **Management Research News**, Vol. 32, pp. 37-49, 2009.

SIMONS, P. A.; HOUBEN, R.; BENDERS, J.; PIJLS-JOHANNESMA, M.; VANDIJCK, D.; MARNEFFE, W.; GROOTHUIS, S. Does compliance to patient safety tasks improve and sustain when radiotherapy treatment processes are standardized? **European Journal of Oncology Nursing**, 18(5), 459-465.

SIMONS, P. A.; HOUBEN, R., VLAYEN, A.; HELLINGS, J.; PIJLS-JOHANNESMA, M.; MARNEFFE, W.; VANDIJCK, D. Does lean management improve patient safety culture? An extensive evaluation of safety culture in a radiotherapy institute. **European Journal of Oncology Nursing**, 19(1), 29-37, 2015.

SINGH, S.; REMYA, T.; SHIJO, T. M.; NAIR, D.; NAIR, P. Lean six sigma application in reducing nonproductive time in operation theaters. **The Journal of National Accreditation Board for Hospitals & Healthcare Providers**, 1(1), 1, 2014.

SINK, D. S.; MORRIS, W. T.; JOHNSTON, C. S. By what method. Norcross, GA: **Institute of Industrial Engineers**, 1995.

SIRKIN, H. L.; KEENAN, P.; JACKSON, A. The Hard Side of Change Management. **Harvard Business Review**, 2005.

SISSON, J., ELSHENNAWY, A. Achieving success with Lean: An analysis of key factors in Lean transformation at Toyota and beyond. **International Journal of Lean Six Sigma**, 6(3), 263-280, 2015.

SMALLEY, A. The starting point for lean manufacturing: Achieving basic stability. **Management services**, 49(4), 8-12, 2005.

SNEE, R. D. Lean Six Sigma – getting better all the time. **International Journal of Lean Six Sigma**. Vol. 1, pp. 9-29, 2010.

SOBEK II, D. K.; JIMMERSON, C. A3 reports: tool for process improvement. In IIE Annual Conference. Proceedings (p. 1). **Institute of Industrial Engineers-Publisher**, 2004.

SONI, G.; KODALI, R. A critical analysis of supply chain management content in empirical research. **Business Process Management Journal,** 17(2), 238-266, 2011.

SOUZA, L. Trends and approaches in lean healthcare. **Leadership in health services**, 22(2), 121-139, 2009.

SOUZA, L. B.; PIDD, M. Exploring the barriers to lean health care implementation. **Public Money & Management**, 31(1), 59-66, 2011.

SPEAR, S. Learning to lead at Toyota. **Harvard Business Review**, Vol. 82, pp. 78-87, 2004.

STEVENSON, W. J. Operations Management. Published by McGraw-Hill Education, New York, NY, US, 2011.

STRAUSS, A.; CORBIN, J. Basics of qualitative research: Techniques and procedures for developing grounded theory. **Sage Publications**, Inc, 1998.

SURAGE, J.; TAWIAH, R.; TAWIAH, R.; TWUMASI-MENSAH, T.; TWUMASI-MENSAH, T. Geographical perspective of modeling primary healthcare accessibility. International Journal of Human Rights in Healthcare, 10(1), 56-67.), 2017.

SVENSSON, G. Processes of substantiations and contributions through theory building towards theory in business research. **European Business Review**, 25(5), 466-480, 2013.

TAPPING, D.; LUYSTER, T.; SHULZER, T. Value Stream Management: Eight Steps to Planning, Mapping and Sustaining Lean Improvements. **Journal for Healthcare Quality**, 25(6), 47, 2003.

TOUSSAINT, J. S.; BERRY, L. L. The promise of Lean in health care. **In Mayo Clinic Proceedings** (Vol. 88, No. 1, pp. 74-82). Elsevier, 2013.

TRILLING, L.; PELLET, B.; DELACROIX, S.; COLELLA-FLEURY, H.; MARCON, E. Improving care efficiency in a radiotherapy center using Lean philosophy: A case study of the proton therapy center of Institut Curie—Orsay. **In Health Care Management (**WHCM), 2010 IEEE Workshop on (pp. 1-6). IEEE, 2010.

