# Impact of Lean on performance: The case of manufacturing SMEs

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## Biographic Note

Catarina Maurício Valente was born on 6th September 1995, in Vila Nova de Gaia, Porto, Portugal. Catarina obtained the Bachelor's degree in Economics by School of Economics and Management of University of Porto in 2016. With the expectation of complementing her knowledge, in the same year, she joined the Master in Management at the same faculty, which allowed her to have a first contact with the areas of quality, supply chain and operations. She is now in process of completing her thesis on "Impact of Lean on performance: The case of manufacturing SMEs"

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## Abstract

**Purpose –** The purpose of this study is to canvass to what extent Lean practices are being implemented in Portuguese manufacturing Small and Medium Enterprises (SMEs), and in which way these practices are affecting their performances.

**Design/methodology/approach** – An on-line questionnaire was distributed among Portuguese organizations that fitted in the category of Small and Medium Enterprises and that belong to the manufacturing sector (companies with code 10 to 32 according to NACE Rev. 2 classification). A sample of 329 enterprises was analysed with model based cluster analysis and partial least squares structural equation modelling (PLS-SEM).

**Findings –** The findings show that the majority of Portuguese manufacturing SMEs are poorly Lean oriented and that there still is a lack of consciousness on the concept among these companies. Moreover, the effects of Lean on performance resulted as positive which outlines the benefits attainable with the implementation of Lean practices.

**Implications –** The results from the study contribute to the investigation on the topic broadening the literature on the implementation of Lean practices in companies around the world. The outcomes of the research may be used as a motivation for other Portuguese SMEs to implement Lean practices when acknowledging the impact on performance that the companies that adopted (partially or globally) this philosophy got. Furthermore, the degree of Lean implementation of the Portuguese industry may constitute a signal for government and/or economic decision makers define incentives such as fiscal benefits for companies who enter in Lean's implementation program, partly financing workers cross-training, among others.

**Originality/value –** This study enriches the researches made on the impact of Lean manufacturing on performance and the degree of implementation in the manufacturing industry by looking over a country that has never been investigated in that topic. Up to our best knowledge this is the first study that examines the impact of aggregated Lean on operational, financial and market performance measures in a discriminated and simultaneous way.

**Key words**: Lean manufacturing; SME; Portugal; Performance; Leanness; PLS-SEM;

**JEL-Codes:** L60; M11

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## 1. Introduction

Lean production is a multi-dimensional system with the central objective of waste elimination through practices that minimize supplier, customer and internal variability (Shah & Ward, 2007). The concept originated in Japan gained wide attention from the moment it was introduced and many authors have even considered it as the best possible production system able to be implemented in any company (Womack *et al.*, 1990; Womack & Jones, 1996). In fact, it is acknowledged by many academics and practitioners the linkage of Lean production with superior operational performance and competitive advantage (Alcaraz *et al.*, 2014; Cua *et al.*, 2001; Godinho Filho *et al.*, 2016; Shah & Ward, 2003), reason why many organizations are resorting to Lean practices (Bonavia & Marin, 2006; Godinho Filho *et al.*, 2016; Pavnaskar *et al.*, 2003). There have been various surveys on its impact in different sectors and countries and therefore in diverse cultural environments. Several of those surveys have been conducted on countries such as India (Eswaramoorthi *et al.,* 2011), Italy (Panizzolo, 1998; Staudacher & Tantardini, 2007), United States of America (Shah & Ward, 2003; White *et al.*, 1999), Spain (Bonavia & Marin, 2006), Malaysia (Nordin *et al.*, 2010), United Kingdom (Achanga *et al.*, 2006), Brazil (Godinho Filho *et al.*, 2016), among others. In Portugal, there was only found a study, by Silva *et al.* (2010), that does a cross-country survey with the intention of seeing Portuguese companies' Lean journey in comparison with companies from Italy, United Kingdom and United States of America. Not assessing, nevertheless, the degree of implementation of Lean and its impact on performance of SMEs.

One of the aims of this paper is to investigate how Lean are Portuguese manufacturing SMEs. Negrão *et al.* (2017) consider that there is a clamour for more investigations about the implementation of Lean production practices in countries, industries and its impacts in organisational performance indicators. Moreover, the focus on SMEs may outcome different results and proposals since smaller firms have different behaviour towards Lean production (Bonavia & Marin, 2006; Shah & Ward, 2003). Furthermore, according to INE[1], in 2016 these enterprises represented 99,92 % of the total number of enterprises in Portugal and, in the same year, these companies were responsible for more than half of the gross value added by enterprises (INE, 2016). In addition, the paper also purposes to analyse the effects of Lean implementation on Portuguese SMEs' performance. There are still few studies on the effect of Lean on performance of SMEs

[1] "Instituto Nacional de Estatística" is the Portuguese official agency responsible for producing and spreading official national statistics.

(Godinho Filho *et al.*, 2016). In fact, no study was found presenting the outcomes of Lean manufacturing on performance of Portuguese SMEs. The present study aims to fill this gap by testing the impact of Lean practices in operational, financial and market performance measures of Portuguese SMEs.

This can be, therefore, considered a relevant study as it broadens the literature on the surveys made in the implementation of Lean practices in companies around the world, exploring a country where researches on the topic are scarce. Moreover, this study integrates three performance dimensions (operational, financial and market) and investigates the impact of Lean on all of them simultaneously and individually. The results may be used as an incentive and promotion for other Portuguese SMEs as well as for public economic policies such as fiscal benefits for companies who enter in Lean's implementation program, partly financing workers cross-training, among others.

In order to accomplish those aims, a questionnaire-based survey was sent to Portuguese SMEs included in the manufacturing sector (companies with code 10 to 32 according to NACE Rev. 2 classification). The data obtained was further analysed resorting to statistics techniques, namely cluster analysis and partial least squares structural equation modelling (PLS-SEM).

The dissertation is divided into five chapters. After the introduction, a literature review of the main topics is presented by covering its origins and the concept itself. This implies referring its principles, practices and main tools, and measures. Further in the literature review it is made an analysis of similar studies, namely in different countries, and the hypotheses to be studied are introduced. In the third chapter it is described the methodology used in the similar studies and in the current study. In the fourth chapter the results are presented. This chapter starts with a brief description of the sample, then focuses on the statistics performed on the sample to test the hypothesis, and finishes with a discussion of the main results. The last chapter is the conclusion with some suggestions for further research.

# 2. Literature Review

In this chapter it is done a theoretical review of the main concepts related with the topic and of the relevant studies on Lean manufacturing. Firstly, it is presented the Lean's origins and the concept itself by introducing some of Lean principles, practices and wastes. Then the revision is deepened by looking over the evolution of the concept as well as its diffusion and measures. Afterwards, measures of Lean performance are presented. This is followed by a more specific review conducted on studies about Lean implementation made in other countries, in order to gather and analyse the contributions of similar studies that can be useful inputs for this research. Finally, the research hypotheses are introduced.

## 2.1. Lean Production Origins

After World War II, Taiichi Ohno and cousins Kiichiro and Eiji Toyoda introduced *Toyota Production System* at the Toyota Motor Company (Ohno, 1988). Its basis was absolute elimination of waste through the support of two pillars: just in time and automation, as referred by Ohno (1988). This system emerged due to the fact that the concepts existent until then weren't fulfilling Japanese industry's necessities at the time (Womack *et al.*, 1990). In fact, after the World War I the age of mass production, pioneered by Henry Ford, invaded the American automobile industry and by the late 1950s this technology was being diffused all over Europe. However, despite the effort to introduce Ford's ideas into Toyota Motor Company, Japanese market's capital constraints and low volumes did not justify the large batches sizes common in mass production (Holweg, 2007; Ohno, 1988; Womack *et al.*, 1990). A new approach needed to be made and, as cited by Ohno (1988, p.11), "The Toyota production system began when I challenged the old system".

