Impact of Lean Management Implementation on Company Performance: a Meta-Analysis

by

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Master Dissertation in Management

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September, 2017

Biographical Note

Telma Inês Gemelgo Gonçalves was born on 19th September, 1994 in the city of Macedo de Cavaleiros, Bragança, Portugal. Telma is the second child of Paulo Jorge Machado Gonçalves and Clementina Augusta Marçal Gemelgo.

Academically, in 2012, she finished her bachelor's degree in Economics at Faculdade de Economia da Universidade do Porto (FEP). In the same year, she joined the Master in Management in FEP which allowed her to get important and usable knowledge in areas as quality and operations and supply chain management.

Professionally, she is starting her path, working as an intern in a portuguese SME located in her hometown.

Acknowledgments

First of all, I would like to thank to my parents for all the support and courage given throughout my academic years. Also, I would like to thank to my boyfriend and my closest friends for all their patience and motivation given during this year.

Furthermore, I must express my sincerely gratitude to my two supervisors who supported me during this process.

Firstly, to Professor Maria do Rosário Mota de Oliveira Alves Moreira, I am extremely grateful for her knowledge, support, guidance, availability and willingness to help.

Secondly, I must thank to Professor Paulo Sérgio Amaral de Sousa for his valuable contributes in crucial phases of this disseration. It would not be possible to finish this work without his expertise in statistical data analysis.

Abstract

Purpose – The purpose of this research is to examine the relationship between Lean Management practices and performance outcomes through the use of meta-analysis. Studies linking the use of lean practices to company performance have been increasing as markets are becoming more competitive and companies are eager for reducing waste and, therefore, implementing Lean Management philosophy as a way to improve performance. However, findings from these studies have found various impacts and some light on which would be beneficial to pursue is needed.

Design/methodology/approach – Extant literature was reviewed and to achieve the research objective a meta-analysis of correlations was carried out.

Findings – The results of this meta-analytic investigation do not support a positive correlation between Lean Management implementation and company performance at aggregate levels. However, the findings of individual analysis suggest a positive relationship between some lean practices and performance measures. Furthermore, the results highlight the presence of moderators influencing the relationship between lean practices and performance outcomes.

Originality/value – According to our best knowledge, this is the first known research that proposes a comparison and combination of results from primary studies on Lean Management implementation. It fills the gap in literature concerning this research area and therefore represents an important contribute to the scientific community. Also, the findings of this research can act as a guide for managers who consider Lean Management implementation as an option.

JEL-codes: L25, M11

Keywords: Meta-Analysis, Lean Management, Company Performance

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1. Introduction

In this era of globalization, markets are becoming more competitive and characterized by customized products making mass production of goods a challenge for organizations that are being forced to reduce costs and to quickly adapt themselves to changed customer mindsets (Bhamu and Sangwan, 2014). As an answer to new market requirements, Lean Management appeared based on many ideologies that emerged prior to it: Just-in-Time (JIT), Zero Inventories, Japanese Manufacturing Techniques and Toyota Production System (Bhamu and Sangwan, 2014) and it has been drawing much attention not only by scientific researchers but also by managers and consultants worldwide (Jasti and Kodali, 2014). Focused on waste elimination (Womack and Jones, 1996 cited in Lucato *et al.*, 2014), Lean philosophy allows the production of goods and services at the lowest cost and as fast as the customer requires with no additional resources (Bhamu and Sangwan, 2014).

However, the adoption of lean practices is not equal for all firms and may vary among companies depending on type of industry, region or country (Lucato *et al.*, 2014). Moreover, contextual factors such as production system and product characteristics might as well affect the success of lean practices implementation on company performance (Büyüközkan *et al.*, 2015). Several studies have been conducted to understand and analyse the impact of Lean Management on firms' performance (e.g.: Lucato *et al.*, 2014; Sharma *et al.*, 2015)

The main aim of this research is to analyse the impact of Lean Management implementation on companies' performance through the use of meta-analysis. It allows us to overcome biased results associated to specific factors mentioned above and cover other topics in addition to JIT, already studied by Mackelprand and Nair (2010). Even though the theoretical foundations explaining the difference between JIT and Lean are not well defined in extant literature, it is noticeable that JIT is a relevant part of Lean (Mackelprang and Nair, 2010). Thus, we want to know if Lean Management implementation positively impacts companies' performance. If so, we want to know if all lean practices affect all company performance measures and which ones produce a greater impact as well as the performance outcomes most affected. Finally, we want to study the influence of moderating factors on the relationship between lean practices and company performance.

In order to accomplish the main purpose of this research, we will follow a meta-analysis of correlations as methodological tool. It enables the researcher to evaluate previous studies as a whole instead of focusing on each one individually and allows the researcher to overcome difficulties such as sampling error, measurement error and restriction range (Eden, 2002). According to our best knowledge, this is the first known research that proposes a comparison and combination of results from primary studies on Lean Management implementation. It fills the gap in literature concerning this research area and therefore represents an important contribute to the scientific community. Moreover, it provides managers with a broader and better interpretation of empirical conclusions from primary studies that might be useful during the process of decision-making when implementing Lean Management into their firms (Mackelprang and Nair, 2010).

To achieve the main aim of this research, this scientific work is organized as follows. In the next section, Section 2, it is performed a literature review concerning aspects related with Lean Management implementation and company performance measures. The research framework is also presented in this section. In Section 3, it is introduced the methodological considerations. Specifically, it is described the method of meta-analysis of correlations as well as the procedures employed in this research. The next section, Section 4, presents the main results, including how the final sample was obtained, the main characteristics of the articles reviewed and the findings of this research. Finally, in Section 5, it is presented the conclusion of this meta-analytic investigation.

2. Lean Management and Company Performance: a Literature Review

In this chapter, it is presented the fundamentals of Lean Management and company performance. The first section, Section 2.1, introduces what is Lean Management and its purpose. It is divided into "Theoretical Background", "Implementing Lean Management: Practices, Tools and Techniques" and "Implementation Issues". The Section 2.2, Company Performance, focuses on company performance measures. In the Section 2.3, it is discussed similar studies. The last section, Section 2.4, presents the framework of this research and the hypotheses to be analysed.

2.1 Lean Management

2.1.1 Theoretical Background

After the Second World War, customers became more demanding in terms of service and quality and mass production was not able to satisfy customer requirements. To fulfill the customers demand, the Japanese engineers Eiji Toyoda and Taiichi Ohno developed the Toyota Production System (TPS), in the 1950s, which targeted at eliminating all types of *muda* – the Japanese term for waste - and inconsistency within the production system (Jasti and Kodali, 2014; Jasti and Kodali, 2015; Gosh, 2012). The concept of Lean Management drives from the TPS which is made of two components: Just-in-Time (JIT) production system and a respect-for-human-system (Bhamu and Sangwan, 2014; Sugimori *et al.*, 1977).

The generic term "lean" first emerged via John Krafcik, a researcher from the Massachusetts Institute of Technology (MIT) working on International Motor Vehicle Programme (IMVP) project, focused on bridging the notable performance gap between Western and Japanese automotive industries at the time (Bhamu and Sangwan, 2014; Samuel *et al.*, 2015). The concept was used in *Sloan Management Review* (1988) article by Krafcik to describe the TPS and to capture the less resources usage of that system comparatively to typical western production systems (Samuel *et al.*, 2015). According to Krafcik (1988, p.44-45), while "the production systems of most Western producers throughout most of the post-war period were buffered against virtually everything (…). Other plants, best exemplified by Toyota, truly were lean operations". Yet, the "lean production" term is cited as being popularized in manufacturing by the authors Womack *et al.* (1990) through their book *The Machine That Changed the World* that came out of the IMVP study at MIT (Jasti and Kodali, 2015; Samuel *et al.*, 2015).

Although the lean movement started in the manufacturing sector, it has been applied in many other sectors of activity such as healthcare, software, constructions, among others (Jasti and Kodali, 2014). In fact, the implementation of lean in different types of industries is recently growing faster (Bhamu and Sangwan, 2014).

A definition of lean is not consensual in extant literature (Pettersen, 2009). Nevertheless, even though the book *The Machine that Changed the World* (1990) does not offer a specific definition, it describes in detail a lean system: "lean production uses half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products" (Womack *et al.*, 1990, p.13). Overtime, several authors have differently classified lean as either a philosophy, a way, a concept, among others. Bhamu and Sangwan (2014) compiled the scholarly definitions of lean that emerged between 1988 and 2012. Some examples are presented below in Table 1.

Author(s)	Definition	Defined as
Liker's (1996)	"A philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste in the production flow."	A philosophy
Storch and Lim (1999)	"Lean production is an efficient way to satisfy customer needs while giving producers a competitive edge."	A way
Naylor *et al.* (1999)	"Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule."	A concept
Taj and Morosan (2011)	"A multi-dimensional approach that consists on production with minimum amount of waste (JIT), continuous and uninterrupted flow (Cellular Layout), well-maintained equipment (TPM), well established quality system (TQM), and well-trained and empowered work force (HRM) that has positive impact on operations/competitive performance (quality, cost, fast response, and flexibility)."	An approach
Alves *et al.* (2012)	"Lean production is evidenced as a model where the persons assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the agility they need to face the market demands and environment changes of today and tomorrow."	A model

Table 1 – Lean Manufacturing Definitions (Source: Bhamu and Sangwan, 2014, p.879-881)

Gosh (2012) states that lean production is seen by scholarly community mainly at three levels, illustrated by Panwar *et al.* (2015) in Figure 1, presented below.

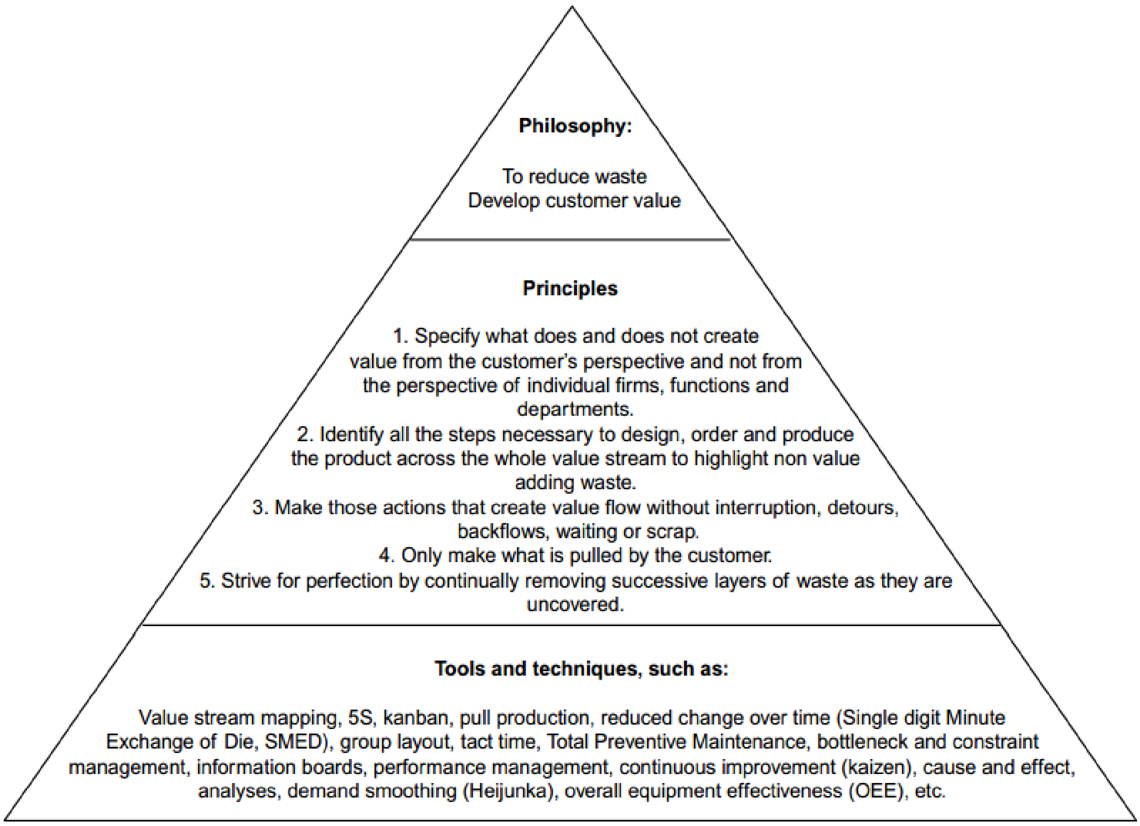

Figure 1 – Three Levels of Lean (Source: Panwar *et al.*, 2015)

The first level is named philosophical level and expresses the fundamental concerns of lean: to eliminate waste (Ohno, 1988; Shingo, 1989 and Womack and Jones, 1996 cited in Gosh, 2012; Womack *et al.*, 1990) and to improve customer value (Hines *et al.* 2004; Gosh, 2012). According to lean philosophy and from a customer perspective, business activities that do not create value are a waste and therefore should be removed or minimized (Womack and Jones, 1996 cited in Panwar *et al.*, 2015). In accordance with Robinson *et al.* (2012), Taiichi Ohno (1988) defined seven categories of waste in manufacturing, identified and described below in Table 2.

Types of Waste	Description
Transportation	Units being moved unnecessarily
Inventory	All types of materials waiting to be processed or delivered
Motion	Resources moving unnecessarily
Waiting	Resources waiting for the next stage of manufacture
Overproduction	Production higher than demand
Processing	Processing more than it is required for production
Defects	Waste due to checking for and fixing defects

Table 2 – Seven Types of Waste (Source: Robinson *et al.*, 2012, p.4)

According to Robinson *et al.* (2012) an adaption of these categories of waste for services was made by Bicheno and Holweg (2009). The authors identified the following wastes: delay, duplication, unnecessary movement, unclear communication, opportunity lost and errors.

The middle level represents the five lean principles related to production suggested by Womack and Jones (1996): value, value stream, flow, pull and continuous improvements (Panwar *et al.*, 2015). A description of such principles can be read in Figure 1.

At the third level, which may be seen as the operational level, lean is viewed as a group of tools and techniques aimed at facilitating the accomplishment of the fundamental concerns of lean (Gosh, 2012; Panwar *et al.*, 2015). According to Shah and Ward (2003) the lean practices can be combined into four bundles: Just-in-Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and Human Resource Management (HRM). Each bundle represents a group of inter-related lean practices.

The implementation of lean practices, discussed in the next subsection, is often related with operational performance improvements (Shah and Ward, 2003). Both quantitative and qualitative benefits associated to lean implementation have been reported by several authors (Bhamu and Sangwan, 2014). Table 3 presents examples of such benefits in different sectors of activity.