TYAGI, S.; CHOUDHARY, A.; CAI, X.; YANG, K. Value stream mapping to reduce the lead-time of a product development process. **International Journal of Production Economics**, 160, 202-212, 2015.

ULHASSAN, W.; SANDAHL, C.; WESTERLUND, H.; HENRIKSSON, P.; BENNERMO, M.; VON THIELE SCHWARZ, U.; THOR, J. Antecedents and characteristics of lean thinking implementation in a Swedish hospital: a case study. **Quality Management in Healthcare**, 22(1), 48-61, 2013.

ULHASSAN, W.; VON THIELE SCHWARZ, U.; THOR, J.; WESTERLUND, H. Interactions between lean management and the psychosocial work environment in a hospital setting–a multi-method study. **BMC health services research**, 14(1), 1, 2014.

ULHASSAN, W.; VON THIELE SCHWARZ, U.; WESTERLUND, H.; SANDAHL, C.; THOR, J. How visual management for continuous improvement might guide and affect hospital staff: A case study. **Quality Management in Healthcare**, 24(4), 222-228, 2015.

UPTON, D. Mechanisms for Building and Sustaining Operations Improvement. **European Management Journal,** Vol.14, No.3, p.215-228, 1996.

VALASIC, B. Toyota's Slow Awakening to a Deadly Problem. **The New York Times Company,** The New York Times, pp. 1, 2010.

VAN AKEN, E. M.; FARRIS, J. A.; GLOVER, W. J.; LETENS, G. A framework for designing, managing, and improving Kaizen event programs. **International Journal of Productivity and Performance Management**, 59(7), 641-667, 2010.

VAN CITTERS, A. D.; FAHLMAN, C.; GOLDMANN, D. A.; LIEBERMAN, J. R.; KOENIG, K. M.; DIGIOIA III, A. M.; NELSON, E. C. Developing a pathway for high-value, patient-centered total joint arthroplasty. **Clinical Orthopaedics and Related Research®,** 472(5), 1619-1635, 2014.

VAN DEN HEUVEL, J.; DOES, R. J.; VERMAAT, M. B. Six Sigma in a Dutch hospital: does it work in the nursing department?. **Quality and Reliability Engineering International,** 20(5), 419-426, 2004.

VAN DER MEULEN, F.; VERMAAT, T.; WILLEMS, P. Case study: an application of logistic regression in a Six Sigma project in health care. **Quality Engineering**, 23(2), 113-124, 2011.

VAN LEIJEN-ZEELENBERG, J. E.; BRUNINGS, J. W.; HOUKES, I.; VAN RAAK, A. J.; RUWAARD, D.; VRIJHOEF, H. J.; KREMER, B. Using Lean Thinking at an otorhinolaryngology outpatient clinic to improve quality of care. **The Laryngoscope**, 2015.

VAN LENT, W. A.; GOEDBLOED, N.; VAN HARTEN, W. H. Improving the efficiency of a chemotherapy day unit: Applying a business approach to oncology. **European journal of cancer**, 45(5), 800-806, 2009.

VAN LENT, W. A.; SANDERS, E. M.; VAN HARTEN, W. H. Exploring improvements in patient logistics in Dutch hospitals with a survey. **BMC health services research**, 12(1), 1, 2012.

VATS, A.; GOIN, K. H.; FORTENBERRY, J. D. Lean analysis of a pediatric intensive care unit physician group rounding process to identify inefficiencies and opportunities for improvement. **Pediatric Critical Care Medicine**, 12(4), 415-421, 2011.

VATS, A.; GOIN, K. H.; VILLARREAL, M. C.; YILMAZ, T.; FORTENBERRY, J. D.; KESKINOCAK, P. The impact of a lean rounding process in a pediatric intensive care unit. **Critical care medicine**, 40(2), 608-617, 2012.

VEGTING, I. L.; VAN BENEDEN, M.; KRAMER, M. H.; THIJS, A.; KOSTENSE, P. J.; NANAYAKKARA, P. W. How to save costs by reducing unnecessary testing: lean thinking in clinical practice. **European journal of internal medicine**, 23(1), 70-75, 2012.