After analysing the Western production system Taichii Ohno had found two flaws. First the excessive waste resultant from the production of large batches and second, the inability to satisfy customers' preferences for product variety (Holweg, 2007). It was in the attempt to overcome these flaws that he came up with innovations such as just-in-time, production levelling, error proofing, multi-skilled work-force, *kanban* method, etc. that integrate the *Toyota Production System* (Eswaramoorthi *et al.*, 2011; Godinho *et al.*, 2016; Hines *et al.*, 2004; Holweg, 2007; Ohno, 1988). This new production concept wasn't, though, invented all at once; Holweg (2007, p.422) defends that it was rather a "continuously interacting learning" that went for decades, and for decades was largely unnoticed.

It was only after the oil crisis in 1973, that left Japanese companies confronted with zero growth, that they started noticing Toyota's superior performance and an enormous interest was generated around the *Toyota Production System* (Ohno, 1988).

According to Hines *et al.* (2004) western manufacturers had limited knowledge on the new Japanese production system until the book *The Machine that Changed the World* highlighted this system, referring to it as "Lean production". This book was responsible for popularizing the Lean concept (Bhamu & Singh Sangwan, 2014; Holweg, 2007) although, for Shah & Ward (2007), it did not offer a specific definition.

**2.2. Lean concept**

Despite being an intensively researched and covered topic, many are the authors who agree that there is a lack of common definition of the concept: (Bhamu & Singh Sangwan, 2014; Hines *et al.*, 2004; Karlsson & Ahlström, 1996; Shah & Ward, 2007; Pettersen, 2009).

Shah & Ward (2007, p. 791) propose as a conceptual definition that "Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer and internal variability". But as these authors refer to it as a system, others denote it as a philosophy: "Leanness is a philosophy intended to significantly reduce cost and cycle time throughout the entire value chain while continuing to improve product performance" (Comm & Mathaisel, 2000, p.122), others as a methodology: "Lean thinking is a business methodology which aims at providing a new way of thinking about how to organize human activities to deliver more benefits to society and value to individuals while eliminating waste" (Ndaita *et al.,* 2015, p.684).

Karlsson & Ahlström (1996) point out that this lack of a precise definition leads to difficulties in assessing if changes made in a company are consistent with Lean production, and therefore in appraising the effectiveness of the concept.

Bhamu & Singh Sangwan (2014) believe that this absence of common definition is due to Lean production evolution over time, in addition to a confusion between the system and its underlying components. This is also stated by Shah & Ward (2007), as they propose to solve this semantic confusion. For them, and for other authors such as Pettersen (2009), Lean is commonly described under two perspectives: philosophical and practical, where the former provides the highest level of abstraction and the latter the least (Ghosh, 2012). However, for Shah & Ward (2007), there is a gap in the two perspectives. They propose to fill this gap by not only suggesting a conceptual definition, but also by formulating an operational measure instrument for Lean production that encompasses 10 factors measured by 48 practices/tools. This instrument, they believe, forms "a foundation for research in Lean production and should prove helpful in enabling researchers to agree on a definition" (Shah & Ward, 2007, p.801). In fact, there are some authors that have resorted to this operational measure to conduct their studies (Alsmadi *et al.*, 2012; Dora *et al.*, 2014; Godinho Filho *et al.*, 2016; Hofer *et al.*, 2012).

### 2.3. Wastes' definition and classification

Lean can't be dissociated from the concept of waste. The basis of Lean manufacturing is the elimination of waste which is stated as any activity that will not create any value to the final product (Pavnaskar, *et al.*, 2003). The customer is not willing to pay for it, and then the aim should be to eliminate it (Karlsson & Ahlström, 1996). However, it is not as straightforward and most organizations have often a hard time in identifying the wastes (Ghosh, 2012). Ohno (1988) defined in *Toyota Production System* seven types of wastes: waste of overproduction, of waiting, of unnecessary motion, of transportation, of processing, of inventory and defects. Many authors agree with this classification of wastes and include it in their studies (Ghosh, 2012; Pettersen, 2009; Wahab *et al.*, 2013; Wong & Wong, 2011). Later on, an eighth waste has been included in Ohno's original list by other authors, namely as "underutilized people" (Eswaramoorthi *et al.*, 2011; Wahab *et al.,* 2013).

### 2.4. Lean Principles and Tools

The philosophical perspective that is one of the perspectives under what Lean is described, is related with guiding principles and overarching goals (Shah & Ward, 2007). In fact, Lean concept can't be dissociated from its underlying principles proposed by Womack & Jones (1996). The principles are: i) specify value to the customer, ii) fully map the value-stream, iii) develop the capability to flow production, iv) let the customer "pull" the product, and v) search for perfection, the happy situation of perfect value provided with zero waste (Womack & Jones 1996). Additionally, Wong & Wong (2011) consider stability, standardization and discipline as pre-requisites for Lean manufacturing.

Regarding the practical perspective of Lean, it involves describing Lean through a set of management practices and tools (Shah & Ward, 2007). This include not only the shop-floor tools developed in Toyota (*kanban*, level scheduling, takt time,…) but also other approaches whose core objective is to provide value to the customer. These approaches refer to quality, responsiveness of the manufacturing system, production capacity, demand variability, availability of production resources and production control (Hines *et al.*, 2004). Therefore, Lean encompasses a number of tools and practices developed at an operational level that help supporting the implementation of Lean thinking in organizations. There are, in fact, several Lean tools that allow companies to identify measure and/or eliminate waste (Pavnaskar *et al.*, 2003). Table 1 synthesizes, according to several authors, some of the most commonly referenced tools.

Some authors aggregate Lean tools and practices into four bundles: JIT, TPM, TQM and HRM (Bonavia & Marin, 2006; Shah & Ward, 2003). Other authors consider only three of these bundles (Furlan *et al.*, 2011; Cua *et al.*, 2001).

According to the JIT method, an organisation should produce the right quantity of the right item at the right time (Womack & Jones, 1996). Shah & Ward (2003) state that a JIT bundle includes practices whose aim is reducing and eventually eliminating all types of waste, for instance, waste of inventory and/or waste of waiting. These may be lot size reduction, set up time reduction/SMED, cellular manufacturing, among others.

| **Lean practice** | **Authors/Sources** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| JIT/continuous flow production | * | * | * | * | * | * | * | * | * | * |
| Production levelling/ *Heijunka* | | * | * | * | * | * | * | * | * | * |
| Cellular manufacturing | * | * | * | * | * | * | * | * | * | * |
| Lot size reduction | * | * | * | | * | | * | | * | * |
| Pull system/ *Kanban* | * | * | * | * | * | * | * | * | * | * |
| Work standardization | | | | | * | * | * | * | | * |
| Set up time reduction/SMED (Single minute exchange) | * | * | * | * | * | * | * | * | * | * |
| Mistake proofing/ *Poka-yoke* | * | | | * | * | | * | * | * | * |
| Total quality management (TQM) | * | * | * | * | * | * | (a) | * | * | |
| Continuous improvement/ *Kaizen* | * | * | * | * | * | | * | * | * | * |
| Total productive maintenance (TPM) | * | * | * | * | * | * | * | * | * | |
| 5S/housekeeping | | | | * | * | * | * | * | * | |
| Multi-functional employees/cross training | * | * | * | | | * | * | * | * | * |
| Quality circles | * | * | * | | | * | * | | | |
| Value stream mapping (VSM) | | | | * | * | | * | * | * | * |
| Statistical quality control (SQC) | * | * | | | | * | * | * | | * |

(a) Pettersen (2009) compares Lean manufacturing with TQM, but does not refer to the later as a Lean practice/tool.