Author(s)	Benefits	Sector
Bhamu and Sangwan (2014)	Production lead time improvement, enhancement of setup, cycle and processing times, less defects and scrap, better overall equipment effectiveness, increased job satisfaction, effective communication, etc.	Manufacturing
Gupta *et al.* (2016)	Reduced waiting time and improved quality of care.	Healthcare
	Lower variability in performance and fewer defects and rework.	Software
	Relevance of course materials and reduction in delivery time of knowledge.	Education

Table 3 – Benefits of Lean Management Implementation

In the next subsection, it is introduced and discussed the lean tools and techniques.

2.1.2 Implementing Lean Management: Practices, Tools and Techniques

The extant literature identifies several practices associated to lean implementation. In his article, Pettersen (2009) listed the most often mentioned features of lean in the reviewed books. The author identified Setup Time Reduction and Continuous Improvement as central to the lean concept since all the examined authors discuss these characteristics in their books. Considering Pull Production as a particular case of JIT production, this characteristic is also lifted by all authors. *Poka-yoke* and *Heijunka* are perceived as central of lean production as well (Pettersen 2009).

Shah and Ward (2003) have also listed the most frequent lean practices among key references (sixteen in total). The practices that appeared at least in half of those references are: Continuous Improvement Programs, Cross Functional Workforce, Just-in-Time/Continuous Flow Production, Lot Size Reductions, *Pull System*, Quick Changeover Techniques, Self-Directed Work Teams and Total Quality Management.

More recently, Sezen *et al.* (2012) also summarized the lean techniques empirically examined in the literature (twelve articles in total). Setup Time Reduction, *Pull System*, Equipment Layout, Employee Involvement and Supplier Involvement were mentioned at least in half of the analysed articles.

In addition to these tools, practices as Inventory Reduction, Preventive Maintenance, One Piece Flow, Value Stream Mapping, Root Cause Analysis and *Jidoka* are often mentioned and studied in literature as components of lean implementation.

The mentioned practices are summarized in Table 4. To analyse them, this research follows the bundles structure of Shah and Ward (2003):

- **Just-in-Time (JIT) bundle:** it encompasses all practices related to production flow (Shah and Ward, 2003). The underlying rationale followed by the authors is that JIT is a manufacturing program intended to continuously reduce and eventually eliminate all classes of waste. We included eight lean practices in this bundle: Quick Changeover Techniques, *Pull System*, One Piece Flow, Equipment Layout, *Heijunka*, *Jidoka*, Inventory Reduction and Small Lot Size;

- **Total Quality Management (TQM) bundle:** it embraces all practices related to continuous improvement as well as products and processes quality sustainability, aimed at meeting or even exceeding customer expectations (Cua *et al.*, 2001; Shah and Ward, 2003). There are two lean practices included in this bundle: Supplier Involvement and *Kaizen* or Continuous Improvement;

- **Human Resource Management (HRM) bundle:** according to Furlan *et al.* (2011), lean HRM relates to employees' commitment and involvement which is achieved through a streamlined organizational structure with decentralized authority, multi-functional training programs and collaboration/communication between workers. There are two lean practices included in this bundle: Flexible, Cross-functional Teams and Self-directed Work Teams;

- **Total Preventive Maintenance (TPM) bundle:** it comprises practices designed with the primary goal of maximizing equipment effectiveness through machinery maintenance and using techniques for maintenance optimization (Shah and Ward, 2003). The lean practice included in this bundle is Preventive Maintenance.

Bundles **(according to Shah and Ward, 2003)**	**Lean Practices**	**Description/Sub Practices**
JIT	Quick Changeover Techniques	The extent to which the plant gradually reduces the setup times in production. It includes tools such as the SMED concept (Shingo, 1985; Koufteros *et al.*, 1998; Mackelprang and Nair, 2010).
	Pull System	The extent to which production is based on the next process step actual demand and ultimately on the client's. It includes practices such as *Kanban System*, JIT link with customers and JIT delivery from suppliers (Sugimori *et al.*, 1977; Koufteros *et al.*, 1998; Ahmad *et al.*, 2003).
	One Piece Flow	Consists on processing items and moving them directly from one processing step to the following, one piece at a time with no waiting materials (Sugimori *et al.*, 1977; Sezen *et al.*, 2012).
	Equipment Layout	The extent of use of cellular manufacturing design including proximity of machinery. Cellular Manufacturing is a practice that measures the extent to which the units are produced in a product oriented layout (Wemmerlöv and Hyer, 1989; Koufteros *et al.*, 1998; Ahmad *et al.*, 2003; Mackelprang and Nair, 2010).
	Heijunka	It consists on distributing the production of different [body types] evenly over the course of the day, a week and month in the assembly processes. It includes concepts as Production Levelling, Production Smoothing, Daily Schedule Adherence, Takt Time and *Kanban* Cards (Sugimori *et al.*, 1977; Coleman and Vaghefi, 1994; Bortolotti *et al.*, 2013).
	Jidoka	Term used to describe a system where the equipment or operation stops whenever an abnormal or defective condition arises. Includes tools as *Poka-Yokes* and *Andons* (Sugimori *et al.*, 1977; Rooney and Rooney, 2005 cited in Sezen *et al.*, 2012; Chen and Tan, 2013; Belekoukias *et al.*, 2014).
	Inventory Reduction	The extent to which excessive inventory storage is avoided (Lieberman and Demeester, 1999; Sezen *et al.*, 2012).
	Small Lot Size	The intention of using or working towards using small lots in production (Sakakibara *et al.*, 1993; Mackelprang and Nair, 2010; Adacher and Cassandras, 2014).
TQM	Supplier Involvement	It relates to the relationship established by companies with their suppliers (Flynn *et al.*, 1995b).
	Kaizen	Methods developed to discipline evolution aimed at reducing defects and enhancing quality. Includes tools such as 5S, Brainstorming, Data Check Sheet, Five Whys, Run Charts, Pareto Chart, Value Stream Mapping and Gantt Chart (Koufteros *et al.*, 1998; Duque & Cadavid, 2007; Sezen *et al.*, 2012; Belekoukias *et al.*, 2014).
HRM	Flexible, Cross-functional Teams	It consists on having flexible, multi-skilled workers. It includes lower level practices as Job Rotation Program, Job Design and Formal, Cross Training Programs (Shah and Ward, 2003; Duque & Cadavid, 2007).
	Self-directed Work Teams	The extent to which workers are organized in teams and participate in problem solving sessions. It includes lower level practices as Work Teams, Problem Solving Groups and Employee Involvement (Koufteros *et al.*, 1998; Sezen *et al.*, 2012).
TPM	Preventive Maintenance	The extent to which equipment is proactive and properly maintained. It includes activities such as Housekeeping, Cross Training, Teams, Operator Involvement, Information Tracking, Disciplined Planning, Schedule Compliance, Training, Early Equipment Design, Early Product Design, Focused Improvement Teams and Support Group Activities (Koufteros *et al.*, 1998; McKone and Weiss, 1998; McKone *et al.*, 1999).

Table 4 – Lean Practices

Table 4 was developed based on an extensive literature review and thus we believe it represents a fairly view of the main components comprising Lean Management implementation. There are several other lean practices that despite mentioned in the literature (Shah and Ward, 2003; Pettersen, 2009; Sezen *et al.*, 2012; Panwar *et al.*, 2015) are not yet well explored nor seen as central to lean production and for that reason will not be described in this research, such as: Time/Work Studies, 100% Inspection, Improvement Circles, Lead Time Reduction, Multi-manning, Design for Manufacture, Cycle Time Reduction, Bottleneck/Constraint Removal, Performance Management, Cause and Effect Analysis, Overall Equipment Effectiveness, among others.

2.1.3 Implementation Issues

Although high benefits of lean implementation have been reported by several organizations some others were not able to accomplish the desired results (Bhamu and Sangwan, 2014). In fact, there is not a stepwise guideline or process to lean implementation which faces many challenges or barriers (Jadhav *et al.*, 2014; Bhamu and Sangwan, 2014).

Jadhav *et al.* (2014) identified 24 barriers to effective implementation of Lean Management. Among them, lack of resources to invest, lack of top management involvement as well as workers' attitude or resistance are the most cited barriers in the literature reviewed. Also, cultural difference and poor leadership belong to the top five of lean barriers. Furthermore, the authors state that lean barriers are not isolated. Not only they impact the successful implementation of lean management but also they are related to each other. Moreover, according to Jadhav *et al.* (2014), the success of lean implementation is not completely based on practices application. It also relies on the relationship between workers and top management.

Bhamu and Sangwan (2014) identified critical issues associated to lean implementation as well. The authors categorized them into: pre-implementation issues (e.g.: lack of lean awareness programs for all employees), implementation issues (e.g.: lack of effective customer-supplier relationships) and post-implementation issues (e.g.: lack of review of employees for recognition and awards).

2.2 Company Performance

Company performance describes "how well a company achieves its market-oriented and financial goals" (Bevilacqua *et al.*, 2016, p.778). In accordance with Büyüközkan *et al.* (2015), firm performance elements are conceptualized into three categories that will be discussed next: operational performance, financial performance and market performance. A performance measurement summary table is presented below.

Company Performance	Measures
Operational Performance	Manufacturing costs, inventory level, cycle-time, delivery times, quality, product defect rates, scrap and rework costs; etc.
Financial Performance	Profits, market value, return on investments (ROI), return on assets (ROA), cash flow margin (CFM), return on sales (ROS); etc.
Market Performance	Sales growth, market share, competitive position, customer service levels; etc.

Table 5 – Company Performance

Operational Performance

Operational Performance measures are from non-financial nature and are taken from the internal management systems. They are related to the way the company works and the activity it performs such as delivery times, inventory level, product defect rates, unproductive space and production hours (Camacho-Miñano *et al.*, 2013). Lean practices implementation is often associated with operational performance progresses, being labor productivity and quality improvements as well as customer lead time, cycle time and manufacturing costs reductions among the most commonly cited benefits (Shah and Ward, 2003). In addition to these measures, Shah and Ward (2003) also included in their study operational indicators as scrap and rework costs and first pass yield.

Mackelprang and Nair (2010) conceptualized operational performance with regard to manufacturing cost, inventory, cycle time, manufacturing flexibility, delivery performance and quality performance. Manufacturing cost can be measured by the unit cost and inventory performance comprises measures as inventory turns and inventory levels. In what concerns cycle time, it can be measured through, for example, manufacturing cycle time or/and lead and throughput times. Mix, modification, volume, new product and expansion are measures of manufacturing flexibility and delivery performance can be measured by delivery reliability and delivery speed. At last, quality performance includes measures as scrap rate or rework rate (Mackelprang and Nair, 2010) and improves both financial and market performance (Kaynak, 2003).

Financial Performance

Financial Performance measures reflect economic-financial information taken from internal and external accounting documents such as profits, market value and return on investment (Camacho-Miñano *et al.*, 2013; Büyüközkan *et al.*, 2015). As referred by Fullerton *et al.* (2003), according to Womack and Jones (1996, p.121), "the result by which any business in a market economy must be measured is the ability to make enough profit to renew itself."

Fullerton *et al.* (2003) included three variants of profitability measures in their study: return on assets (ROA), return on sales (ROS) and cash flow margin (CFM). Asset turnover, a component of ROA, is expected to increase as lean practices, particularly the JIT ones, free up assets and capital. Moreover, asset base is reduced by lower inventory levels and therefore asset turnover improves in the short-term (Fullerton *et al.*, 2003). Also, less buffer inventories lead to elimination of non-value added activities that negatively impact the profit margin (Alles *et al.*, 1995 cited in Fullerton *et al.*, 2003).

As mentioned earlier, quality performance improves financial performance. There are at least two explanations for that. Firstly, the elasticity of demand might be reduced if a firm delivers goods and services of high quality. This reduction can enable a company to practice higher prices and consequently get increased profits (Shetty, 1988 cited in Kaynak, 2003). Secondly, reducing waste and improving efficiency, which improves the quality of the product, will increase the return on assets (Handfield *et al.*, 1998 cited in Kaynak 2003) and therefore the profitability (Kaynak, 2003). Thus, since production improvements lead to increased financial results, it is possible to argue that the ultimate measure of company performance as well as its strategic success should be financial performance (Büyüközkan *et al.*, 2015; Camacho-Miñano *et al.*, 2013).

Market Performance

Market Performance measures, such as sales growth, reflect market information (Camacho-Miñano *et al.*, 2013). In addition to sales growth, Büyüközkan *et al.* (2015) suggests market share as a typical market performance measure. Market share, customer service levels and competitive position were measures used by Kannan and Tan (2005) in what concerns market performance. Also, Flynn *et al.* (1995b) used the competitive advantage to cover this performance category.

Kaynak (2003) refers that quality performance improves market performance and presents two explanations for that based on literature. On one side, companies' costs structure can be reduced through less rework and scrap as well as productivity improvements allowing them to offer lower prices which in turn can lead to increased market share and sales (Kaynak, 2003). On the other side, quality improvements will lead to higher customers' satisfaction and loyalty as well as improved competitive position (Kaynak, 2003).

2.3 Similar Studies

Throughout this section, two distinctive similar studies are presented and discussed. First, it is presented some studies that through methodologies other than meta-analysis studied the impact of Lean Management practices on company performance. Second, it is introduced some studies that are similar in what concerns the methodology to be applied in this research regardless of the theme under analysis. It is important to clarify that there is a lack of use of meta-analysis as methodological tool regarding the implementation of lean, being Mackelprang and Nair (2010) the closest study to the purpose of this dissertation.

The authors Bevilacqua *et al.* (2016) studied the relationship between lean practices implementation and operation responsiveness and company's growth performance, through Structural Equation Modelling, applied to Italian manufacturing companies. The authors selected thirteen lean best practices and grouped them in four impact areas: JIT, TQM, Supplier Management and HRM. To measure the operational responsiveness, it was used as latent variables the product mix variety, the product innovation and the time effectiveness. As observed variables for growth performances, the authors used: employee growth, sales growth and customer retention. Concerning operational effectiveness, the study results sustain that lean practices implementation is (a) negatively related to the product mix variety and (b) positively related to time effectiveness. Also, the results did not reflect a positive connection between lean practices and product innovation. Finally, it was found that there is no direct relationship between lean implementation and company growth performance.