VEIGA, G. L.; DE LIMA, E. P.; DA COSTA, S. E. G. A discussion about the strategic role of the Lean Production Model. **Sistemas & Gestão**, 3(2), 92-113, 2009.

VINK, P.; IMADA, A. S.; ZINK, K. J. Defining stakeholder involvement in participatory design processes. **Applied ergonomics**, 39(4), 519-526, 2008.

VINODH, S.; SOMANAATHAN, M.; ARVIND, K. R. Development of value stream map for achieving leanness in a manufacturing organization. **Journal of Engineering, Design and Technology,** 11(2), 129-141, 2013.

VOELKER, R. Specialty hospitals generate revenue and controversy. **JAMA**, 289(4), 409-410, 2003.

VOSS, C.; TSIKRIKTSIS, N.; FROHLICH, M. Case research in operations management. **International journal of operations & production management**, 22(2), 195-219, 2002.

WACKER, J. G. A definition of theory: research guidelines for different theory-building research methods in operations management. **Journal of operations management**, 16(4), 361-385, 1998.

WALKER, T. The contributions of Total Quality Management to a theory of work performance. **Academy of Management Review**, Vol. 19, pp. 510-536, 1992.

WANG, T. K.; YANG, T.; YANG, C. Y.; CHAN, F. T. Lean principles and simulation optimization for emergency department layout design. **Industrial Management & Data Systems**, 115(4), 678-699, 2015.

WARING, J. J.; BISHOP, S. Lean healthcare: rhetoric, ritual and resistance. **Social science & medicine**, 71(7), 1332-1340, 2010.

WARNER, C. J.; WALSH, D. B., HORVATH, A. J.; WALSH, T. R.; HERRICK, D. P.; PRENTISS, S. J.; POWELL, R. J. Lean principles optimize on-time vascular surgery operating room starts and decrease resident work hours. **Journal of vascular surgery**, 58(5), 1417-1422, 2013.

WEBSTER, A.; WYATT, S. Health, Technology and Society. London: **Palgrave Macmillan,** 2007.

WEIGEL, C.; SUEN, W.; GUPTE, G. Using lean methodology to teach quality improvement to internal medicine residents at a safety net hospital. **American Journal of Medical Quality**, 28(5), 392-399, 2013.

WESTBROOK, R. Action research: a new paradigm for research in production and operations management. **International Journal of Operations & Production Management**, 15(12), 6-20, 1995.

WHITE, M.; WELLS, J. S.; BUTTERWORTH, T. The impact of a large-scale quality improvement programme on work engagement: Preliminary results from a national cross-sectional-survey of the 'Productive Ward'. **International journal of nursing studies**, 51(12), 1634-1643, 2014.

WILSON, G. Implementation of releasing time to care–the productive ward. **Journal of nursing management**, 17(5), 647-654, 2009.

WINCH, S., HENDERSON, A. J. Making cars and making health care: a critical review. **Medical Journal of Australia**, 191(7), 415, 2009.

WINKEL, J.; EDWARDS, K.; BIRGISDÓTTIR, B. D.; GUNNARSDÓTTIR, S. Facilitating and inhibiting factors in change processes based on the lean tool value stream mapping': an exploratory case study at hospital wards. **International Journal of Human Factors and Ergonomics**, 3(3-4), 291-302, 2015.

WOLF, L.; COSTANTINOU, E.; LIMBAUGH, C.; RENSING, K.; GABBART, P.; MATT, P. Fall prevention for inpatient oncology using lean and rapid improvement event techniques. **HERD: Health Environments Research & Design Journal**, 7(1), 85-101, 2013.

WOMACK, J. P.; JONES, D. T. Lean thinking: banish waste and create wealth in your corporation. **Simon and Schuster**, 2010.

WOMACK, J. P.; BYRNE, A. P.; FIUME, O. J.; KAPLAN, G. S.; TOUSSAINT, J. Going lean in health care. Cambridge, MA: **Institute for Healthcare Improvement**, 2005.

WOMACK, J. P.; JONES, D. T. Lean thinking: banish waste and create wealth in your corporation. **Simon and Schuster**, 2003.