(1) Karlsson & Ahlström (1996); (2) White *et al.* (1999); (3) Shah & Ward (2003); (4) Hines *et al.* (2004); (5) Abdulmalek *et al.* (2006); (6) Bonavia & Marin (2006); (7) Pettersen (2009); (8) Eswaramoorthi *et al.* (2011); (9) Belekoukias *et al.* (2014); (10) Sundar *et al.,* (2014)

**Table 1 -** Lean tools according to several authors

TPM program consists of establishing a routine of predictive, preventive and corrective maintenance, and replacement programs. This implies the participation of the machine operator in minor machine maintenance (White *et al.*, 1999). The TPM bundle comprises practices such as safety improvement programs (Shah & Ward, 2003).

TQM is a management philosophy that targets customer satisfaction through high quality by capitalizing on the involvement of management, workforce, suppliers, and customers (Abdulmalek *et al.*, 2006; Cua *et al.*, 2001). It includes practices such as continuous improvement/*Kaizen* (Shah & Ward, 2003), or statistical process control (Bonavia & Marin 2006; White *et al.*, 1999).

Finally, HRM is based on employees' involvement and commitment (de Treville and Antonakis, 2006 as cited in Furlan *et al.*, 2011). It includes practices such as multi-functional employees/cross training and quality circles (Bonavia & Marin, 2006).

### 2.5. Measures of Lean Implementation

Measuring Leanness has been the aim of many authors, nonetheless, there is no consensus on how Lean should be measured being that in a company, industry or country. Several authors have proposed to develop methods to measure the degree of Lean activity. Some of them have formulated instruments that are well-accepted (Karlsson & Ahlström, 1996; Panizzolo, 1998; Shah & Ward, 2003; Shah & Ward, 2007; Susilawati *et al.*, 2015) and therefore used by several other researchers.

Karlsson & Ahlstrom (1996) developed an operationalized model to measure progress made in an effort to become Lean. This includes nine determinants, each of them with associated measurements, which are able to reflect changes towards Lean production. They are: waste elimination, continuous improvement, zero defects, JIT delivery, pull production, multifunctional teams, decentralization, functional integration and vertical information systems. Despite some limitations pointed to this model, some authors have included Karlsson & Ahlstrom (1996)'s nine principles in their model for evaluating Leanness (Bonavia & Marin, 2006; Soriano-Meier & Forrester 2002). Namely, Soriano-Meier & Forrester (2002) designed a questionnaire specifically to measure two dependent variables and nine independent, related to the adoption of Lean production. One of the dependent variables, degree of Leanness (DOL), corresponds to the mean of the nine principles proposed by Karlsson & Ahlstrom (1996), each one rated on a seven-points scale. Panizzolo (1998) have proposed a model, of 48 practices categorised in 6 areas of intervention, which the author claims to be similar to the one suggested by Karlsson & Ahlstrom (1996).

In their turn Shah & Ward (2003) combined 22 Lean practices representative of the multi-dimensional nature of Lean manufacturing, and aggregated them in four bundles. Many authors have adapted these practices in their studies. Authors such as Gebauer *et al.* (2009) and Rahman *et al.* (2010) have selected some practices among the 22 suggested and used them in their questionnaires as measures of Leanness.

One of the most well accepted instrument to assess the state of Lean implementation in firms is the 10 factors proposed by Shah & Ward (2007). These authors resorted to a data from a large sample and to a rigorous empirical method to identify a set of 48 items, grouped in 10 constructs that the authors believe will allow researchers to identify the Leanness of firms. This has been already used by quite a few researchers (Alsmadi *et al.*, 2012; Dora *et al.*, 2014; Godinho Filho *et al.*, 2016; Hofer *et al.*, 2012).

Additionally, some authors have proposed measures including fuzzy set theory to remove eventual bias. For instance, Susilawati *et al.* (2015) suggested a method for the measurement of degree of Leanness that included 6 parameters (supplier issues, customer issues, manufacturing and internal business, research and development, learning perspectives and investment priority). These parameters were evaluated by at least two experts, and the vagueness of subjective human judgement on degree of application of Lean was modelled by fuzzy number.

### 2.6. Measures of Lean Performance

Authors such as, Godinho Filho *et al.* (2016), Shah & Ward (2003) and White *et al.* (1999) have proposed to study the impact of Lean bundles and practices on operational performance. They cited improved quality, improved productivity, stocks reduction, and both lead and cycle time reduction as the main operational benefits from Lean implementation. Other authors have also studied Lean's relationship with performance, and concluded that, implementing Lean impacts positively operational performance (Cua *et al.*, 2001; Furlan *et al.,* 2011; Ghosh, 2012; Rahman *et al,* 2010).

Cua *et al.* (2001) investigated the implementation of practices related to three bundles (JIT, TQM and TPM) and of Human and strategic-oriented practices and their impact on cost efficiency, conform quality, on-time delivery, volume flexibility and weighted performance. The conclusions suggest that simultaneous implementation of TQM, JIT, and TPM resulted in higher performance than implementation of practices and techniques from only one bundle. This last conclusion is in line with Shah & Ward (2003) and Furlan *et al.* (2011) who reinforce that total system effect on performance will exceed the sum of the effects of each practice in isolation.

Some authors have also studied the impacts of Lean in financial or/and market performance indicators (Fullerton & Wempe, 2009; Hofer *et al.*, 2012; Jayaram *et al.*, 2008; Yang *et al.*, 2011). The conclusions were not, nevertheless, totally coherent. Whilst Fullerton & Wempe (2009) and Yang *et al.* (2011) concluded in their study that Lean practices present a positive relationship with both financial and market performance, for Hofer *et al.* (2012) only internal Lean practices have a significantly positive effect on financial performance whereas external practices do not have a significant impact. On the contrary, Jayaram *et al.* (2008) found no statistically significant relationship between Lean manufacturing and firm profitability.

When addressing Lean's impact on firm performance several authors consider that the latter should be balanced between financial, operational and market measures (Alsmadi *et al.*, 2012; Büyüközkan *et al.*, 2015). Table 2 presents some measures as cited by some authors aggregated in three categories proposed by Büyüközkan *et al.* (2015).

| Firm performance | Measures | Authors/Sources |
| --- | --- | --- |
| **Operational performance** | Cycle time | (2); (3); (4); (10); (11) |
| | Manufacturing costs | (1); (2); (3); (4); (6); (9); (10); (11) |
| | Labour productivity | (2); (3); (9); (10); (11) |
| | Quality | (1); (3); (4); (6); (10); (11) |
| | Inventory | (1); (4); (11) |
| | Flexibility | (3); (4); (6) |
| | Delivery | (3); (4); (6); (9) |
| **Financial performance** | Return on sales (ROS) | (4); (5); (7); (8); (12) |
| | Returns on assets (ROA) | (2); (4); (8) (12) |
| | Return on investments (ROI) | (4); (8) |
| | Profit | (4) |
| **Market performance** | Market share | (2); (4); (12) |
| | Sales growth | (4); (12) |

(1) Alcaraz *et al.* (2014); (2) Alsmadi *et al.* (2012); (3) Belekoukias *et al.* (2014) (4) Büyüközkan *et al.* (2015) (5) Fullerton & Wempe (2009) (6) Furlan *et al.* (2011) ; (7) Hofer *et al.* (2012); (8) Jayaram *et al.* (2008) (9) Rahman *et al.* (2010) (10) Shah & Ward (2003); (11) White *et al.* (1999) (12) Yang *et al.* (2011)

**Table 2 -** Measures for firm performance

## 2.7. Some studies on Lean implementation in companies in several countries

There have been several surveys on Lean implementation conducted in different countries. Jasti & Kodali (2014) made a literature review of empirical research methodology in Lean manufacturing where 178 articles published between 1990 and 2009 were analysed and the authors observed that the USA, UK and Spain accounted for 65% of the articles as countries of sample data collection. Among the developing countries India stood out as the one from where more data was collected.