Sharma *et al.* (2015) proposed to investigate the impact of lean practices on performance measures, regarding the machine tool industry in India. To evaluate this relationship, the authors used reliability test, factor analysis and stepwise multiple regression. As independent variables, the authors used 21 practices associated to Lean Management. Moreover, as dependent variables, and following a Balanced Score Card approach, the authors used the following key performance indicators: quality of design (QOD), quality of conformance (QOC), quality of information (QOI), quality of material flow (QOMF), quality of relationships and (QOR) overall competitive potential (OCP). It was found by the authors that two lean criteria - strategic partnership with suppliers and cross-functional cross-organizational design and development teams - significantly influenced most of the key performance measures. However, some lean criteria were found to have a negative impact on overall competitive potential of machine tool firms.

Another study performed by Belekoukias *et al.* (2014) analysed the impact of lean methods and tools on the operational performance of manufacturing organizations around the world. The JIT, TPM, Autonomation, Value Stream Mapping (VSM) and *Kaizen* were the methods, as called by the authors, selected as independent variables. As dependable variables, the authors used quality, speed, dependability, flexibility, cost and operational performance (average of the ones mentioned before) as measures of operational performance. The results showed that JIT and Autonomation are the practices with the strongest effect on operational performance while *Kaizen*, TPM and VSM appeared to have a lower or even negative impact on operational outcomes.

The relationship between lean manufacturing and performance was also object of study of Shah and Ward (2003) that studied USA manufacturing companies. Additionally, the authors examined the effect of contextual factors (plant size, plant age and unionization status) and categorized the identified lean practices in four bundles, namely, JIT, TQM, TPM and HRM. As measures of performance, the authors used manufacturing cycle time, scrap and rework costs, labor productivity, unit manufacturing costs, first pass yield, customer lead time. The results showed a strong support for the impact of plant size on lean implementation and a less pervasive than expected effect of unionization and plant age (Shah and Ward, 2003). The findings also reflect a substantial contribution of lean bundles on operational performance, explaining about 20% of its variation after considering the influence of industry and contextual factors.

The authors Cua *et al.* (2001) studied the relationships between implementation of TQM, JIT and TPM and manufacturing performance applied to manufacturing companies in Germany, Italy, Japan, United Kingdom and United States. It was decided to include this study here once, few years later, Shah and Ward (2003) have identified TQM, JIT and TPM as three of the four bundles of lean. Seventeen practices belonging to all three programs were taken into analysis. Cost, quality, delivery, flexibility and weighted performances were the chosen indicators of performance. Cua *et al.* (2001) also examined the effect of contextual factors, namely: process type, plant size and capacity utilization, on performance. The results support the compatibility of the practices of the three programs. Furthermore, there is evidence that manufacturing performance is linked to the degree of implementation of such programs. Also, the findings indicate that manufacturing performance is better explained by plant internal practices and techniques than it is by the context in which the plant operates.

A synthesis of the aforementioned studies is presented below in Table 6.

Author(s)	Country	Sector of Activity	Methodology	Practices[1]	Performance	Key Findings
Bevilacqua *et al.* (2016)	Italy	Manufacturing	Structural Equation Modelling	**13 lean best practices distributed in 4 impact areas:** Human Resources Management, Total Quality Management, Just-In-Time and Supplier Management	**a. Operational Responsiveness**: Product Mix; Product Variation; Time Effectiveness **b. Company Growth Performance** Employee Growth; Sales Growth; Customer Retention	It was confirmed that lean practices **negatively relate** to product mix variety; it was **not accepted** the positive relationship between lean practices and product innovation; it **was sustained** the positive influence of lean practices on time effectiveness. There is **no direct relationship** between lean best practices application and company growth performance.
Sharma *et al.* (2015)	India	Machine Tool Industry	Stepwise Multiple Regression Analysis	**21 lean production practices divided in 8 sets of practices**: Procurement, Quality, Inventory, Design and Engineering, Marketing, Information, Distribution and Customers' Engagement	**Company Performance**: QOD; QOC; QOI; QOMF; QOR; OCP	Strategic partnership with suppliers and cross-functional cross-organizational design and development teams **significantly influenced** most of the key performance measures. Some lean criteria were found to **negatively affect** the overall competitive potential of machine tool firms.
Belekoukias *et al.* (2014)	Several Countries	Manufacturing	Linear Regression Analysis	**5 lean practices:** Just-In-Time, Total Productive Maintenance, Autonomation, Value Stream Mapping and *Kaizen*	**Operational Performance**: Quality; Speed; Dependability; Flexibility; Cost; Overall Operational Performance (average of above).	The results reflect that JIT and Autonomation are the practices with the **strongest impact** on operational performance. *Kaizen*, TPM and VSM seem to have a **lower or negative influence** on operational performance.
Shah and Ward (2003)	USA	Manufacturing	Hierarchical Regression Analysis	**22 manufacturing practices distributed in 4 bundles**: JIT practices, TQM practices, TPM practices and HRM practices	**Operational Performance**: Manufacturing Cycle Time; Scrap and Rework Costs; Labor Productivity; Unit Manufacturing Costs; First Pass Yield; Customer Lead Time	Lean bundles **substantially contribute** to operational performance. **Strong support** for the effect of plant size on lean implementation and **less pervasive impact** of unionization and plant age.
Cua *et al.* (2001)	Germany, Italy, Japan, United Kingdom, USA	Electronics, Machinery and Transportation	Multiple Discriminant Analysis	**17 basic techniques and practices distributed in three programs:** TQM techniques, JIT techniques and TPM techniques	**Manufacturing Performance**: Cost; Quality; Delivery; Flexibility; Weighted Performance.	Compatibility among practices of the three programs. Manufacturing performance is **linked** with the level of implementation of practices. Manufacturing practices implementation can cover the **influence of contextual factors** on manufacturing performance.

[1] For detailed information on practices, access the study.

Table 6 – Similar Studies (Lean Effect)

Among similar articles regarding the methodology, Mackelprang and Nair (2010) is the closest study to the purpose of this dissertation. Not only the authors used a meta-analytic investigation as methodological tool but also they proposed to study the relationship between JIT practices (a lean bundle identified by Shah and Ward (2003)) and performance as well as the effect of moderating factors. The authors analysed the impact of ten JIT practices (Setup Time Reduction; Small Lot Sizes; JIT delivery from Suppliers; Daily Schedule Adherence; Preventive Maintenance; Equipment Layout; *Kanban*; JIT link with Customers; *Pull System* and Repetitive Nature of Master Schedule) on six sets of operational performance indicators already mentioned. The results indicate a positive link between JIT practices and aggregate performance. Nevertheless, the results also show that not all individual practices are related to all performance measures. Moreover, the findings suggest that some practices have greater impact on individual performance outcomes than others. Finally, the study shows that half of the relationships between individual JIT practices and performance measures are influenced by moderating factors.

The findings of the remain articles presented next in Table 7 are not relevant for discussion since the analysed practices (Mehra and Ranganathan, 2008; El Shenawy *et al.*, 2007; Nair, 2006) or theme (Leonidou *et al.*, 2002) are not much closer to the practices identified in the literature review nor to the purpose of this dissertation. Therefore, the studies were only included for methodological characteristics analysis.

From the table, it is possible to conclude that search for keywords is the most common search method for articles to be included in the meta-analysis. Also, the number of eligibility criteria does not vary much among different studies, being 5 to 7 the span of the studies presented. The final number of studies included in the analysis (sample size) after accounting for the eligibility criteria is not high, ranging from 23 (Nair, 2006) to 36 (Leonidou *et al.*, 2002), apart from El Shenawy *et al.* (2007) that included 51 studies. Finally, it is possible to observe that the most common statistical method used to perform the analysis is Hunter and Schmidt (1990). Only Leonidou *et al.* (2002) used a different method - Mosteller and Bush (1954).

Author(s)	**Theme**	**Search Method(s)**	**#Eligibility Criteria**	**Sample Size**	**Statistical Method**
Mackelprang and Nair (2010)	JIT Practices and Performance	Citation analysis: articles published in 1992-2008 that cited Mehra and Inman (1992) and Sakakibara *et al*. (1993); Keywords (lean, JIT, just-in-time) on 23 journals.	6	25	Hunter and Schmidt (1990, 2004)
Mehra and Ranganathan (2008)	Total Quality Management and Customer Satisfaction	Search using Boolean expression – TQM and customer satisfaction. Keywords on databases: ABI-Inform global and EBSCOhost.	5	34	Hunter and Schmidt (1990)
El Shenawy *et al*. (2007)	TQM and Competitive Advantage	Databases such as ProQuest, PsychInfo, ElSiver, etc.; Keywords (TQM, total quality, quality management, quality, firm performance, and competitive advantage); manual research in periodical's indices and contents.	7	51	Hunter and Schmidt (1990)
Nair (2006)	Quality Management Practices and Firm Performance	Computer search on ABI/INFORMS database using the Boolean expression - (total quality management) or (quality management) and (performance) – 13 known journals were examined.	5	23	Hunter and Schmidt (1990)
Leonidou *et al*. (2002)	Marketing Strategy Determinants and Export Performance	Combination of computerized and manual bibliographic search by publications in journals, books, and conference proceedings.	6	36	Mosteller and Bush (1954)

Table 7 – Similar Studies (Methodology)

2.4 Research Framework

The main aim of this research is to analyse the impact of the identified Lean Management practices on companies' performance. In case a relationship is detected, we want to study it deeper in order to understand if all lean practices affect all company performance measures, which ones produce a greater impact as well as which performance measures are more affected. Finally, this study also intends to analyse the effect of moderators in the relationship between lean practices and company performance.

Regarding the independent variables of the model to be tested, to ensure a complete coverage of Lean Management implementation, it will be included as many practices as possible. Therefore, the independent variables are: Quick Changeover Techniques, *Pull System*, One Piece Flow, Equipment Layout, *Heijunka*, *Jidoka*, Inventory Reduction, Small Lot Size, Supplier Involvement, *Kaizen*, Cross-functional Teams, Self-directed Work Teams and Preventive Maintenance. Also, it will be considered Aggregate Lean representing all lean practices.

Since the primary goal of the research is to study the impact of lean practices on company performance, as dependent variables it will be considered: Operational Performance, Financial Performance and Market Performance. Moreover, it will be considered Aggregate Performance, representing all performance measures.

The research framework is presented in Figure 2. As already stated, it is also intended to study the impact of moderators on the effect of lean practices on company performance. Thus, the model also considers the presence of moderating factors such as geographic focus. Based on the literature review, the following hypotheses were built in order to, first, study the impact of lean practices on company performance, second, deeply understand such impact and third, study the presence of moderators.

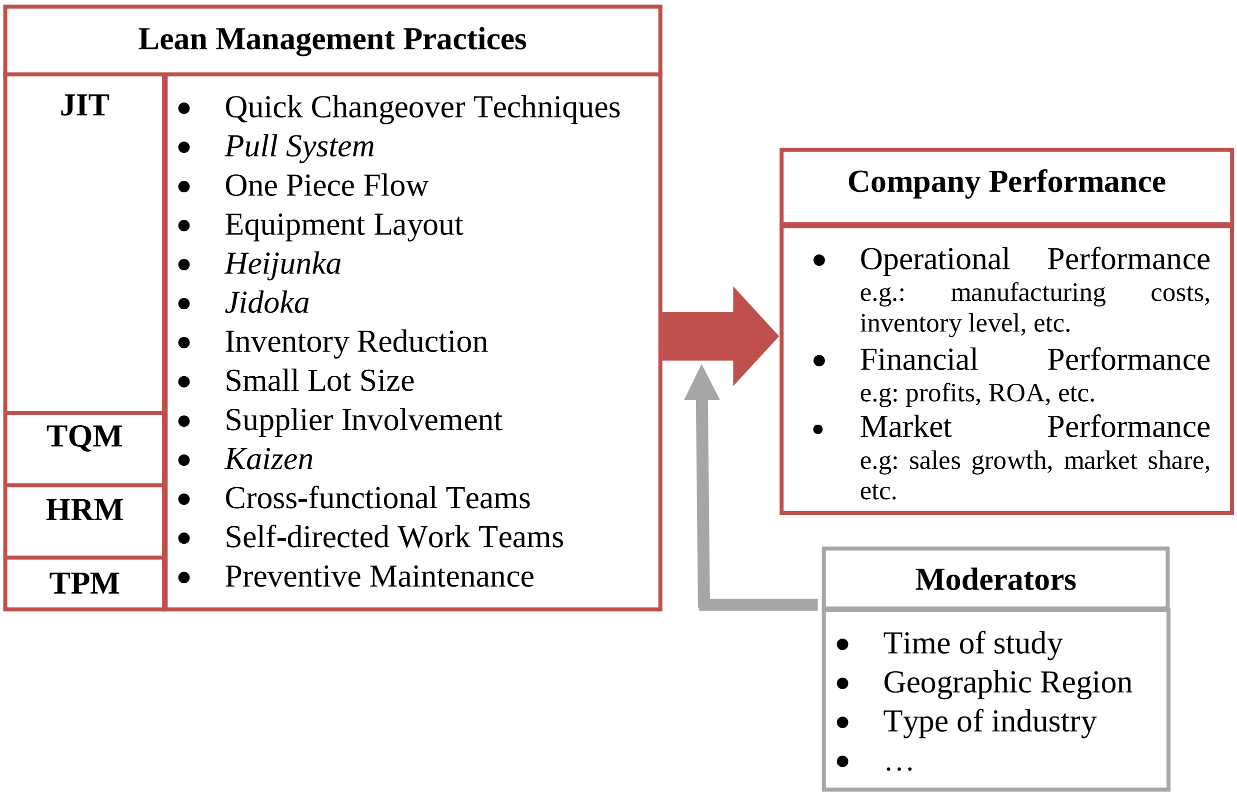

Figure 2 – Research Framework

Considering the extant literature reviewed, it is possible to infer that, overall, the implementation of lean practices positively impacts company performance. Therefore, the first hypothesis to be tested is:

H1: Hypothesis 1 – Lean Management implementation is positively correlated with company performance.

According to Belekoukias *et al.* (2014) and Sharma *et al.* (2015), there are practices which have lower or even negative impact on company performance. Therefore, to study which lean practices affect company performance as well as which measures are impacted, the second hypothesis to be tested is:

H2: Hypothesis 2 – Lean practice$_i$ is positively correlated with performance measure$_j$. (i= Quick Changeover Techniques, *Pull System*, One Piece Flow, Equipment Layout, *Heijunka*, *Jidoka*, Inventory Reduction, Small Lot Size, Supplier Involvement, *Kaizen*, Cross-functional Teams, Self-directed Work Teams and Preventive Maintenance; j= Operational Performance, Financial Performance, Market Performance and Aggregate Performance)

Considering the influence of unknown moderating factors on JIT practices, Mackelprang and Nair (2010) suggested that it should be analyse under which conditions specific lean practices produce greater impact on performance. Additionally, according to Lucato *et al.* (2014), the adoption of lean practices is not equal for all firms and may vary among companies depending on type of industry, region or country. Therefore, to examine if there is an influence of external factors, the third hypothesis to be tested is:

H3: Hypothesis 3 – The relationship between lean practices and performance measures is affected by moderators.