WOMACK, J. P.; JONES, D. T.; ROOS, D. Machine that changed the world. **Simon and Schuster**, 1990.

YANG, T., WANG; T. K., LI; V. C.; SU, C. L. The Optimization of Total Laboratory Automation by Simulation of a Pull-Strategy. **Journal of medical systems**, 39(1), 1-12, 2015.

YIN, R. K. Case study research: Design and methods. **Sage publications**, 2013.

YOUNG, T. P.; MCCLEAN, S. I. A critical look at Lean Thinking in healthcare. **Quality and Safety in Health Care,** 17(5), 382-386, 2008.

YOUNG, T. P.; MCCLEAN, S. I. Some challenges facing Lean Thinking in healthcare. 309-310, 2009.

YUN, E. K.; CHUN, K. M. Critical to quality in telemedicine service management: application of DFSS (design for six sigma) and SERVQUAL. **Nursing Economics**, 26(6), 384, 2008.

YUSOF, M. M.; KHODAMBASHI, S.; MOKHTAR, A. M. Evaluation of the clinical process in a critical care information system using the Lean method: a case study. **BMC medical informatics and decision making**, 12(1), 1, 2012.

ZADEH, R. S.; SHEPLEY, M. M.; WAGGENER, L. T. Rethinking efficiency in acute care nursing units: Analyzing nursing unit layouts for improved spatial flow. **HERD: Health Environments Research & Design Journal**, 6(1), 39-65, 2012.

APPENDIX A. Hospital units' descriptions

H1 is a private oncology clinic with chemotherapy and drug infusion applications. It has approximately 320 employees and began their lean journey in May 2014.

H2 is a large philanthropic Institution, essentially working with public service. It receives mainly medium and high complexity patients. The hospital has 273 beds and 1400 employees. They began their lean journey in September 2014.

H3 is a private non-profit organization dedicated to fighting cancer. The hospital has 166 beds and 1300 employees. They began their lean journey in January 2014.

H4 has 187 beds and 1100 employees. It is a private institution that receives mainly high complexity patients. They started their lean journey in February 2012.

H5 is an institution dedicated to the study and treatment of cancer. Founded in 1920, it has a philanthropic profile and serves 100% public service. It has 76 beds and around 600 employees. They started their lean journey in March 2011.

H6 started its lean journey most recently, in March 2015. H6 is a private hospital with 88 beds, 500 employees and mainly serve patients of medium and high complexity.

APPENDIX B - Case Study Protocol

1. An overview of the case study project

This case study project describes the procedures necessary to conduct a case study to increase the research reliability. The information sources provided to the researcher in

the interviews will be kept confidential. The people and the corporate names of the interviewed companies will not be released. After study finalization, a copy will be provided to each healthcare organization researched.

1.1 Case study objectives

The case study purpose is to investigate how six Brazilian hospitals have sustained the lean initiatives implemented in their operations. The study will assess the barriers faced, the critical factors for successful or failure on sustainability and the results obtained in each case.

The study also aims to elaborate propositions through case studies and literature analyses to present important lean implementation particularities in the healthcare sector, especially in Brazil, and suggest relevant topics for future research.

1.2 Research Questions

The research questions were defined after conducting a literature review about lean manufacturing sustainability and lean healthcare sustainability. The main research question is:

- How do healthcare organizations sustain a competitive advantage in lean?

Other questions that this research should answer:

- What are the key points that differentiate hospitals that have been able to sustain lean improvements than hospitals that failed?
- What are the main factors that hospitals can not neglect to achieve long-term sustainability in lean initiatives?

To answer the research questions, the following variables were defined:

- Motivational factor for implementation and priority;
- Employee involvement;
- Results;
- Sustainability aspects;
- Method;
- Leadership;
- Training;
- Communication.

2. Field procedure

The field procedure in this study presents the data collection plan, the preparation to realize the visits and the interviewed members.

2.1. Data collection plan

To perform the data collection, strategical and operational members of the six selected hospitals will be interviewed. The interviews will be scheduled personally, and by email. A date for the interview will be proposed, but the interviewee will determine the best date according to his or her availability.