Deepening the analysis of the studies on Lean implementation in companies in various countries, we can conclude that, although they all are about implementation of Lean, the focus of the study is different among them. Table 3 systematizes the main conclusions and classifies the studies in terms their target.

| Study Focus | Main Conclusions | Authors/Sources |
|---|---|---|
| **Degree of Lean implementation** | Wider adoption in internal operations than in external relationships | Panizzolo, 1998 (Italy) |
| | Fragmented implementation | Godinho Filho *et al.*, 2016 (Brazil) |
| | Infant age | Eswaramoorthi *et al.*, 2011 (India) |
| | In-transition | Nordin *et al.*, 2010 (Malaysia) |
| **Contextual variable (plant size)** | Higher likelihood of implementation of most Lean practices by larger manufacturers than small manufacturers | Bonavia & Marin, 2006 (Spain)<br>Shah & Ward, 2003 (USA)<br>White *et al.*, 1999 (USA) |
| | Critical factors for a successful Lean implementation in SMEs: leadership, management, finance, organisational culture and skills and expertise. | Achanga *et al.*, 2006 (UK) |
| **Impact on operational performance** | Positive impact | Alcaraz *et al.,* 2014 (Mexico)<br>Godinho Filho *et al.*, 2016 (Brazil)<br>Shah & Ward, 2003 (USA)<br>Staudacher & Tantardini, 2007 (Italy)<br>White *et al.*, 1999 (USA) |
| | No impact | Bonavia & Marin, 2006 (Spain) |
| **Comparison between countries** | Portuguese companies are implementing a smaller number of Lean techniques when compared with the other countries analysed | Silva *et al.*, 2010 (Portugal, UK, USA and Italy) |

**Table 3 -** Classification of some similar studies and main conclusions

In Italy, Panizzolo (1998) interviewed 27 Italian firms operating in international markets on 48 practices developed by the author himself, to analyse the extent Lean production model was being adopted and they concluded that the most widely adopted programmes were on the internal operations whilst in the external relationships (supplier and customer) revealed to be more difficult. Also in Italy, Staudacher & Tantardini (2007) questioned both Lean and non-Lean implementers on the strategic objectives, the main barriers, and results over-time, and concluded that among the Lean implementers the ones who had implemented for longer, stated much bigger improvements.

The investigation of Godinho Filho *et al.* (2016), conducted in Brazil to research the effect of Lean on the performance encompassed the 10 factors proposed by Shah & Ward (2007). They concluded that Lean was being implemented in a fragmented way and that, even in a fragmented way, it helped improving their operational performance. This notion that Lean has a positive effect on operational performance is supported by others authors such as Alcaraz *et al.* (2014), Shah & Ward (2003) and White *et al.* (1999). However authors like Bonavia & Marin (2006) concluded, in their study to the Spanish ceramic tile industry, that the degree of use of the Lean practices, in most cases, did not have statistically significant influence on operational performance. This, they argue, is probably due to the fact that they studied each practice in isolation rather than bundles.

Some studies have shown that in some countries/sectors Lean implementation is still in its infancy: Eswaramoorthi *et al.* (2011) conducted a survey Lean in Indian machine tool manufacturers and they concluded that the sector was still in an infant age of Lean implementation. Similarly, Nordin *et al.* (2010) in their study to Malaysian automotive industries measured Lean manufacturing implementation adapting the measures from Shah & Ward (2003) and Panizzolo, 1998 (Italy), and found that most of the respondent firms were in-transition towards Lean manufacturing practice.

Various authors have directed their studies to the impact of Lean under contextual variables. For instance, in USA, White *et al.* (1999) made an important contribution to the topic by studying the impact of plant size in Lean implementation. The findings suggest that large U.S. manufacturers are more likely to implement JIT systems than small manufacturers. Shah & Ward (2003) have not only proposed to investigate the impact of plant size but also of plant age and unionization on the implementation of 22 Lean manufacturing practices proposed by the authors themselves, in a large number of USA companies. This study provided strong support for the notion that plant size influences Lean implementation and that implementation contributes substantially to the operating performance of plants. Another study that investigated Lean's relationship with plant size was conducted in Spain, by Bonavia & Marin (2006). The authors, basing on the instruments of Karlsson & Ahlström, (1996) and White *et al.,* (1999) found, similarly, that the contextual variable plant size impacted the degree of use of Lean production practices.

Specifically in relation to Portugal, Silva *et al.* (2010) studied Lean production in Portuguese companies and compared the results with companies from Italy, UK and USA. Similarly to Staudacher & Tantardini (2007) both Lean implementers and non-Lean implementers were questioned.

Table 4, depicted in the chapter of methodology, contains more detail about the methodological aspects of those similar studies.

### 2.8. Hypotheses and Research framework

One of the study's purposes is to bridge gaps in literature concerning the studies on Lean implementation in Portugal. Only one research by Silva *et al.* (2010), who compared the level of implementation in Portugal with other countries, has been found. However, for one thing, in this study no measure of Leanness was used. Instead the companies were asked to state whether they were Lean or not. In the current study we propose to canvass the Lean implementation status resorting to a well-accepted measuring instrument, as done by several other authors (Bonavia & Marin, 2006; Godinho Filho *et al.*, 2016; Nordin *et al.,* 2010; Panizzolo, 1998). Besides, this study distinguishes itself from the one by Silva *et al.* (2010) since it focuses on SMEs. These are major drivers of countries' economies and are often neglected on Lean implementation studies (Godinho Filho *et al.*, 2016). Through cluster analysis the study aims to draw conclusions on the Leanness of Portuguese manufacturing SMEs.