3. Methodological Considerations

In this chapter, it is presented the methodological tool used in this research. The first section, Section 3.1, introduces what is Meta-Analysis and its purpose. The Section 3.2 focuses on explaining the steps needed to perform a meta-analysis according to Field and Gillet (2010)

3.1 The Meta-Analysis

Meta-analysis, known as “analysis of the analysis” (Glass, 1976, p. 3), has been widespread recognized as a fundamental tool for integrating knowledge and it has been largely utilized by scholarly literature for further theory development (Edden, 2002; Mackelprang and Nair, 2010). This methodological tool is defined by Field and Gillett (2010, p.665) as “a statistical tool for estimating the mean and variance of underlying population effects from a collection of empirical studies addressing (…) the same research question”.

Empirical studies are susceptible to “artifacts” such as sampling error (Hunter and Schmidt (2004) have identified 11 “artifacts”) or study imperfections that cause the research correlation among two variables to differ from the actual valid correlation. By correcting for such “artifacts” using additional information (e.g.: reliability estimates), meta-analysis provides a better estimate of the population correlation between dependent and independent variables (Mackelprang and Nair, 2010; Hunter and Schmidt, 2004). In addition to sampling error, Eden (2002) states that meta-analysis allows to overcome other difficulties as measurement error and restriction range associated to individual studies.

Through combining data from multiples sources, meta-analytic investigation provides information about (a) the mean and variance of underlying population effects as well as confidence intervals for population effects; (b) variability in effects across studies: variability statistics provide relevant information concerning the distribution of effect sizes in the meta-analysis and, for that reason, should be reported on studies and (c) moderator variables: the variability of effect sizes, existent in the majority of cases, can be explained by moderator variables (Field and Gillet, 2010).

The process required to perform a meta-analysis can be divided in six steps, as proposed by Field and Gillet (2010), presented in Table 8.

Steps of Meta-Analysis	
1st Step	Do a literature research
2nd Step	Decide on inclusion criteria
3rd Step	Calculate the effect sizes
4th Step	Do the basic meta-analysis
5th Step	Do some more advanced analysis
6th Step	Write up the results

Table 8 – Steps of Meta-Analysis (Field and Gillet, 2010)

The meta-analysis begins with the collection of studies that addressed the same research question using electronic databases. Once the articles are selected, the second step is to decide on inclusion criteria to ensure a minimum level of research quality as well as to avoid subjective bias in the analysis. The criteria should reflect the relevant concerns to the research question such as the measures used. The third step, after collecting the articles considering the inclusion criteria, is to calculate the effect sizes from each one. Generally, an effect size is a standard measure of the magnitude of the observed effect so that effect sizes across different studies can be directly compared. Among many measures of effect size, Pearson correlation coefficient, Cohen's d and odds ratio are the most common ones. The fourth step consists on doing the basic meta-analysis. It requires the selection of appropriate method for the situation (e.g.: fixed vs. random effects) and consequently its application. The fifth step consists on performing some more advanced analysis such as moderators analysis and/or estimation of publication bias. The final step is to write up the results of the meta-analysis. It should be provided clear information about the search and inclusion criteria, the effect size measure used and the meta-analytic technique applied, along with explanations (Field and Gillet, 2010).

3.2. Steps of Meta-Analysis

3.2.1 First Step: Literature Search

The first step of the meta-analysis is the literature search, as Field and Gillet (2010) suggested. The sources of relevant articles to be included in this meta-analysis were mostly online databases such as SCOPUS, EBSCO, B-On and Google Scholar. To ensure a complete coverage of articles linking lean practices to company performance, specific keywords were searched on databases: “Lean and Performance”; “Just-in-Time and Performance”; “Total Quality Management and Performance”; “Human Resource Management, Lean and Performance” and “Total Preventive Maintenance and Performance”. The search was limited to pertinent subject areas as Business Management and Accounting; Economics, Econometrics and Finance and Social Sciences.

Moreover, two specific articles were included as sources: Mackelprang and Nair (2010) – the articles considered by the authors in their meta-analysis are as much as possible included in this research – and Negrão *et al.* (2016) which is a literature review of articles studying lean practices and their effect on performance. The articles analysed by the authors are also as much as possible included in this research.

3.2.2 Second Step: Decide on Inclusion Criteria

The second step is to decide on inclusion criteria which should be rigorous in order to reflect the concerns of the research question.

First, the data of articles must be collected from primary sources by means of a survey. Therefore, case studies and other qualitative studies which do not provide empirical information for the association between lean and performance were excluded from analysis.

Second, it was decided to include articles published between 1990 and 2017 since the concept of lean became popular in the nineties.

The third criteria states that the study must analyse the direct relationship between lean practices and performance through statistical techniques, in accordance with the framework of this research. Thus, articles describing the benefits of lean implementation without quantifying them or analysing critical success factors or practices/measures of performance not aligned with the framework in Figure 2 were also excluded.

Fourth, the articles must provide data from at least one relation between one dependent and one independent variables. Consequently, articles studying the impact of lean as a single construct (e.g.: Degree of Leaness, Lean, TQM, etc.) were excluded from analysis as well.

The fifth criteria states that articles must provide the minimum quantitative data required to perform the meta-analysis.

Table 9 summarizes the inclusion criteria.

Inclusion Criteria	
1st	*Data type:* collected from primary sources through survey
2nd	*Time amplitude:* 1990-2017
3rd	*The study has to analyse:* the relationship between lean practices and performance
4th	*Minimum number of analysed relations:* data of at least one relation between one dependent and one independent variable
5th	*Statistical data:* minimum quantitative data required to perform the meta-analysis

Table 9 – Studies Inclusion Criteria

3.2.3 Third Step: Calculate the Effect Sizes

Once the articles were selected, the third step consisted on finding the effect sizes within them or personally calculate them. In order to gather useful data and reduce coding error, the articles were divided into three-part coded categories.

The first-part includes specific methodological aspects from each study such as geographic focus, year of study, type of industry, company size, industry coverage, sample size, response rate, number of determinants and number of performance measures used. Table 10 presents the coded methodological characteristics in detail.

Methodological Aspects Codification	
1st	*Geographic focus:* Europe, Africa, Asia, America, Oceania, Several
2nd	*Year of study:* 1990s, 2000s, 2010-2017
3rd	*Type of industry:* Manufacturing, Service, Both, N.A.
4th	*Company size:* Small, SME, Medium to Large, Large, All, N.A.
5th	*Industry coverage:* 1 to 3 industries, 4 to 6 industries, 7 to 9 industries, more than 10 industries, N.A.
6th	*Sample size:* Below 100, 100 to 300, Above 300, N.A.
7th	*Response rate:* Below 30%, 30% to 50%, Above 50%, N.A.
8th	*Number of determinants:* 1 to 5 determinants, 6 to 10 determinants, more than 11 determinants
9th	*Number of performance measures:* 1 to 3 measures, 4 to 6 measures, more than 7 measures

Table 10 – Methodological Aspects Codification

The second-part relates to lean practices and company performance measures. Lean practices were categorized into thirteen determinants previously presented and firm performance was coded into operational, market and financial performances. In both cases, an exhaustive analysis was carried out to avoid arbitrary codifications since it was noted that different articles categorize and/or interpret concepts differently.

The third-part of data collection is related with specific meta-analysis details. The metric chosen as a measure of effect sizes was the correlation coefficient between individual practices and performance. Therefore, each article was analysed in detail and relevant quantitative data was collected.

3.2.4 Fourth Step: Do the Basic Meta-Analysis

The fourth step comprises performing the meta-analysis itself. Among several methods that can be applied, Field and Gillet (2010) propose the use of Hunter and Schmidt (2004) method or Hedges and colleagues' method. This research follows the same approach as Mackelprang and Nair (2010) and, therefore, the Hunter and Schmidt (2004) method provides the foundation for the meta-analytic procedures to be employed, which has been widely employed by other researchers (e.g: Mehra and Ranganathan, 2008; El Shenawy *et al.,* 2007; Nair, 2006).

The aim of meta-analysis of correlations is to provide a description of the distribution of actual correlations between independent and dependent variables of a given phenomenon (Hunter and Schmidt, 2004). Empirical researches are vulnerable to study imperfections (or "artifacts", as referred by Hunter and Schmidt (2004)) that cause errors in study results and therefore makes the study correlation to diverge from the real correlation. Some of the "artifacts" can be corrected as it is the case of sampling error or measurement error, using additional information such as study sample sizes and reliability estimates, among others, providing more reliable conclusions (Hunter and Schmidt, 2004).

Eleven "artifacts" have been identified (for detailed information, see Hunter and Schmidt (2004)), being sampling error the one causing more damages. Since individual studies' sampling error is random, the accumulation of findings across studies in the context of meta-analytic investigation allows the individual studies' sampling error to effectively cancel one another, being their average approximately equal to zero. By correcting this type of error, meta-analysis of correlations makes possible to obtain a better estimate of the population correlation among dependent and independents variables (Hunter and Schmidt, 2004; Mackelprang and Nair, 2010).

The sequence of calculations to be performed is presented in Table 11. As it is possible to note, in addition to the effect sizes previous mentioned, from each study it was necessary to collect information regarding sample size and reliabilities of dependent and independent variables in order to correct the correlations for sampling and measurement errors. Similar to what Mackelprang and Nair (2010) have done, average reliabilities described across studies was replaced when reliability was not available.

In accordance with Mackelprang and Nair (2010), to guide the interpretation of results, Hunter and Schmidt (1990) developed two heuristics - RATIO 1 and RATIO 2 - that should be analysed as follows:

- **RATIO 1** is used to detect if the population correlation significantly diverges from zero. The ratio is based on the concept of credibility interval, similar to a confidence interval that uses the standard deviation of correlations rather than the standard error. A RATIO 1 larger than or equal to 2 means that it is likely that the correlation of population is larger than zero. Moreover, it indicates that the likelihood of a correlation being less than or equal to zero is less than 5% as long as the population correlation has a normal distribution. Since it is based on the credibility interval which has been proved to be robust to deviations from normality, RATIO1 represents a reliable measure even in conditions when normality assumptions are not respected (Mackelprang and Nair, 2010).
- **RATIO 2** is used to analyse the existence of moderators effects in meta-analysis of correlations researches. It tells the amount of the observed variance that is due to existence of “artifacts”. A RATIO 2 larger than or equal to 0.75 indicates that there is likely only one population correlation. Therefore, the relationship is not subject to moderators (Mackelprang and Nair, 2010).

Process Steps	Input Variables	Formula	Purpose
Step 1- Attenuation factor	1a. Reliability of lean practices (α_{xx}). 1b. Reliability of performance measures (α_{yy}).	$A = (\alpha_{xx})^{1/2} \times (\alpha_{yy})^{1/2}$	It is used to correct the correlation for measurement error, create the error variance across studies and to weight the studies.
Step 2 - Corrected study correlations	2a. Attenuation factor (A) 2b. Study correlations (r)	$r' = r/A$	It is used in calculating RATIO1, which is used to identify significant population correlations.
Step 3 - Individual study weights	3a. Study sample size (N) 3b. Attenuation factor (A)	$W_i = N \times A^2$	It is used to find the average corrected correlations, average error variances and variance of the corrected correlations.
Step 4 - Corrected study sampling error	4a. Weighted sample mean correlations ($\bar{r}$) 4b. Study sample size (N). 4c. Attenuation factor (A).	$e_i = \left(1 - \bar{r}^2\right)^2 / (N-1)A^2$	Each study's corrected sampling error variance is used to calculate the weighted mean sampling error variance across studies.
Step 5 - Weighted mean sampling error variance	5a. Study weight (W_i). 5b. Study error variances (e_i).	$\bar{e} = \sum W_i e_i / \sum W_i$	It is used to estimate the population SD.
Step 6 - Weighted mean corrected correlations	6a. Study weight (W_i). 6b. Corrected study correlations (r').	$\bar{r}' = \sum W_i r' / \sum W_i$	It is used to find both the variance of the corrected correlations as well as RATIO1
Step 7 - Variance of the corrected correlations	7a. Study weight (W_i). 7b. Corrected study correlations (r'). 7c. Weighted mean corrected correlations ($\bar{r}'$).	${\sigma_{r'}}^2 = \sum W_i [r' - \bar{r}']^2 / \sum W_i$	The variance of the corrected correlations is used to estimate the population SD.
Step 8 - Estimate the population SD	8a. Variance of the corrected correlations (${\sigma_{r'}}^2$). 8b. Mean error variances ($\bar{e}$).	$S_p = [({\sigma_{r'}}^2) - (\bar{e})]^{1/2}$	The estimate of the population standard deviation is used to calculate RATIO1.
Step 9 - Calculate RATIO1	9a. Average corrected correlations ($\bar{r}'$). 9b. Estimated population standard deviation (S_p).	$RATIO1 = \bar{r}' / S_P$	RATIO1 values greater than 2 imply that a positive correlation exists between the considered variables.
Step 10 - Calculate RATIO2	10a. Weighted mean sampling error variances ($\bar{e}$). 10b. Variance of the corrected correlations (${\sigma_{r'}}^2$).	$RATIO2 = \bar{e} / {\sigma_{r'}}^2$	RATIO2 values greater than or equal to 0.75 imply that there is only one population correlation and that the relationship is not subject to moderating factors.
Step 11 - Credibility interval	11a. Estimated population standard deviation (S_p). 11b. Average corrected correlations ($\bar{r}'$). 11c. Z-value of desired credibility level (Z).	$\text{Credibility Interval} = \bar{r}' \pm Z \times S_p$	It returns the endpoints whereby the percentage selected of the values in the correlation distribution are contained.

Table 11 – Meta-Analytic Procedure (Adapted from: Mackelprang and Nair, 2010, p.287)

In accordance with the hypotheses previously formulated, the meta-analysis was performed in two stages. First, the relationship between lean practices and performance was examined at an aggregate level. Second, it was examined the relationship between individual practices and performance, both at individual and aggregate levels.

In line with Mackelprang and Nair (2010), in this meta-analytic research both non-significant and significant correlations between lean practices and performance measures were taken into account with the aim of reducing potential bias in the outcomes.

3.2.5 Fifth Step: Do Some More Advanced Analysis

The fifth step consists on performing advanced analysis. In this research, a moderators analysis is carried out. As previously stated, RATIO 2 enables the researcher to analyse the presence of moderators. Therefore, a meta-analysis of correlations will allow us to study if there are moderating factors influencing the link between independent and dependent variables.