Data collection will be conducted through semi-structured interviews, in-loco observations, and consulting the information made available by the hospitals.

In addition to the notes, interviews will be recorded and transcribed for future reference.

After each interview, an interview summary will be drafted. This summary should contain the respondent employee's position, interview duration, and other important points.

2.2. Preparation to conduct the visits

An email with a general study description will be sent to interviewees, providing the interviewees with some context regarding the research subject. Available information by the hospitals will be collected prior to the interview to obtain important information that can later be discussed in the interviews. It will also elaborate printed tables with the research variables to facilitate note taking during the interview. The material to be taken into the field of research is: interview protocol, plus copies of this protocol for interviewees, printed tables for data collection, recorder, and notepad.

2.3. Interviewed members

The interviews will be conducted with CEOs, directors, managers and consultants that participated in the lean implementation in the six healthcare organizations.

3. Case study questions

The following interview protocol was developed for this study:

1. General information

What are the main particularities that characterize the hospital studied? Describe each of these characteristics (for example: beds, physicians, and specialties numbers, classification with regard to hospital size, among others).

2. Motivational factor for implementation and priority

2.1 What were the main motivations for implementing the lean healthcare philosophy in the Institution?

2.2 Lean priority. How much was lean a top priority? When was the priority lost or gained? How many programs were being implemented at the same time?

3. Employee involvement

3.1 Was the lean implementation performed by a consultancy or internally? Did the Institution create an internal continuous improvement team?

3.2 How was/is the availability of time on the agenda of participants?

3.3 How was/is the enrollment of the physicians? What was/is done to involve them?

3.4 How was/is the enrollment of the nurses? What was/is done to involve them?

3.5 How was/is the enrollment of the pharmacists? What was/is done to involve them?

4. Results

4.1 What were the main results obtained (quantitative and/or qualitative)?

4.2 Is there any data on the amount of savings due to lean projects or due to customer satisfaction?

4.2 How fast did the results come?

4.4 How much pressure for short-term performance was there in the project?

4.5 Overall, the improvements are isolated and focused on some local results or they are looking for impact across the value stream?

5. Sustainability aspects

5.1 What was the period of implementation? Was there continuity/sustainability of the program over more than 2 years?

5.2 In your opinion, after the implementation of the lean program, the continuous improvement culture became part of the company? In positive case, cite the main aspects that influenced in bringing this new culture to the company. In negative case, cite the main aspects that contribute to failure.

5.3 What are the main lean tools used in the sustainability of the implementations?

5.4 Is there any form of visual management of improvements, indicators and sustainability?

5.5 What were the main barriers faced during the pre-implementation, the implementation and post implementation phase?

5.6 What were the main critical factors that ensured the success of lean implementation and maintenance?

6. Method

6.1 Was some type of continuous improvement method used (Ex: DMAIC, PDCA)?

6.2 Do staff know and apply the method? Does the company's top management apply the method? Are there routines to apply the method?

6.3 Describe how the team was involved in each phase of the method (pre-implementation, the implementation and post implementation phase).

7. Leadership

7.1 What role has the top leadership of the Institution played in implementing and sustaining lean?

7.2 Were the decisions about improvement projects taken in consensus or centralized (top down)?

7.3 Core values. How much emphasis was put on translating core lean values into managerial behavior at all levels?

7.4 Future leaders. How much emphasis is focused on developing future leaders in the Institution? Were there significant changes over the past years?

8. Training

8.1 How much training took place in the Institution over the past years related to continuous improvement and lean principles?

8.2 Is there any data on the amount of training on lean principles (number of employees trained by year)?

9. Communication

9.1 The lean events (kaizens for example) are well communicated to the entire organization? The performance improvements and results are well communicated to the entire organization?

9.2 The lean program kick-off was well communicated to all company?

9.3 The operational vision and the main goals of the project were and continue to be clear to the personal involved?

10. Additional information

10.1 Is there any other information you want to add that was not addressed in this interview?

Guide for the case report

The present study report will be structured from the notes made and the consultation of audio recorded during the interviews, being conducted as quickly as possible. The results will be presented in a descriptive way in a textual format for each of the six cases and will be discussed and compared with the literature on the subject.