The other aim is to test whether Lean manufacturing is positively linked with better overall performance and specifically with better operational, financial and market performance of Portuguese SMEs. The great majority of authors have suggested that the impact of different Lean practices or bundles in performance measures is positive (Alsmadi *et al.* 2012; Cua *et al.*, 2001; Shah & Ward, 2003; White *et al.*, 1999). In this study we propose to complement and clarify the previous research in this area, but by testing the impact of the aggregated Lean practices/bundles in the spirit of what have been done by Godinho Filho *et al.* (2016) and Yang *et al.* (2011), instead of testing them individually. In addition, we propose to test the impact on operational, financial and market measures. Few authors have associated all these measures (Alsmadi *et al.*, 2012; Büyüközkan *et al.*, 2015). In fact, up to our best knowledge no study has investigated the impact of aggregated Lean practices in all these performance measures simultaneously and individually, particularly in SMEs. The research framework is represented in Figure 1. The figure represents a higher-order structural equation modelling (SEM) in which Lean manufacturing and Performance are second-order constructs being measured by first-order constructs and their manifest variables (the last for space constraints not being represented in the figure). It is important to note that the study does not propose to test the relationships between the 10 constructs and Lean manufacturing, neither the impact of each singular Lean practice on performance, as the reflective nature of Lean production measures do not allow for these impacts to be tested. Instead, these are only required to measure Lean manufacturing in order to test the following 4 hypotheses:

**H1**: *Lean manufacturing impacts positively overall performance.*
**H2**: *Lean manufacturing impacts positively operational performance.*
**H3**: *Lean manufacturing impacts positively financial performance.*
**H4:** *Lean manufacturing impacts positively market performance.*

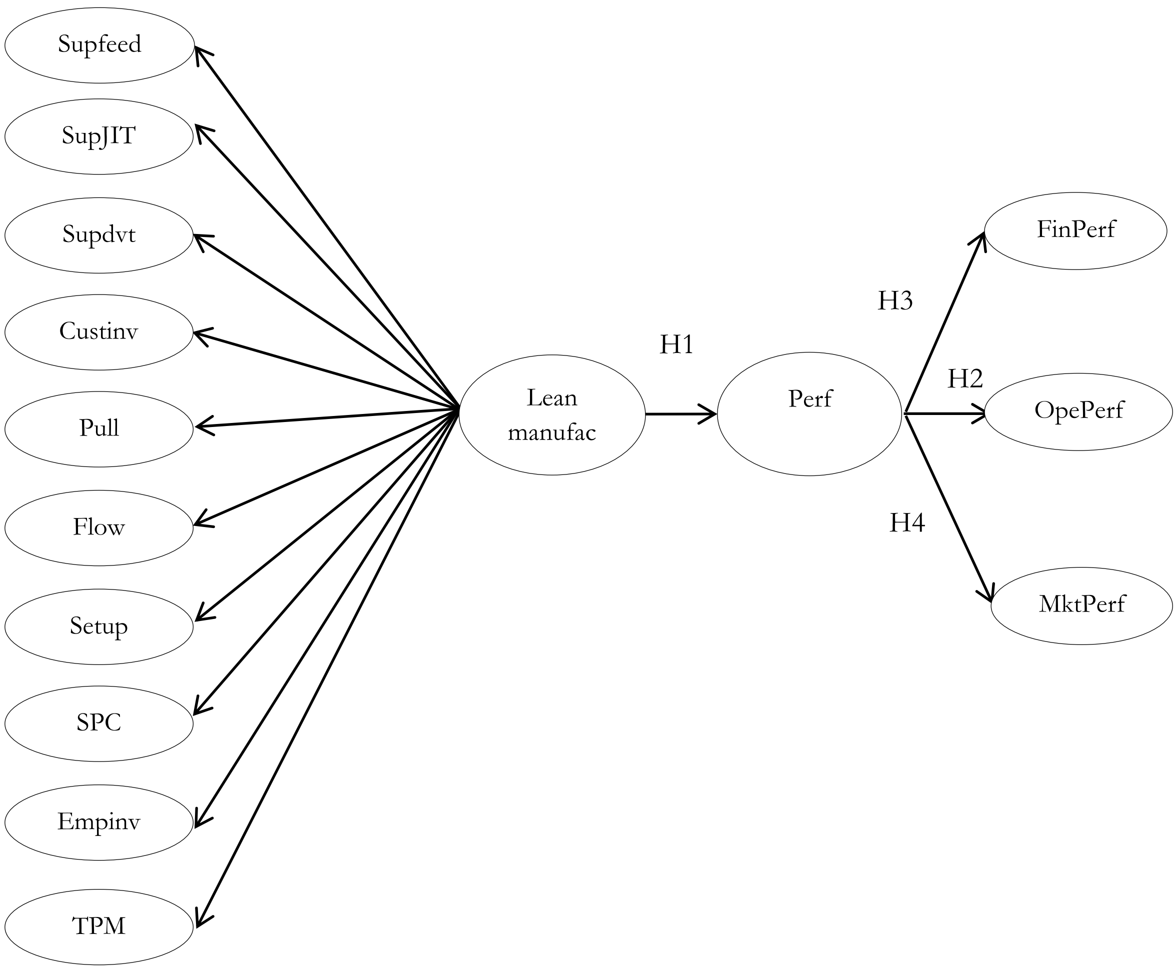


**Figure 1 –** Research Framework

# 3. Methodology

This chapter starts with a brief revision about the methodologies employed in similar studies. Then, it is presented the method selected for the research and the definition of each of its steps, the structure of the survey, its measures and scales, and the sources of information.

## 3.1. Methodological aspects of similar studies

Studies on Lean implementation in different countries present different methodological aspects regarding the studied industry, data collection, statistical analysis and sample.

Table 4 presents a synthesis of the methodological aspects of the similar studies made in countries such as Italy, USA, India, among others. From this we can observe that most of studies are conducted in multiple industries rather than focusing exclusively on a sector. Regarding the sample, it can be noted that the studies conducted in USA (Shah & Ward, 2007; White *et al.,* 1999) have the biggest sample size. Additionally, some authors have divided their sample into Lean and Non- Lean implementers (Silva *et al.*, 2010; Staudacher & Tantardini, 2007). The choice of sample firms' size is heterogeneous. Whilst certain authors propose to study all firms' sizes (Eswaramoorthi *et al.,* 2011), others focus only on smaller firms (Godinho Filho *et al.*, 2016) and some solely on larger firms (Nordin *et al.*, 2010).

The methods for collecting data are mostly questionnaires. Bonavia & Marin (2006) associated their questionnaire or interview with visits to the facilities to obtain data by direct observation whereas Alcaraz *et al.* (2014) associated both interviews and questionnaires. To all of these methods, the respondents are mainly managers, directors or executives. Further, it can be observed that almost all authors conducted some sort of statistical analysis. The most commonly used were descriptive statistics analysis and analysis of variance using ANOVA. Also, both Alcaraz *et al.* (2014) and Godinho Filho *et al.* (2016) resorted to PLS-SEM to test the impact of Lean practices on operational performance. Despite not being expressed in Table 4, almost all authors have performed reliability and validity tests for data using Cronbach's α.

| Author | Country of study | Industrial Sector | Sample Size | Response rate | Informant | Firm Size | Data collection | Statistical analysis |
|---|---|---|---|---|---|---|---|---|
| **Alcaraz *et al.* (2014)** | Mexico | *Maquilladoras* | 159 LI | (b) | Personnel working in supply chain | L & ME | Interview and Questionnaire | PLS-SEM |
| **Panizzolo (1998)** | Italy | Multiple industries | 27 | 100% | Managers from various areas | L & SME | Interview | Descriptive statistics; Cluster analysis |
| **Staudacher & Tantardini (2008)** | Italy | Multiple industries | 61 LI<br>51 NLI | 3,9% | Not clear | L & ME | Questionnaire | Descriptive statistics |
| **Shah & Ward (2003)** | USA | Multiple industries | 1757 LI | 6.7% | Plant/ Manufacturing Leaders and Managers; | L & SME | Questionnaire | Descriptive statistics; $\chi^2$test; Regression analysis; ANOVA |
| **White *et al.* (1999)** | USA | Multiple industries | 454 | 44.1% | Middle to top managers position | L & SE | Questionnaire | Descriptive statistics<br>Regression analysis |
| **Godinho Filho *et al.* (2016)** | Brazil | Multiple industries | 52 | 2.72% | Mostly Managers and Directors | SME | Questionnaire | Descriptive statistics; ANOVA; PLS-SEM |
| **Silva *et al.* (2010)** | Portugal | Multiple industries | 27 LI<br>125 NLI(a) | 4% | Not clear | L & SME | Questionnaire | Descriptive statistics |
| **Eswaramoorthi *et al.* (2011)** | India | Machine tool industries | 43 | 29% | Managers and shop floor engineers | L & SME | Questionnaire | Descriptive statistics; Non parametric test |
| **Nordin *et al.* (2010)** | Malaysia | Automotive Industry | 61 | 24.4%. | Production and Quality Managers and Executives | L & ME | Questionnaire | ANOVA; Clusters analysis |
| **Bonavia & Marin (2006)** | Spain | Ceramic tile industry | 76 | 79.17 % | Senior production managers | L & SME | Questionnaire and Participants Obs. | Non parametric tests; Mantel Haenszel Test |

(a) The article does not say specifically how many Non-Lean Implementers. Calculated through response rate. (b) Not referred.