4. Main Results

In this chapter, it is presented the main results of this research. In the first section, Section 4.1, it is described the process of articles selection. The Section 4.2, Characteristics of the Articles Reviewed, presents the profile of the articles included in the meta-analysis. The last section, Section 4.3, displays and analyses the results obtained through the application of meta-analysis of correlations.

4.1 Articles Selection Process

As mentioned in Sections 3.2.1 and 3.2.2., the process started with the literature search on online databases through specific keywords in the period of 1990-2017. More than 3500 articles were found in this first step. Moreover, two specific articles were considered as sources of studies. The 25 articles considered by Mackelprang and Nair (2010) in their meta-analysis were considered in this research. Also, the literature review of Negrão *et al.* (2016) listed 65 potential articles to be included. From those, twenty papers were in common with Mackelprang and Nair (2010).

The total number of articles were then analysed taken into account the type of data and articles which did not collect data from primary sources by means of a survey were excluded from analysis. This reduced our sample to 216 articles.

The studies that did not respect the third, fourth and fifth inclusion criteria presented in Table 9 were also excluded which lead us to a final sample size of 77 articles to be included in our meta-analysis. From those, 45 are from online databases search, 25 from Mackelprang and Nair (2010) and 7 from Negrão *et al.* (2016). The source of the articles is presented in Appendix 1.

Our final sample size compares favorably to other meta-analysis previously presented which sample sizes ranged from 23 to 51 studies. The database containing all the information collected from the 77 studies to be used in the meta-analysis is available upon request to the author.

The process of articles selection is summarized below in Figure 3.

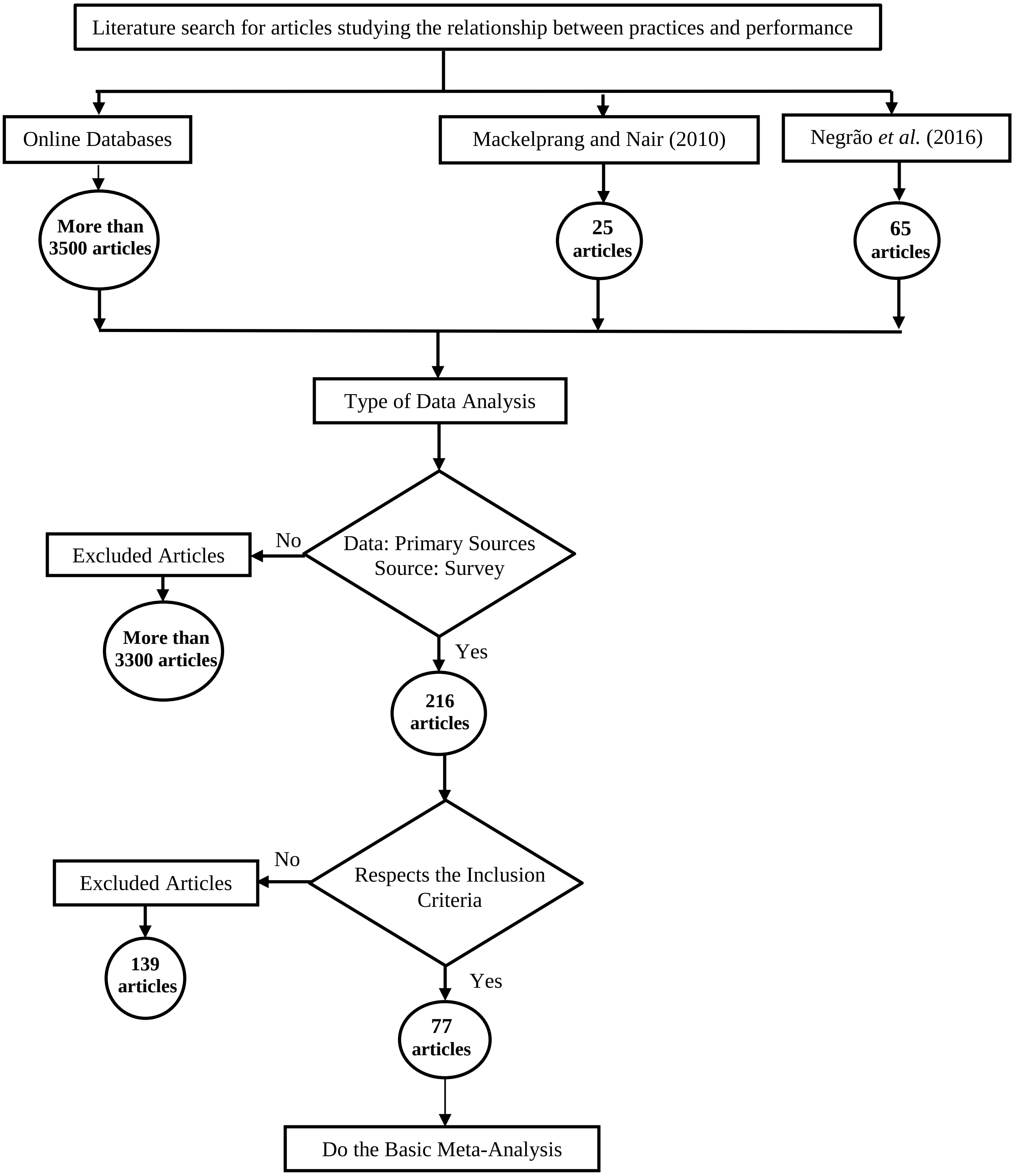

Figure 3 – Process of Articles Selection

4.2 Characteristics of the Articles Reviewed

The 77 articles included in the meta-analysis were not homogenous, presenting diverse statistical information. Since it is known that results tend to be related to the employed methodology, the articles were analysed taking into account particular methodological aspects. Namely, the studies were examined in terms of type of industry, time of study and geographic focus. These three dimensions were categorized relatively to company size, industry coverage, response rate, sample size, number of determinants and number of performance measures used. The information is displayed in detail in Table 12.

In terms of type of industry, it is possible to see that the vast majority of the articles relates to manufacturing companies (61), as it was expected since Lean emerged in the manufacturing industry. Only 9 articles considered a mix of manufacturing and service industries and 6 included only service companies.

The time of study was categorized in: 1990s, 2000s and 2010-2017. From the table, it can be seen that the 2000s was the decade comprising more studies (36), followed by 2010-2017 with 27 studies.

Relatively to geographic focus, it is possible to conclude that the impact of Lean Management implementation on company performance is being explored worldwide, with 11 articles considering countries in more than one continent. America stands out in this analysis with 30 studies, followed by Asia with 20. Europe and Oceania have the same number of studies, six. The geographic focus with lower number of studies is Africa with only two.

Concerning company size, studies were organized in Small, SME, Medium to Large and Large according to aspects such as number of employees and turnover. The majority of the articles include companies from all sizes (36) mainly located in America and conducted in the manufacturing industry. Fifteen articles did not provide information regarding this aspect and fourteen studied medium to large sized companies. Almost 12% of the studies focused on large companies mostly located in America and only a small part (approximately 4%) considered small companies and SME, located in Asia and/or Oceania.

Studies Characteristics	Total (n=77)	Type of industry				Time of study			Geographic Focus					
		Manufacturing (n=61)	Service (n=6)	Both (n=9)	N.A. (n=1)	1990s (n=14)	2000s (n=36)	2010-2017 (n=27)	Europe (n=6)	Africa (n=2)	Asia (n=22)	America (n=30)	Oceania (n=6)	Several (n=11)
Company Size														
Small	1	1	-	-	-	-	1	-	-	-	1	-	-	-
SME	2	1	-	1	-	-	1	1	-	-	1	-	1	-
Medium to Large	14	12	-	2	-	4	6	4	1	-	3	6	-	4
Large	9	9	-	-	-	4	3	2	-	-	2	7	-	-
All	36	26	3	6	1	5	18	13	5	2	6	12	5	6
N.A.	15	12	3	-	-	1	7	7	-	-	9	5	-	1
Industry Coverage														
1 to 5 industries	37	32	5	-	-	7	18	12	2	-	9	17	-	9
6 to 10 industries	16	14	1	1	-	2	5	9	1	2	6	6	-	1
11 or more industries	4	4	-	-	-	-	4	-	-	-	-	2	2	-
N.A.	20	11	-	8	1	5	9	6	3	-	7	5	4	1
Response rate														
Below 30%	21	16	1	4	-	5	11	5	1	-	4	13	2	1
30 to 50%	22	15	2	5	-	3	12	7	4	-	7	5	4	2
Above 50%	17	15	2	-	-	3	7	7	1	1	5	6	-	4
N.A.	17	15	1	-	1	3	6	8	-	1	6	6	-	4
Sample Size														
Below 100	26	22	2	2	-	5	12	9	2	2	11	10	1	-
100 to 300	38	31	4	3	-	5	16	17	1	-	11	14	2	10
Above 300	13	8	-	4	1	4	8	1	3	-	-	6	3	1
Nr. of Determinants														
1 to 5 determinants	33	24	4	5	-	6	15	12	4	-	13	9	2	5
6 to 10 determinants	24	21	-	2	1	5	10	9	1	1	3	12	2	5
11 or more determinants	20	16	2	2	-	3	11	6	1	1	6	9	2	1
Performance Measures														
1 to 3 measures	19	16	2	1	-	6	9	4	-	-	6	8	4	1
4 to 6 measures	30	26	-	3	1	4	16	10	-	-	8	13	1	8
7 or more measures	28	19	4	5	-	4	11	13	6	2	8	9	1	2

Table 12 – Profile of Lean Management Practices Impact on Company Performance Research

Regarding industry coverage, twenty articles failed to provide this information. The majority of the articles focused on 1 to 5 industries, including both manufacturing and services industries. It was not common to consider 11 or more industries (4 studies only).

Considering the response rate, the studies are almost equally divided across the following categories: below 30%, 30% to 50% and above 50%. There are 21 articles with low response rate mainly located in Asia, 22 with a moderate response rate worldwide located and 17 studies present high response rate mostly located in America and Asia. Among the articles, 17 did not provide information about response rate.

In terms of sample size, the majority of the articles presented samples sizes between 100 and 300 (38), generally related to manufacturing companies and conducted since the 2000s in America and Asia. A small number of studies (13) presented samples higher than 300 and 26 studies have sample sizes lower than 100.

Relatively to the number of determinants, the dominating amount is 1 to 5 determinants. However, it is not uncommon to study a higher number of determinants as it is the case of this research. Twenty-four studies analysed 6 to 10 determinants and twenty articles analysed 11 or more.

In what concerns the number of performance measures, there is a preference to use a high number of measures. Approximately 75% of the studies presented 4 or more measures of performance.

4.3 Findings and Analysis

In this section, it is presented and analysed the results obtained through the use of meta-analysis of correlations. As mentioned before, the meta-analysis was performed in two stages.

The first stage of the analysis examined the relationship between lean practices and performance at an aggregate level. Aggregate Lean (representative of Lean Management implementation) was defined as a cumulative set including all lean practices and Aggregate Performance (representative of company performance) as a cumulative set encompassing all performance measures. In detail, the variables were computed as in Ataseven and Nair (2017): the correlation between Aggregate Lean and Aggregate Performance was calculated by averaging the correlations between lean practices and performance measures included in each study. Also, the average of reliability estimates of lean practices in each study was used as the Aggregate Lean reliability. Likewise, the average of the reliability estimates of the performance measures was used as the performance reliability in each study.
The data used in this part of the analysis is presented in Appendix 2.

The second stage analysed the relationship between specific lean practices and performance measures. The data used in this stage of analysis is presented in Appendix 3. Due to insufficient data available regarding the variables One Piece Flow and Inventory Reduction, thy were entirely excluded from further analysis.

The first hypothesis to be tested is the theoretically assumed positive link between Lean Management implementation and company performance:

$\boldsymbol{H_0}$ = *Lean Management implementation is not positively correlated with company performance.*

$\boldsymbol{H_1}$ = *Lean Management implementation is positively correlated with company performance.*

Following the heuristics presented in Section 3.2.4, the relationship between Aggregate Lean and Aggregate Performance was not found to be significantly positively correlated with a value of RATIO 1 equal to 1,680. Therefore, the null hypothesis cannot be rejected. The credibility interval for population correlation between lean and performance is [-

0,056; 0,733] meaning that if the normality assumptions are satisfied 95% of the values of the distribution of population correlation are within this range. The width of the interval represents the variety of the effect sizes' magnitude of population correlation distribution and since it includes 0, it cannot be asserted a valid positive correlation between lean practices and performance.

Unfortunately, according to our best knowledge, this is the first Lean Management meta-analytic investigation and therefore we are not able to directly compare our results to other similar researches' findings. However, through the use of other methodologies, other researches demonstrated similar conclusions. In their review of international peer-reviewed journal articles, Arlbjørn and Freytag (2013) concluded that overall the evidence that lean works in the reviewed articles is low.

Considering the influence of moderating factors, the value of RATIO 2 is 0,118. Since it is lower than 0,75 it can be concluded that the relationship between Aggregate Lean and Aggregate Performance is influenced by moderators.

The second goal of this research is to identify if individual lean practices are positively correlated with performance outcomes, both at individual and aggregate levels:

$\boldsymbol{H}_{\boldsymbol{0}_{i,j}}$ = *Lean practice$_i$ is not positively correlated with company performance measure$_j$.*

$\boldsymbol{H}_{\boldsymbol{1}_{i,j}}$ = *Lean practice$_i$ is positively correlated with company performance measure$_j$.*

Being i= Quick Changeover Techniques, Pull System, Equipment Layout, Heijunka, Jidoka,, Small Lot Size, Supplier Involvement, Kaizen, Flexible, Cross-functional Teams, Self-directed Work Teams and Preventive Maintenance; j= Operational Performance, Financial Performance, Market Performance and Aggregate Performance.

The results are presented in Table 13. Values of RATIO 1 higher than 2 and RATIO 2 lower than 0,75 are presented in bold.

Regarding *Quick Changeover Techniques*, the practice proved to be positively correlated with Aggregate Performance and Financial Performance since the RATIO 1 values are higher than 2. However, even though it is positively correlated with Aggregate Performance, the practice was not found to be positively correlated with Operational Performance. Due to lack of data, it was not possible to analyse the relationship between Quick Changeover Techniques and Market Performance.