**Table 4 -** Methodological considerations of similar studies

### 3.2. Methodology selection

In order to trace the implementation status of Lean production across Portuguese manufacturing SMEs and its effects on their performance, the methodology chosen was the questionnaire. This was considered the most adequate method, since targeting a representative sample was compulsory to be able to outcome conclusions regarding Portuguese manufacturing SMEs. To this degree of analysis it would not be feasible to conduct any other methodology. In addition, questionnaire has been the chosen method by several others studies with a purpose similar the one of study.

The questionnaire was divided in four parts (complete questionnaire in Annexes 1 and 2). Part 1 captures the organization profile and personal information of the respondent. Part 2 captures the level of Leanness of the company. Part 3 assesses the impacts of Lean on performance measures. Finally, part 4 addresses a question regarding company perception of self-Leanness. This description can be seen in Table 5:

| **Part** | **Content** | **Description** |
|---|---|---|
| **I** | General Information | 5 questions: NIF, CAE, sales volume, employees number, job position |
| **II** | Current practices in production planning | 36 questions: 5-point Likert scale about production's practices |
| **III** | Performance Evaluation | 8 questions: 5-point Likert scale on performance measures |
| **IV** | Perception of Lean | 1 question |

**Table 5 -** Structure of the questionnaire

Concerning the statistics methodology to explore the sample, cluster analysis was used to group the companies according to their use of Lean practices. This goes in line with what has been done by Nordin *et al.* (2010) and Panizzolo (1998). Partial least squares structural equation modelling (PLS-SEM) was used to assess the impact of Lean on overall performance. This method was chosen since it allows estimating complex cause-effect relationship in an extensive variety of research circumstances. Moreover, its requirements are quite flexible in terms of sample size, distribution and number of items measuring a construct. (Hair Jr *et al.,* 2016). In fact, according to Hair Jr *et al.* (2016) PLS-SEM is a good alternative to covariance-based structure equation modelling (CB-SEM) when certain assumptions are not fulfilled. For instance, in the current study the distribution of data was non-normal (as can be seen in the following chapter) and some constructs had less than the minimum 3 items required for using the CB-SEM. Authors such as Alcaraz *et al.* (2014) and Godinho Filho *et al.* (2016) have also resorted to this technique to test the relationship between Lean manufacturing and operational performance.

### 3.3. Measures definition

In order to assess companies' degree of Lean implementation it was used an instrument adapted from the one proposed by Shah & Ward (2007). This instrument captures internal and external practices and both people and process components (Dora *et al.*, 2014) and is "the only measure that was developed and validated in the literature" (Alsmadi *et al.*, 2012, p.386). It encompasses 36 items related with 10 underlying constructs. Of these items 12 are related with suppliers, 6 are related with customers, 4 with workers, 4 with processes and the remaining 10 with equipment. To every item the company is expected to express their level of implementation according to a 5 point Likert scale being 1 "never" and 5 "very frequently, if not always". This is discriminated in Table 6:

| | | Item Code | Question |
|---|---|---|---|
| | *Supplier Feedback (Suppfeed)* | | |
| **Suppliers** | Our suppliers visit our plants | SupFeed1 | 1 |
| | We visit our suppliers' plants | SupFeed2 | 2 |
| | We give our suppliers feedback on quality and delivery performance | SupFeed3 | 3 |
| | We strive to establish long-term relationship with our suppliers | SupFeed4 | 4 |
| | *Supplier Just in Time (SuppJIT)* | | |
| | Suppliers are directly involved in the new product development process | SupJIT1 | 5 |
| | Our key suppliers deliver to plant on JIT (just-in-time) basis | SupJIT2 | 6 |
| | We have a formal supplier certification program | SupJIT3 | 12 |
| | *Supplier Development(Suppdvt)* | | |
| | We have corporate level communication on strategic issues with key suppliers | SupDvt1 | 7 |
| | We take active steps to reduce the number of suppliers in each category of products/consumables | SupDvt2 | 8 |
| | Our key suppliers manage our inventory (concerning the component they provide) | SupDvt3 | 9 |
| | Our suppliers are contractually committed to annual costs reduction | SupDvt4 | 10 |
| | Our key suppliers are located in close proximity to our plants | SupDvt5 | 11 |
| | *Customer Involvement (Custinv)* | | |
| **Customers** | We are in close contact with our customers | CustInv1 | 13 |
| | Our customers visit our plants | CustInv2 | 14 |
| | Our customers give us feedback on quality and delivery performance | CustInv3 | 15 |
| | Our customers are actively and directly involved in current and future product offerings | CustInv4 | 16 |

| | | | |
|---|---|---|---|
| | Our customers share current and future demand information with marketing department | CustInv5 | 17 |
| | We conduct customer satisfaction surveys | CustInv6 | 18 |
| | *Pull* | | |
| Processes | Production decisions are made only after the arrival of an order or need for an intermediate product | Pull1 | 23 |
| | We use Kanban or other signals for production control | Pull2 | 24 |
| | *Continuous Flow (Flow)* | | |
| | Products are classified with similar processing provision requirements | Flow1 | 25 |
| | Pace of production is directly linked with the rate of customer demand | Flow2 | 26 |
| Equipment | Equipment is grouped to produce a continuous flow of families of products, and consequently families of products determine the factory layout | Flow3 | 27 |
| | *Total Productive Maintenance (TPM)* | | |
| | We dedicate a portion of everyday to planned equipment maintenance related activities | TPM1 | 28 |
| | We maintain rigorous records of all equipment maintenance related activities | TPM2 | 29 |
| | We post equipment maintenance records on shop-floor for active sharing with employees | TPM3 | 30 |
| | *Statistical Process Control (SPC)* | | |
| | We use statistical techniques to reduce production process variance | SPC1 | 31 |
| | Charts showing defect rates are used as tools on production | SPC2 | 32 |
| | We use fishbone type diagrams to identify causes of quality problems | SPC3 | 33 |
| | We conduct production process capability studies before product launch in the market | SPC4 | 32 |
| | Our equipment/ processes in the production area are currently being controlled using a statistical process quality control tool | SPC5 | 36 |
| | *Set up Time Reduction (Setup)* | | |
| | Production employees undergo cross functional training | Setup1 | 35 |
| Employers | The machines in our plant have low setup times | Setup2 | 19 |
| | *Employee Involvement (Empinv)* | | |
| | Our employees are trained to reduce set-up time required for the equipment to start up | Empinv1 | 20 |
| | Production employees are key to problem solving teams | Empinv2 | 21 |
| | Production employees participate actively in product/process improvement efforts | Empinv3 | 22 |