		# of studies	Weighted Sample Mean Correlations (r|)	Weighted Mean Corrected Correlations (r|')	Mean Error Variance (e|)	Variance of Corrected Correlations (σ²r')	Sp	RATIO 1	RATIO 2
Quick Changeover Techniques									
	Operational Performance	20	0,1580	0,1992	0,0059	0,0188	0,1137	1,7514	**0,3136**
	Financial Performance	6	0,1839	0,2291	0,0106	0,0192	0,0928	**2,4704**	**0,5518**
	Market Performance	1	Insufficient data for analysis						
	Aggregate Performance	23	0,1927	0,2389	0,0059	0,0168	0,1042	**2,2933**	**0,3530**
Pull System									
	Operational Performance	22	0,1861	0,2319	0,0061	0,0102	0,0640	**3,6238**	**0,5982**
	Financial Performance	4	0,2842	0,3317	0,0077	0,0180	0,1015	**3,2690**	**0,4280**
	Market Performance	2	0,3384	0,3750	0,0078	0,0042	0,0000	**∞**	1,8484
	Aggregate Performance	25	0,2207	0,2700	0,0060	0,0342	0,1680	1,6076	**0,1757**
Equipment Layout									
	Operational Performance	15	0,1718	0,2186	0,0054	0,0215	0,1268	1,7246	**0,2531**
	Financial Performance	3	0,2473	0,3200	0,0140	0,0156	0,0398	**8,0446**	0,8986
	Market Performance				-				
	Aggregate Performance	17	0,1679	0,2137	0,0060	0,0216	0,1247	1,7142	**0,2789**
Heijunka									
	Operational Performance	12	0,1583	0,2016	0,0121	0,0219	0,0993	**2,0300**	**0,5502**
	Financial Performance	1	Insufficient data for analysis						
	Market Performance				-				
	Aggregate Performance	12	0,1630	0,2084	0,0120	0,0221	0,1006	**2,0717**	**0,5422**
Jidoka									
	Operational Performance	6	0,2230	0,2820	0,0112	0,0230	0,1087	**2,5943**	**0,4859**
	Financial Performance	1	Insufficient data for analysis						
	Market Performance	3	0,3139	0,3747	0,0059	0,0080	0,0455	**8,2331**	**0,7401**
	Aggregate Performance	7	0,3515	0,4270	0,0076	0,0043	0,0000	**∞**	1,7709

Small Lot Size							
Operational Performance	11	0,1827	0,2233	0,0042	0,0181	0,1179	1,8931	**0,2318**
Financial Performance	3	0,1610	0,1845	0,0047	0,0619	0,2391	0,7719	**0,0764**
Market Performance	2	0,2045	0,2360	0,0036	0,0196	0,1267	1,8628	**0,1819**
Aggregate Performance	11	0,1785	0,2184	0,0042	0,0165	0,1108	1,9708	**0,2549**
Supplier Involvement								
Operational Performance	18	0,2016	0,2419	0,0066	0,1196	0,3362	0,7196	**0,0549**
Financial Performance	7	0,1680	0,2137	0,0106	0,0454	0,1866	1,1449	**0,2330**
Market Performance	8	0,2045	0,2521	0,0053	0,0324	0,1646	1,5317	**0,1639**
Aggregate Performance	29	0,3219	0,4025	0,0055	0,0834	0,2791	1,4418	**0,0660**
Kaizen								
Operational Performance	17	0,3892	0,4710	0,0068	0,0674	0,2462	1,9131	**0,1012**
Financial Performance	5	0,3175	0,3832	0,0105	0,0305	0,1411	**2,7149**	**0,3462**
Market Performance	5	0,2733	0,3080	0,0056	0,0334	0,1670	1,8443	**0,1660**
Aggregate Performance	29	0,3908	0,4742	0,0063	0,0537	0,2178	**2,1767**	**0,1164**
Flexible, Cross-functional Teams								
Operational Performance	14	0,1236	0,1334	0,0080	0,1937	0,4308	0,3097	**0,0416**
Financial Performance	3	0,2877	0,3936	0,0168	0,0580	0,2029	1,9397	**0,2896**
Market Performance	5	0,1914	0,2238	0,0076	0,0361	0,1687	1,3266	**0,2107**
Aggregate Performance	23	0,2693	0,3317	0,0060	0,1629	0,3961	0,8374	**0,0367**
Self-directed Work Teams								
Operational Performance	18	0,1838	0,2207	0,0065	0,1461	0,3737	0,5904	**0,0442**
Financial Performance	3	0,2392	0,3043	0,0177	0,0174	0,0000	**∞**	1,0209
Market Performance	5	0,2787	0,3334	0,0044	0,0280	0,1536	**2,1706**	**0,1560**
Aggregate Performance	30	0,3110	0,3741	0,0065	0,1185	0,3346	1,1180	**0,0552**
Preventive Maintenance								
Operational Performance	13	0,2981	0,3793	0,0087	0,0659	0,2393	1,5854	**0,1318**
Financial Performance	1			Insufficient data for analysis				
Market Performance				-				
Aggregate Performance	16	0,3959	0,4855	0,0072	0,1021	0,3082	1,5754	**0,0702**

Table 13 – Meta-Analysis of Correlations Results

The practice *Pull System* was found to be positively correlated with all performance measures at individual levels. However, when considered at an aggregate level, it was not found a positive correlation between the two variables.

In what concerns *Equipment Layout*, we were unable to examine its relationship with Market Performance due to inexistence of studies. The practice was only found to be positively correlated with Financial Performance.

Considering *Heijunka*, the practice proved to have a positive correlation with Operational Performance. Due to lack of available, we were not able to analyse the relationship between *Heijunka* and Financial and Market Performances. Furthermore, the relationship between *Heijunka* and Aggregate Performance has little meaning since it mostly relates to articles studying Operational Performance, including only one related to Financial Performance.

The practice *Jidoka* was found to be positively correlated with Operational Performance, Market Performance and Aggregate Performance. Due to lack of data, it was not possible to examine the relationship between the practice and Financial Performance.

At individual level, *Kaizen* was only found to be positively correlated with Financial Performance. However, when considering financial, operational and market measures all together, the practice proves to be positively correlated with them.

Regarding the practice *Self-directed Work Teams*, the results indicate a positive correlation with Financial and Market Performances. However, the practice was not found to be positively correlated with Operational Performance. Moreover, even though it is positively related with financial and market measures of performance, a positive relationship with Aggregate Performance was not found.

The practices *Small Lot Size, Supplier Involvement, Flexible, Cross-functional Teams* and *Preventive Maintenance* were not found to be positively correlated with any of the performance measures. Therefore, we cannot reject the null hypothesis for the majority of the analysed pairs of relationship.

From a performance perspective, the results indicate that Operational Performance is positively correlated with *Pull System*, *Heijunka* and *Jidoka*; Financial Performance is positively correlated with Quick Changeover Techniques, *Pull System*, Equipment

Layout, *Kaizen* and Self-directed Work Teams and Market Performance is positively correlated with *Pull System*, *Jidoka* and Self-directed Work Teams. Bearing this in mind, when implementing lean, companies should not assume that all lean practices improve all performance measures.

These results considerably differ from Mackelprang and Nair (2010) findings, considering common practices (Quick Changeover Techniques, Small Lot Sizes, *Heijunka*, Preventive Maintenance, Equipment Layout and Pull System). The authors found all practices to be positively correlated with aggregate performance (equivalent to our operational performance variable, since the authors only analysed operational measures). The difference might be explained by the number of studies included in both meta-analysis. According to Hunter and Schmidt (2004), the higher the number of studies included in sample, the better the estimate of the actual population correlation. Moreover, the authors confined their search to articles published until 2008 in a specific number of journals. Our research not only includes the following years but also covers a larger number of articles in an effort to locate all relevant articles and avoid publication bias.

The third hypothesis to be tested is the influence of moderators in the relationship between lean practices and performance measures:

$\boldsymbol{H}_{\mathbf{0}_{i,j}}$ = *The relationship between lean practice$_i$ and performance measure$_j$ is not influenced by moderators.*

$\boldsymbol{H}_{\mathbf{1}_{i,j}}$ = *The relationship between lean practice$_i$ and performance measure$_j$ is influenced by moderators.*

Being i= Quick Changeover Techniques, Pull System, Equipment Layout, Heijunka, Jidoka, Small Lot Size, Supplier Involvement, Kaizen, Flexible, Cross-functional Teams, Self-directed Work Teams and Preventive Maintenance; j= Operational Performance, Financial Performance, Market Performance and Aggregate Performance.

From Table 13, it can be seen that overall the relationship between lean practices and performance measures is influenced by moderators. Only the relationships *Pull System* vs Market Performance, Equipment Layout/Self-directed Work Teams vs Financial Performance and *Jidoka* vs Aggregate Performance revealed to not be influenced by moderators. Thus, the Hypothesis 3 is supported. This result indicates that the context under which the practices are implemented has impact on the outcomes produced by them. Mackelprang and Nair (2010) also found a significantly influence of moderating factors in almost half of their examined relationships.

The results are summarized next in Table 14. As it is possible to conclude, about 58% of the analysed correlations are not significant. Again, this suggests that when evaluating lean practices it should not be assumed that all practices lead to performance gains in all aspects of performance.

To better understand the results, two columns were added to the table: breadth of impact and depth of impact. The breadth of the effect is considered high when one individual lean practice improves multiple performance measures. The depth of impact captures the magnitude of the significant correlations between practices and performance outcomes. From the table, it is possible to conclude that *Jidoka, Heijunka* and *Pull System* yield the greatest impact in terms of breadth of impact, influencing in a positive way all the analysed performance measures. It is important to note that *Heijunka* has a very high breadth of impact but only one performance measure was analysed due to lack of data. Considering the depth of impact, the magnitude of the significant correlations does not considerably differ among individual practices, ranging from 0,202 to 0,383. Even though *Kaizen* presents very low breadth of impact, it is the practice with the highest depth of impact.

Lean Practice	**Operational Performance**	**Financial Performance**	**Market Performance**	**Breadth of Impact (% of possible significant outcomes)**	**Depth of Impact (average significant corrected correlations)**
Jidoka	X*	n/a	X*	Very High (100%)	0,328
Pull System	X*	X*	X	Very High (100%)	0,313
Heijunka	X*	n/a	n/a	Very High (100%)	0,202
Self-directed Work Teams		X	X*	Medium (67%)	0,319
Equipment Layout		X	n/a	Low (50%)	0,320
Quick Changeover Techniques		X	n/a	Low (50%)	0,229
Kaizen		X*		Very Low (33%)	0,383
Small Lot Size				-	-
Supplier Involvement				-	-
Flexible, Cross-functional Teams				-	-
Preventive Maintenance		n/a	n/a	-	-

X – significant positive correlation

* - subject to moderating factors

n/a – not analysed due to insufficient data

Table 14 – Impact Analysis of Individual Lean Practices on Performance Measures (Adapted from: Mackelprang and Nair, 2010, p.295)

5. Conclusion

The results of this dissertation did not prove a significantly positive relationship between Lean Management implementation and company performance, when evaluated at an aggregate level. On one hand, this was a surprising finding given the widespread adoption of Lean Management and the conceptually assumed benefits derived from its implementation. On the other hand, other researches previously analysed have found some lean practices to have lower or even negative impact on performance measures. Therefore, considering a combination of such results the finding was not entirely unexpected.

The analysis at individual level provides some guidelines for managers that consider Lean Management as an option. Given the results, it should not be expected that all lean practices will yield improvements of all performance measures. Furthermore, the impact factors analysis also suggests that some practices yield greatest performance benefits than others, as it is the case of *Jidoka* comparing to the other analysed practices. Moreover, the analysis of moderating factors proved that almost all of the pairs of relationships are influenced by such factors. Therefore, managers should take the underlying context into account when implementing lean. By instance, even though Quick Changeover Techniques was found to be significantly positively related to Aggregate Performance, it should not be expected this to happen in every context where the practice is implemented.

Notwithstanding the undertaken effort to cover as many research findings as possible, this dissertation has some limitations. First, this meta-analysis of correlations only corrects two out of eleven "artifacts" identified by Hunter and Schmidt (2004): measurement and sampling errors. Thus, the studies included in this research were subject to other types of "artifacts" that were not accounted for in this scientific work. Second, when reliabilities were not available it was necessary to substitute them by the average reliabilities across all studies which might not exactly reflect the true properties of the variables.

Despite the worldwide adoption of Lean Management, this research suggests that several of the relationships between lean practices and performance measures have yet to be subject to further empirical search. One Piece Flow and Inventory Reduction were not object of analysis due to lack of studies analysing them. Also, other pairs of relationships such as Quick Changeover Techniques – Market Performance (see Table 13) did not have sufficient data available for analysis. Additionally, future research on the magnitude of the impact of lean practices on performance outcomes can act as guide for implementation of practices that produce greater improvements. Furthermore, given the proved influence of moderating factors, it would be interesting to provide some light on this aspect in future researches and to analyse which specific factors most influence the relationship between lean practices and performance measures. By instance, it would be insightful to analyse the impact of geographic focus on the results. Finally, future research should also provide insights on how Lean Management should be implemented: if practices should be simultaneous implemented or in a sequential model, since practices might interact with each other yielding different levels of improved performance.

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Appendixes

Appendix 1 – List of Studies included in the Meta-Analysis

Author(s)	Journal
Mehra and Inman (1992)	Decision Sciences
Sakakibara *et al.* (1993)	Production and Operations Management
Lawrence and Hottenstein (1995)	Journal of Operations Management
Flynn *et al.* (1995a)	Academy of Management Journal
Flynn *et al.* (1995b)	Decision Sciences
Powell (1995)	Strategic Management Journal
Dean and Snell (1996)	Strategic Manufacturing Journal
Forza (1996)	International Journal of Physical Distribution and Logistics Management
Jayaram and Vickery (1998)	Journal of Supply Chain Management
Claycomb *et al.* (1999a)	International Journal of Logistics Management
Sim and Curatola (1999)	International Journal of Quality and Reliability Management
Claycomb *et al.* (1999b)	International Journal of Physical Distribution & Logistics Management
Sun (1999)	Total Quality Management
Dow *et al.* (1999)	Production and Operations Management
Callen *et al.* (2000)	International Journal of Production Economics
Agus *et al.* (2000)	Total Quality Management
Sun (2000)	International Journal of Quality & Reliability Management
Fullerton and McWatters (2001)	Journal of Operations Management
McKone *et al.* (2001)	Journal of Operations Management
Swanson (2001)	International Journal of Production Economics
Fawcett and Myers (2001)	International Journal of Production Research
Rahman (2001)	Total Quality Management
He and Hayya (2002)	Total Quality Management
Brah *et al.* (2002)	International Journal of Quality & Reliability Management
Shah and Ward (2003)	Journal of Operations Management
Das and Jayaram (2003)	International Journal of Production Research
Kaynak (2003)	Journal of Operations Management
Ketokivi and Schroeder (2004)	International Journal of Operations and Production Management
Nahm *et al.* (2004)	Decision Sciences
Montes and Jover (2004)	The Service Industries Journal
Swink *et al.* (2005)	Decision Sciences
Challis *et al.* (2005)	International Journal of Production Research
Li *et al.* (2005)	Journal of Operations Management
Kannan and Tan (2005)	Omega
Sila and Ebrahimpour (2005)	International Journal of Operations & Production Management
Rahman and Bullock (2005)	Omega
Agus (2005)	Singapore Management Review

Ward and Zhou (2006)	Decision Sciences
Narasimhan *et al.* (2006)	Journal of Operations Management
Terziovski (2006)	Management Research News
Brah and Lim (2006)	International Journal of Physical Distribution & Logistics Management
Matsui (2007)	International Journal of Production Economics
Avittathur and Swamidass (2007)	Journal of Operations Management
Dal Pont *et al.* (2008)	Operations Management Research
Jayaram *et al.* (2008)	International Journal of Production Research
Ahuja and Khamba (2008)	International Journal of Quality & Reliability Management
Jung and Hong (2008)	International Journal of Quality & Reliability Management
Arumugam *et al.* (2008)	The TQM Journal
Fullerton and Wempe (2009)	International Journal of Operations & Production Management
Hallgren and Olhager (2009)	International Journal of Operations & Production Management
Fotopoulos and Psomas (2010)	The TQM Journal
Phan and Matsui (2010)	International Journal of Productivity and Quality Management
Wali and Boujelbene (2010)	International Journal of Productivity and Quality Management
Bonavia and Marin-Garcia (2011)	International Journal of Manpower
Agus and Hassan (2011)	Procedia Social and Behavioral Sciences
Valmohammadi (2011)	The TQM Journal
Baird *et al.* (2011)	International Journal of Operations & Production Management
Danese *et al.* (2012)	Industrial Management & Data Systems
Alsmadi *et al.* (2012)	Total Quality Management & Business Excellence
Kaur *et al.* (2012)	International Journal of Productivity and Performance Management
Agus and Hajinoor (2012)	International Journal of Quality & Reliability Management
Chen and Tan (2013)	International Journal of Operations & Production Management
Nawanir *et al.* (2013)	Journal of Manufacturing Technology Management
Ahuja and Singh (2013)	International Journal of Technology, Policy and Management
Talib *et al.* (2013)	International Journal of Quality & Reliability Management
Abusa and Gibson (2013)	International Journal of Quality & Reliability Management
Alcaraz *et al.* (2014)	Computers in Industry
Belekoukias *et al.* (2014)	International Journal of Production Research
Gao and Low (2014)	Journal of Professional Issues in Engineering Education and Practice
García *et al.* (2014)	International Journal of Production Research
Foon and Terziovski (2014)	Journal of Manufacturing Technology Management
Maitah *et al.* (2014)	International Business Management
Alaraki (2014)	Quality Management in Healthcare
Marodin *et al* (2016).	Supply Chain Management: An International Journal
Modgil and Sharma (2016)	Journal of Quality in Maintenance Engineering
Sweis *et al.* (2016)	International Journal of Productivity and Quality Management
Kumar and Kumar (2016)	International Journal of Productivity and Quality Management

Appendix 2 - Full Sample Data

Author	N	Average Practice-Performance Correlation (r)	Attenuation Factor (A)	Corrected Correlation (r')	Study Weights (Wi)
Alcaraz *et al.* (2014)	159	0,110	0,828	0,133	109,129
Belekoukias *et al.* (2014)	140	0,274	0,803	0,341	90,272
Gao and Low (2014)	93	0,519	0,853	0,609	67,638
Chen and Tan (2013)	224	0,195	0,774	0,252	134,229
Nawanir *et al.* (2013)	139	0,366	0,706	0,518	69,326
Danese *et al.* (2012)	207	0,251	0,747	0,335	115,581
Fullerton and Wempe (2009)	121	0,300	0,847	0,354	86,877
Dal Pont *et al.* (2008)	266	0,162	0,803	0,202	171,517
Matsui (2007)	46	0,224	0,786	0,285	28,442
Ward and Zhou (2006)	769	0,164	0,803	0,204	495,851
Swink *et al.* (2005)	57	0,150	0,803	0,187	36,754
Shah and Ward (2003)	1508	0,166	0,803	0,207	972,359
Fullerton and McWatters (2001)	95	0,237	0,803	0,295	61,256
McKone *et al.* (2001)	117	0,304	0,847	0,359	83,937
Callen *et al.* (2000)	100	-0,078	0,803	-0,097	64,480
Dean and Snell (1996)	92	0,060	0,760	0,079	53,139
Lawrence and Hottenstein (1995)	124	0,420	0,745	0,564	68,823
Mehra and Inman (1992)	114	0,193	0,794	0,243	71,870
Sakakibara *et al.* (1993)	822	0,301	0,727	0,414	434,451
Flynn *et al.* (1995a)	42	0,178	0,786	0,227	25,931
Forza (1996)	248	0,310	0,853	0,363	180,420
Jayaram and Vickery (1998)	57	0,187	0,803	0,232	36,754
Claycomb *et al.* (1999a)	200	0,180	0,704	0,256	99,213
Sim and Curatola (1999)	83	0,135	0,803	0,168	53,518
He and Hayya (2002)	48	0,125	0,803	0,155	30,950
Das and Jayaram (2003)	309	0,243	0,782	0,311	188,899
Ketokivi and Schroeder (2004)	164	0,194	0,756	0,256	93,820
Nahm *et al.* (2004)	224	0,267	0,616	0,433	84,998
Challis *et al.* (2005)	1024	0,135	0,616	0,219	388,563
Li *et al.* (2005)	196	0,147	0,803	0,182	126,381
Narasimhan *et al.* (2006)	224	0,070	0,720	0,097	116,099
Avittathur and Swamidass (2007)	26	0,233	0,815	0,286	17,270
Alsmadi *et al.* (2012)	278	0,831	1,815	0,458	915,795
Marodin *et al.* (2016)	64	0,095	0,803	0,118	41,267
Wickramasinghe and Perera	236	0,602	0,767	0,785	138,946
Kannan and Tan (2005)	556	0,060	0,798	0,075	353,836
Hallgren and Olhager (2009)	211	0,069	0,811	0,084	138,687
Jayaram *et al.* (2008)	57	0,117	0,781	0,149	34,756
García *et al.* (2014)	195	0,105	0,896	0,117	156,702
Kaur *et al.* (2012)	34	0,684	0,722	0,946	17,734
Ahuja and Khamba (2008)	80	0,482	0,925	0,521	68,434

Swanson (2001)	287	0,200	0,803	0,249	185,058
Foon and Terziovski (2014)	108	0,478	0,798	0,599	68,718
Ahuja and Singh (2013)	36	0,899	0,756	1,189	20,586
Modgil and Sharma (2016)	254	0,440	0,854	0,515	185,166
Fawcett and Myers (2001)	158	0,442	0,829	0,533	108,457
Claycomb *et al.* (1999b)	200	0,190	0,871	0,218	151,680
Flynn *et al.* (1995b)	706	0,063	0,791	0,079	441,815
Agus and Hajinoor (2012)	200	0,334	0,915	0,364	167,492
Talib *et al.* (2013)	172	0,563	0,880	0,639	133,348
Sila and Ebrahimpour (2005)	220	0,511	0,830	0,616	151,379
Sun (1999)	316	0,465	0,803	0,579	203,757
Powell (1995)	54	0,256	0,803	0,319	34,819
Agus and Hassan (2011)	169	0,558	0,916	0,609	141,798
Abusa and Gibson (2013)	57	0,170	0,801	0,212	36,610
Jung and Hong (2008)	230	0,545	0,853	0,639	167,461
Terziovski (2006)	1289	0,340	0,722	0,471	671,572
Brah *et al.* (2002)	188	0,866	0,803	1,078	121,222
Rahman and Bullock (2005)	261	0,074	0,707	0,104	130,278
Brah and Lim (2006)	81	0,644	0,830	0,776	55,767
Maitah *et al.* (2014)	142	0,275	0,813	0,338	93,915
Valmohammadi (2011)	53	0,293	0,837	0,350	37,146
Kaynak (2003)	382	0,296	0,854	0,346	278,406
Baird *et al.* (2011)	145	0,125	0,754	0,166	82,476
Agus *et al.* (2000)	30	0,353	0,857	0,412	22,035
Agus (2005)	50	0,309	0,832	0,371	34,618
Fotopoulos and Psomas (2010)	370	0,158	0,912	0,173	307,574
Montes and Jover (2004)	77	0,361	0,917	0,394	64,707
Rahman (2001)	49	0,357	0,803	0,444	31,595
Sun (2000)	363	0,457	0,803	0,569	234,063
Arumugam *et al.* (2008)	122	0,359	0,776	0,463	73,488
Dow *et al.* (1999)	698	-0,036	0,700	-0,051	341,635
Sweis *et al.* (2016)	165	0,470	0,825	0,569	112,283
Kumar and Kumar (2016)	62	0,370	0,746	0,496	34,463
Phan and Matsui (2010)	210	0,323	0,788	0,410	130,364
Wali and Boujelbene (2010)	66	0,126	0,834	0,150	45,905
Alaraki (2014)	269	0,728	0,803	0,906	173,451

Appendix 3 – Individual Lean Practices vs Performance Data

Operational Performance Author(s)	N	Practice-Performance Correlation (r)	Attenuation Factor (A)	Corrected Correlation (r')	Study Weights (Wi)
Quick Changeover Techniques					
Chen and Tan (2013)	224	0,156	0,779	0,200	136,092
Nawanir *et al.* (2013)	139	0,260	0,615	0,423	52,542
Fullerton and Wempe (2009)	121	0,510	0,865	0,590	90,532
Marodin *et al.* (2016)	64	-0,070	0,803	-0,087	41,267
Agus and Hajinoor (2012)	200	0,117	0,915	0,128	167,373
Dow *et al.* (1999)	698	0,051	0,627	0,081	274,370
Kumar and Kumar (2016)	62	0,403	0,779	0,518	37,578
Phan and Matsui (2010)	210	0,367	0,764	0,480	122,656
Dal Pont *et al.* (2008)	266	0,210	0,803	0,262	171,517
Matsui (2007)	46	0,169	0,779	0,217	27,888
Ward and Zhou (2006)	769	0,116	0,803	0,144	495,851
Shah and Ward (2003)	1508	0,157	0,803	0,196	972,359
Fullerton and McWatters (2001)	95	0,268	0,803	0,334	61,256
Callen *et al.* (2000)	100	-0,260	0,803	-0,324	64,480
Flynn *et al.* (1995a)	42	0,210	0,716	0,293	21,507
Sim and Curatola (1999)	83	0,140	0,803	0,174	53,518
He and Hayya (2002)	48	0,116	0,803	0,144	30,950
Das and Jayaram (2003)	309	0,124	0,782	0,159	188,899
Ketokivi and Schroeder (2004)	164	0,264	0,825	0,320	111,534
Li *et al.* (2005)	196	0,176	0,803	0,219	126,381
Pull System					
Chen and Tan (2013)	224	0,158	0,771	0,205	133,032
Nawanir *et al.* (2013)	139	0,350	0,749	0,467	77,937
Danese *et al.* (2012)	207	0,119	0,768	0,155	122,196
Marodin *et al.* (2016)	64	-0,020	0,803	-0,025	41,267
Agus and Hajinoor (2012)	200	0,382	0,915	0,418	167,373
Phan and Matsui (2010)	210	0,223	0,795	0,280	132,737
Dal Pont *et al.* (2008)	266	0,030	0,803	0,037	171,517
Matsui (2007)	46	0,255	0,793	0,321	28,955
Ward and Zhou (2006)	769	0,138	0,803	0,172	495,851
Swink *et al.* (2005)	57	0,277	0,803	0,345	36,754
Shah and Ward (2003)	1508	0,173	0,803	0,215	972,359
Fullerton and McWatters (2001)	95	0,143	0,803	0,178	61,256
Callen *et al.* (2000)	100	0,195	0,803	0,243	64,480
Flynn *et al.* (1995a)	42	0,090	0,849	0,106	30,244
Forza (1996)	248	0,310	0,853	0,363	180,420
Claycomb *et al.* (1999a)	200	0,180	0,704	0,256	99,213
Sim and Curatola (1999)	83	0,250	0,803	0,311	53,518
Das and Jayaram (2003)	309	0,320	0,782	0,409	188,899
Ketokivi and Schroeder (2004)	164	0,123	0,681	0,181	76,106
Li *et al.* (2005)	196	0,117	0,803	0,146	126,381
Narasimhan *et al.* (2006)	224	0,147	0,726	0,202	118,065
Avittathur and Swamidass (2007)	26	0,233	0,815	0,286	17,270
One Piece Flow					
Marodin *et al.* (2016)	64	0,220	0,803	0,274	41,267
Equipment Layout					
Chen and Tan (2013)	224	0,137	0,775	0,177	134,643
Nawanir *et al.* (2013)	139	0,260	0,645	0,403	57,796
Danese *et al.* (2012)	207	0,382	0,726	0,527	108,965
Fullerton and Wempe (2009)	121	0,330	0,899	0,367	97,816