**Table 6** - Measures of Lean manufacturing
(Adapted from Shah & Ward, 2007)

In its turn, Lean's impact on performance is determined by market, financial and operational measures as proposed by Büyüközkan *et al.* (2015). At this point, the companies are expected to assess the impact of their production planning and execution practices on four operational measures, two financial measures and two market performance measures. Financial and market measures are rated using a 5 point Likert scale in which 1 corresponds to "Decreased a lot (more than 50%)", 3 to "Remain the same" and 5 to

"Increased a lot (more than 50%)". Contrarily, operational measures are rated with the same scale but inverted, where 1 is "Increased a lot (more than 50%)" and thus, 5 is "Decreased a lot (more than 50%)". Table 7 displays all performance measures:

| | Item Code | Question |
|---|---|---|
| *Operational Performance (OpePerf)* | | |
| Stocks level (raw material/unfinished products/finished products) | Stocks | 37 |
| Number of defects (quality) | Defects | 38 |
| Manufacturing Costs | MC | 39 |
| Cycle Time | CT | 40 |
| *Financial Performance (FinPerf)* | | |
| Net Income | NI | 41 |
| Return on Assets | ROA | 42 |
| *Market Performance (MktPerf)* | | |
| Market Share | MS | 43 |
| Sales Growth | SG | 44 |

**Table 7 -** Measures of performance

### 3.4. Sample

The sample was built considering Portuguese enterprises registered in SABI[2]. There was the need to place some restrictions in order to come up with a database only with manufacturing SMEs. Firstly, the manufacturing sector selection was made according to NACE Rev. 2 classification, and therefore, only enterprises coded 10 to 32 were considered. Then, concerning firms' size, the criteria used was bearing in mind the definition of SMEs by European Union Commission: "The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million" (Commission, 2003, p.4).

Hence, there were only considered companies with less than 250 employees and with an annual turnover lower than 50 million. Furthermore, a couple of restrictions were imposed. Firstly, a minimum annual turnover of 100 thousand was established. This additional restriction was imposed because financial capability is a critical success factor for Lean implementation, meaning that, financial inadequacy is a major barrier to Lean implementation or success (Achanga *et al.*, 2006). Therefore, it is expected that companies

[2] "Sistema de Análise de Balanços Ibéricos" is a database with complete financial information of Portuguese and Spanish enterprises with accounts up to 25 years.

with very low annual turnover won't have the will to implement Lean, neither the ability to reach success if they try to implement it. Secondly, companies with a number of employees lower than 10 (microenterprises) were also excluded, bearing in mind that the great majority of microenterprises have an annual turnover lower than 100 thousand. Moreover, according to Achanga *et al.*, (2006), companies led by owner managers (which is very common in microenterprises) usually have more difficult to implement successfully Lean, as to them it usually lacks the tactful management know-how.

After this selection, a database with 10 418 companies was organized including companies' operating revenue, sales, number of employees telephone contact and e-mails of 7 526 companies. Once some research was made additional 300 e-mails were found and the database accounted for 7830 general e-mails.

In order to decrease the subjectivity of the study it was crucial that the survey targeted respondents familiarized with the production processes of the company and with an accurate understanding of the company's performance. Therefore, a first step was to reach each of the companies from the database in order to have indication about the name and the e-mail contact of the production's director as well as their availability to participate in the study. Hence, throughout the months of January until March a first e-mail (Annex 3) was sent to the 7830 companies requesting them for the person responsible for the production in their company. After this first contact our database included 1031 e-mails belonging to production's directors, which corresponded to a response rate of approximately 13%.

By the end of April, the questionnaire was sent to the 1031 production's director's e-mails and to the remaining general e-mails extracted from SABI (Annex 4). From the approximately 340 responses obtained, only 329 were complete and suitable for analysis which represents a response rate of around 4.3%. Nevertheless, considering that some of the emails in SABI were already not operational or out-dated, one can assume that the response rate is undervalued. In fact, the sample can be considered relatively large if compared with the similar studies.

## 4. Results

In this chapter the data collected through the questionnaire is discriminated and analysed. Firstly, it starts with a brief statistical description of the sample. Afterwards the hypotheses previously formulated are tested and scrutinized.

### 4.1. Sample demographics and descriptive statistics

The sample provides a fairly diverse coverage. The sector of metals is the one that accounts for most responses. As far as the number of employees, considering European Union Commission definition for SMEs the sample counts with 93 medium enterprises and 236 small enterprises (Commission, 2003). The sample demographics are discriminated in the following table (Table 8):

| | **Sample (%)** |
|---|---|
| *Nace code/Sector* | |
| 24 and 25. Metals | 23 |
| 10 and 11. Food and beverages | 17 |
| 13, 14 and 15. Textiles | 15 |
| 19, 20, 21, 22 and 23. Petroleum, chemicals, pharmaceutical, plastic and non-metallic mineral products | 12 |
| 16 and 17. Wood and Paper | 9 |
| 32. Other manufacturing | 8 |
| 18. Printing and reproduction | 5 |
| 26, 27 and 28. Computer, electric, machinery and equipment | 4 |
| 31. Manufacture of furniture | 4 |
| 29 and 30. Motor vehicles, trailers, transport equipment | 2 |
| *Number of employees* | |
| 10 to 50 | 76 |
| 51 to 100 | 13 |
| 101 to 250 | 12 |
| *Sales Volume* | |
| >=10Million | 15 |
| 2Million> <10Million | 36 |
| <=2Million | 49 |
| *Respondents characteristics – departments* | |
| Direction/Management | 34 |
| Production | 33 |
| Direction assistant | 7 |
| Accounting | 6 |
| Others | 6 |
| Financial | 5 |
| Quality | 5 |
| Commercial | 3 |
| Human Resources | <1 |

**Table 8-** Sample demographics

The mean and the standard deviation of each construct are discriminated in Table 9. The data puts on view that pull production, customer involvement and supplier feedback are the practices most used by companies, being their average higher than 3.5. On the contrary, statistical process control and supplier development have their average bellow 2.5 meaning that fewer companies claim to have implemented SPC or supplier development practices. This is in line with Alsmadi *et al.* (2012) and Hofer *et al.* (2012) who also reported these practices to be the least implemented by the companies they have studied.  Also one can observe that SPC construct has the highest standard deviation which means that its practices have the most variability. In the Annex 5 it is shown a complete table with all items' descriptive statistics.

| | | **Mean** | **SD** |
|---|---|---|---|
| | Supplier feedback | 3,620061 | 0,51504 |
| **Suppliers** | JIT delivery by suppliers | 3,088146 | 0,59032 |
| | Supplier development | 2,463830 | 0,72039 |
| **Customers** | Customer involvement | 3,670213 | 0,63310 |
| **Processes** | Pull | 3,784195 | 0,78219 |
| | Continuous Flow | 3,418440 | 0,77664 |
| **Equipment** | Total Productive Maintenance | 3,138804 | 0,96937 |
| | Statistical Process Control | 2,381763 | 1,00117 |
| | Set up Time reduction | 3,483283 | 0,72448 |
| **Employees** | Employee involvement | 3,324215 | 0,87202 |
| | Operational Performance | 3,500760 | 0,599955 |
| **Performance** | Financial Performance | 3,469605 | 0,791910 |
| | Market Performance | 3,621581 | 0,763370 |

**Table 9 -** Sample descriptive statistics

To test the normality of the data the Shapiro test was conducted for each measurement item. The results reject for 5% significance level the hypothesis of normality. For this reason, to test the impact of Lean practices on business performance of enterprises the partial least squares structural equation modelling (PLS-SEM) was used since, as seen in the previous chapter, this technique does not require normality of data.