Hallgren and Olhager (2009)	211	0,201	0,736	0,273	114,298
Phan and Matsui (2010)	210	0,377	0,780	0,483	127,696
Dal Pont *et al.* (2008)	266	0,180	0,803	0,224	171,517
Matsui (2007)	46	0,386	0,786	0,491	28,443
Ward and Zhou (2006)	769	0,149	0,803	0,186	495,851
Swink *et al.* (2005)	57	0,046	0,803	0,057	36,754
Shah and Ward (2003)	1508	0,165	0,803	0,205	972,359
Fullerton and McWatters (2001)	95	0,098	0,803	0,122	61,256
Callen *et al.* (2000)	100	-0,324	0,803	-0,403	64,480
He and Hayya (2002)	48	0,037	0,803	0,046	30,950
Narasimhan *et al.* (2006)	224	0,059	0,710	0,083	112,918
Heijunka					
Chen and Tan (2013)	224	0,217	0,771	0,282	133,032
Nawanir *et al.* (2013)	139	0,110	0,650	0,169	58,672
Marodin *et al.* (2016)	64	0,100	0,803	0,125	41,267
Hallgren and Olhager (2009)	211	-0,064	0,852	-0,075	153,121
Phan and Matsui (2010)	210	0,132	0,800	0,165	134,417
Dal Pont *et al.* (2008)	266	0,260	0,803	0,324	171,517
Matsui (2007)	46	0,284	0,822	0,345	31,095
Fullerton and McWatters (2001)	95	0,372	0,803	0,463	61,256
Callen *et al.* (2000)	100	0,214	0,803	0,267	64,480
Flynn *et al.* (1995a)	42	0,130	0,743	0,175	23,187
Sim and Curatola (1999)	83	0,110	0,803	0,137	53,518
He and Hayya (2002)	48	0,166	0,803	0,207	30,950
Jidoka					
Belekoukias *et al.* (2014)	140	0,312	0,803	0,389	90,272
Marodin *et al.* (2016)	64	0,259	0,803	0,323	41,267
Abusa and Gibson (2013)	57	0,336	0,773	0,435	34,068
Kaynak (2003)	382	0,359	0,790	0,454	238,368
Baird *et al.* (2011)	145	0,140	0,749	0,187	81,331
Phan and Matsui (2010)	210	0,402	0,810	0,496	137,778
Small Lot Size					
Nawanir *et al.* (2013)	139	0,320	0,757	0,423	79,689
Kannan and Tan (2005)	556	0,061	0,792	0,077	348,603
Agus and Hajinoor (2012)	200	0,510	0,915	0,557	167,373
Dal Pont *et al.* (2008)	266	0,130	0,803	0,162	171,517
Matsui (2007)	46	0,028	0,749	0,037	25,826
Ward and Zhou (2006)	769	0,253	0,803	0,315	495,851
Swink *et al.* (2005)	57	0,128	0,803	0,159	36,754
Shah and Ward (2003)	1508	0,170	0,803	0,212	972,359
Flynn *et al.* (1995a)	42	-0,120	0,790	-0,152	26,211
He and Hayya (2002)	48	0,133	0,803	0,166	30,950
Narasimhan *et al.* (2006)	224	0,003	0,726	0,004	118,065
Supplier Involvement					
Nawanir *et al.* (2013)	139	0,410	0,740	0,554	76,186
Kannan and Tan (2005)	556	0,129	0,804	0,161	359,069
García *et al.* (2014)	195	0,420	0,896	0,469	156,702
Flynn *et al.* (1995b)	706	-0,260	0,745	-0,349	391,830
Talib *et al.* (2013)	172	0,297	0,894	0,332	137,581
Agus and Hassan (2011)	169	0,532	0,917	0,580	142,109
Abusa and Gibson (2013)	57	0,142	0,812	0,175	37,625
Brah *et al.* (2002)	188	0,858	0,803	1,068	121,222
Rahman and Bullock (2005)	261	0,030	0,685	0,044	122,409
Kaynak (2003)	382	0,420	0,829	0,506	262,816
Baird *et al.* (2011)	145	0,110	0,759	0,145	83,622
Agus (2005)	50	0,280	0,822	0,341	33,744
Arumugam *et al.* (2008)	122	0,460	0,748	0,615	68,320

Dow *et al.* (1999)	698	0,063	0,690	0,091	331,899
Kumar and Kumar (2016)	62	0,340	0,726	0,468	32,724
Phan and Matsui (2010)	210	0,297	0,748	0,397	117,615
Wali and Boujelbene (2010)	66	0,082	0,838	0,098	46,324
Flynn *et al.* (1995a)	42	0,450	0,775	0,581	25,203
Kaizen					
Belekoukias *et al.* (2014)	140	0,210	0,803	0,262	90,272
Gao and Low (2014)	93	0,519	0,853	0,609	67,638
Chen and Tan (2013)	224	0,276	0,779	0,354	135,931
Nawanir *et al.* (2013)	139	0,340	0,692	0,491	66,553
Fullerton and Wempe (2009)	121	0,430	0,829	0,518	83,248
Kaur *et al.* (2012)	34	0,787	0,711	1,107	17,196
Agus and Hajinoor (2012)	200	0,537	0,915	0,587	167,373
Talib *et al.* (2013)	172	0,659	0,880	0,748	133,348
Agus and Hassan (2011)	169	0,608	0,917	0,663	142,109
Abusa and Gibson (2013)	57	0,215	0,783	0,275	34,934
Brah *et al.* (2002)	188	0,890	0,803	1,108	121,222
Rahman and Bullock (2005)	261	0,060	0,675	0,089	118,912
Brah and Lim (2006)	81	0,489	0,856	0,571	59,305
Maitah *et al.* (2014)	142	0,153	0,863	0,177	105,861
Agus (2005)	50	0,321	0,826	0,389	34,120
Dow *et al.* (1999)	698	0,236	0,738	0,320	380,578
Sim and Curatola (1999)	83	0,170	0,803	0,212	53,518
Flexible, Cross-funcitonal Teams					
Alcaraz *et al.* (2014)	159	0,120	0,830	0,145	109,477
Chen and Tan (2013)	224	0,249	0,775	0,321	134,482
Nawanir *et al.* (2013)	139	0,370	0,659	0,561	60,423
Marodin *et al.* (2016)	64	0,040	0,803	0,050	41,267
Talib *et al.* (2013)	172	0,686	0,872	0,787	130,778
Abusa and Gibson (2013)	57	0,258	0,836	0,309	39,814
Rahman and Bullock (2005)	261	0,030	0,746	0,040	145,142
Maitah *et al.* (2014)	142	0,337	0,875	0,385	108,644
Kaynak (2003)	382	0,312	0,858	0,364	281,152
Arumugam *et al.* (2008)	122	0,258	0,803	0,321	78,656
Dow *et al.* (1999)	698	-0,460	0,725	-0,634	367,302
Phan and Matsui (2010)	210	0,351	0,796	0,441	132,905
Wali and Boujelbene (2010)	66	0,096	0,806	0,119	42,849
Flynn *et al.* (1995a)	42	0,310	0,834	0,372	29,236
Self-directed Work Teams					
Fullerton and Wempe (2009)	121	0,330	0,855	0,386	88,451
Alcaraz *et al.* (2014)	159	0,781	0,827	0,944	108,781
Marodin *et al.* (2016)	64	0,030	0,803	0,037	41,267
García *et al.* (2014)	195	-0,210	0,896	-0,234	156,702
Kaur *et al.* (2012)	34	0,580	0,733	0,791	18,272
Flynn *et al.* (1995b)	706	-0,150	0,840	-0,179	497,730
Talib *et al.* (2013)	172	0,608	0,875	0,695	131,685
Brah *et al.* (2002)	188	0,849	0,803	1,058	121,222
Rahman and Bullock (2005)	261	0,030	0,718	0,042	134,650
Brah and Lim (2006)	81	0,542	0,856	0,633	59,305
Maitah *et al.* (2014)	142	0,278	0,734	0,379	76,462

Kaynak (2003)	382	0,425	0,844	0,504	271,984
Agus (2005)	50	0,225	0,848	0,265	35,989
Fotopoulos and Psomas (2010)	370	0,177	0,902	0,196	301,212
Dow *et al.* (1999)	698	-0,070	0,712	-0,098	354,026
Kumar and Kumar (2016)	62	0,241	0,745	0,324	34,387
Phan and Matsui (2010)	210	0,438	0,808	0,542	137,106
Sim and Curatola (1999)	83	0,050	0,803	0,062	53,518
Preventive Maintenance					
Belekoukias *et al.* (2014)	140	0,300	0,803	0,374	90,272
Chen and Tan (2013)	224	0,172	0,769	0,224	132,388
Nawanir *et al.* (2013)	139	0,430	0,664	0,648	61,299
Marodin *et al.* (2016)	64	0,200	0,803	0,249	41,267
Wickramasinghe and Perera	236	0,602	0,767	0,785	138,946
Swanson (2001)	287	0,200	0,803	0,249	185,058
Ahuja and Singh (2013)	36	0,899	0,756	1,189	20,586
Modgil and Sharma (2016)	254	0,440	0,854	0,515	185,166
Fullerton and McWatters (2001)	95	0,302	0,803	0,376	61,256
Callen *et al.* (2000)	100	-0,213	0,803	-0,265	64,480
Sim and Curatola (1999)	83	0,090	0,803	0,112	53,518
He and Hayya (2002)	48	0,171	0,803	0,213	30,950
Das and Jayaram (2003)	309	0,285	0,782	0,365	188,899

Financial Performance	**N**	**Practice-Performance Correlation (r)**	**Attenuation Factor (A)**	**Corrected Correlation (r')**	**Study Weights (Wi)**
Author(s)					
Quick Changeover Techniques					
Nawanir *et al.* (2013)	139	0,310	0,648	0,478	58,380
Fullerton and Wempe (2009)	121	0,220	0,834	0,264	84,227
Jayaram *et al.* (2008)	57	0,053	0,790	0,067	35,543
Claycomb *et al.* (1999b)	200	0,170	0,871	0,195	151,680
Agus and Hajinoor (2012)	200	0,112	0,915	0,122	167,552
Kumar and Kumar (2016)	62	0,414	0,769	0,539	36,645
Pull System					
Nawanir *et al.* (2013)	139	0,460	0,789	0,583	86,597
Claycomb *et al.* (1999b)	200	0,210	0,871	0,241	151,680
Agus and Hajinoor (2012)	200	0,297	0,915	0,324	167,552
Jayaram and Vickery (1988)	57	0,118	0,803	0,147	36,754
One Piece Flow					
Equipment Layout					
Nawanir *et al.* (2013)	139	0,310	0,680	0,456	64,218
Fullerton and Wempe (2009)	121	0,270	0,867	0,311	91,004
Jayaram *et al.* (2008)	57	0,076	0,790	0,096	35,543
Heijunka					
Nawanir *et al.* (2013)	139	0,260	0,685	0,380	65,191

Jidoka					
Abusa and Gibson (2013)	57	0,119	0,773	0,154	34,068
Small Lot Size					
Nawanir *et al.* (2013)	139	0,450	0,798	0,564	88,543
Kannan and Tan (2005)	556	-0,020	0,792	-0,025	348,603
Agus and Hajinoor (2012)	200	0,385	0,915	0,421	167,552
Supplier Involvement					
Nawanir *et al.* (2013)	139	0,530	0,780	0,679	84,651
Kannan and Tan (2005)	556	0,077	0,804	0,096	359,069
Jayaram *et al.* (2008)	57	0,083	0,774	0,107	34,186
Abusa and Gibson (2013)	57	0,092	0,812	0,113	37,625
Kumar and Kumar (2016)	62	0,419	0,717	0,584	31,911
Wali and Boujelbene (2010)	66	0,21	0,862	0,244	49,064
Jayaram and Vickery (1998)	57	0,107	0,803	0,133	36,754
Kaizen					
Nawanir *et al.* (2013)	139	0,480	0,729	0,658	73,948
Fullerton and Wempe (2009)	121	0,100	0,800	0,125	77,450
Jayaram *et al.* (2008)	57	0,254	0,770	0,330	33,752
Agus and Hajinoor (2012)	200	0,386	0,915	0,422	167,552
Abusa and Gibson (2013)	57	0,188	0,783	0,240	34,934
Flexible, Cross-functional Teams					
Nawanir *et al.* (2013)	139	0,4600	0,695	0,662	67,137
Abusa and Gibson (2013)	57	0,195	0,836	0,233	39,814
Wali and Boujelbene (2010)	66	0,114	0,829	0,137	45,384
Self-directed Work Teams					
Fullerton and Wempe (2009)	121	0,210	0,825	0,255	82,291
Kumar and Kumar (2016)	62	0,403	0,735	0,548	33,533
Jayaram and Vickery (1998)	57	0,155	0,803	0,193	36,754
Preventive Maintenance					
Nawanir *et al.* (2013)	139	0,480	0,700	0,686	68,110

Market Performance	**N**	**Practice-Performance Correlation (r)**	**Attenuation Factor (A)**	**Corrected Correlation (r')**	**Study Weights (Wi)**
Author(s)					
Quick Changeover Techniques					
Agus and Hajinoor (2012)	200	0,096	0,915	0,105	167,552
Pull System					
Agus and Hajinoor (2012)	200	0,371	0,915	0,405	167,552
Jayaram and Vickery (1998)	57	0,190	0,803	0,237	36,754
One Piece Flow					
Equipment Layout					
Heijunka					
Jidoka					
Abusa and Gibson (2013)	57	0,391	0,773	0,506	34,068
Fawcett and Myers (2001)	158	0,422	0,863	0,489	117,789

Kaynak (2003)	382	0,256	0,833	0,307	265,184
Small Lot Size					
Kannan and Tan (2005)	556	0,110	0,792	0,139	348,603
Agus and Hajinoor (2012)	200	0,401	0,915	0,438	167,552
Supplier Involvement					
Kannan and Tan (2005)	556	0,004	0,804	0,005	359,069
Flynn *et al.* (1995b)	706	0,250	0,740	0,338	386,606
Agus and Hassan (2011)	169	0,531	0,915	0,580	141,487
Abusa and Gibson (2013)	57	-0,058	0,812	-0,071	37,625
Rahman and Bullock (2005)	261	0,21	0,685	0,307	122,409
Kaynak (2003)	382	0,244	0,875	0,279	292,383
Agus *et al.* (2000)	30	0,318	0,861	0,369	22,232
Jayaram and Vickery (1998)	57	0,294	0,803	0,366	36,754
Kaizen					
Agus and Hajinoor (2012)	200	0,408	0,915	0,446	167,552
Agus and Hassan (2011)	169	0,559	0,915	0,611	141,487
Abusa and Gibson (2013)	57	0,096	0,783	0,123	34,934
Fotopoulos and Psomas (2010)	370	0,139	0,921	0,151	313,599
Rahman and Bullock (2005)	261	0,15	0,675	0,222	118,912
Flexible, Cross-funcitonal Teams					
Abusa and Gibson (2013)	57	0,069	0,836	0,083	39,814
Fawcett and Myers (2001)	158	0,461	0,792	0,582	99,125
Rahman and Bullock (2005)	261	-0,01	0,746	-0,013	145,142
Kaynak (2003)	382	0,205	0,905	0,227	312,782
Agus *et al.* (2000)	30	0,335	0,851	0,393	21,749
Self-directed Work Teams					
Flynn *et al.* (1995b)	706	0,410	0,834	0,492	491,094
Rahman and Bullock (2005)	261	0,09	0,718	0,125	134,650
Kaynak (2003)	382	0,143	0,890	0,161	302,582
Agus *et al.* (2000)	30	0,407	0,859	0,474	22,124
Jayaram and Vickery (1998)	57	0,256	0,803	0,319	36,754
Preventive Maintenance					