The statistics relatively to the last section of the questionnaire, with one question on companies' self-perception of Leanness are presented in Table 10. It can be observed that only 74% of inquired companies know what Lean is and, amongst those, half claims to be Lean and the other half claims to be non-Lean.

| Answers | Sample (%) |
|---|---|
| Lean | 37 |
| Non-Lean | 37 |
| Don't know what Lean is | 26 |

**Table 10 –** Responses on self-Leanness

### 4.2. Cluster analysis

Model-based Cluster analysis was used with the goal of identifying homogeneous groups of enterprises with distinct Lean adoption profiles. This division was done with the aim of drawing conclusions regarding the Lean status of the studied enterprises. In addition, the groups were examined to identify patterns and tested on significant differences. Accordingly, the aim was first to identify groups of companies based on their response on current practices in production planning (part II of the questionnaire); secondly to attribute a Lean profile to each group; thirdly to identify and examine differences in each group regarding companies' dimension, sector and response on self-Leanness.

Cluster analysis has been used by other authors to convey the differences in Lean implementation amongst companies (Nordin *et al.*, 2010; Panizzolo, 1998). This technique is advantageous in comparison with the division of groups using a subjective criterion. In this study we have chosen Model-based Cluster analysis which is an advanced clustering procedure that, on contrary to other heuristic clustering, fits the data without having to predefine arbitrarily the number of clusters (Lane *et al.*, 2014).

These statistical analyses were performed using the package "mclust 5.4.1" in R-3.5.1. Firstly, Cronbach's alpha was calculated to test the 10 constructs on internal consistency reliability. The most commonly acknowledged limit for this measure is 0.7, although some authors believe that in exploratory research the bound should be 0.6 (Hair Jr *et al.*, 2016; Nunnally, 1978 as cited in Pannizolo, 1998). The results of consistency reliability are summarised in the next table (Table 11) from where we can conclude that only constructs CustInv, Flow, SPC and TPM can be considered reliable. Afterwards, data was standardised and model-based cluster analysis was performed using Bayesian Information Criteria (BIC). In this method, the data is fitted to several potential Gaussian models, which allows not only to consider the model's complexity combined with data fit, but also does not require the arbitrary decision of the number of clusters. BIC values are attributed to each model and the highest indicate the best balance between data fit and complexity (Lane *et al.*, 2014).

| Constructs | Items | Raw_alpha | Standard alpha |
|---|---|---|---|
| SupFeed | 4 | 0.58* | 0.59* |
| SupJIT | 3 | 0.23* | 0.30* |
| SupDvt | 5 | 0.59* | 0.59* |
| CustInv | 6 | 0.71 | 0.76 |
| Pull | 2 | 0.57* | 0.59* |
| Flow | 3 | 0.62 | 0.64 |
| Setup | 2 | 0.19* | 0.19* |
| SPC | 5 | 0.82 | 0.83 |
| Empinv | 3 | 0.51* | 0.52* |
| TPM | 3 | 0.74 | 0.74 |

*Do not achieve criteria suggested by the authors

**Table 11 -** Constructs reliability results

In Figure 2 are displayed the BIC values for each Gaussian Model (in the legend identified by a combination of the letters E, V, and I). As can be seen, the highest BIC value corresponds to two clusters.

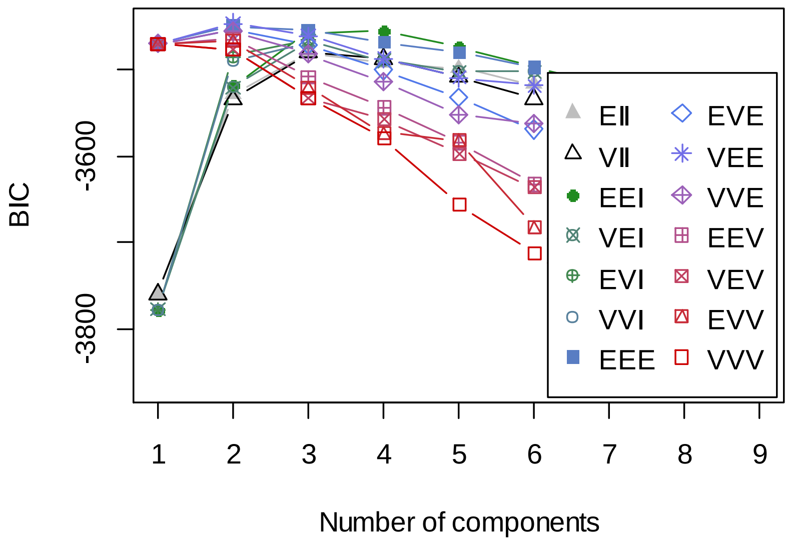


**Figure 2 –** BIC diagram for model-based cluster analysis of Lean practices

The two clusters solution represented the best balance between data fit and complexity and, hence, was analysed. Cluster 1 included 107 firms and cluster 2 included 222. Tests on differences of means showed significant differences in Lean adoption between the two clusters. These are displayed in Table 12:

| Constructs | Cluster 1 (N=107)<br>Mean (SD) | Cluster 2 (N=222)<br>Mean (SD) | t (df) | p-value |
|---|---|---|---|---|
| SupFeed | 3,789720 (0,477253) | 3,538288 (0,513614) | 4,254869 (327) | <0.0001 |
| SupJIT | 3,442368 (0,639011) | 2,917417 (0,695953) | 6,578801 (327) | <0.0001 |
| SupDvt | 2,695327 (0,541379) | 2,352252 (0,581517) | 5,124921 (327) | <0.0001 |
| CustInv | 4,010903 (0,551951) | 3,506006 (0,604545) | 7,296053 (327) | <0.0001 |
| Pull | 4,158879 (0,650102) | 3,603604 (0,777562) | 6,387563 (327) | <0.0001 |
| Flow | 3,825545 (0,577978) | 3,222222 (0,784892) | 7,856552 (274,255) | <0.0001 |
| Setup | 3,560748 (0,643217) | 3,445946 (0,759112) | 1,348132 (327) | 0,179 |
| SPC | 3,607477 (0,507993) | 1,790991 (0,534688) | 29,333617 (327) | <0.0001 |
| Empinv | 3,788162 (0,794890) | 3,100601 (0,819195) | 7,200273 (327) | <0.0001 |
| TPM | 3,806854 (0,716732) | 2,816817 (0,909962) | 10,71902 (259,544) | <0.0001 |

**Table 12 –** t-test of clusters on Lean practices

Companies in cluster 1 had significantly higher level of Lean implementation in all of the 10 constructs except for Setup time reduction in which there was no significant differences in implementation between the two groups. Therefore, cluster 1 was nominated as "enterprises more Lean oriented", whereas in cluster 2 they were noted as "enterprises less Lean oriented".

Finally, differences in dimension, sectors and perception of self-Leanness in each cluster were analysed with the goal of identifying association between contextual variables and lean practices implementation. To this end, Pearson's Qui-Square ($\chi^2$) tests were performed in SPSS and the results showed significant differences in dimension between clusters ($\chi^2$=9.437; p=0.002) but no significant differences in aggregated sectors ($\chi^2$=7.570; p=0.578) or perception of self-Leanness ($\chi^2$=3.937; p=0.140). Table 13 displays a cross table between clusters and dimension with expected counts calculated as product of the row and column totals, divided by the sample size. The differences between clusters are straightforward: in cluster 1 "enterprises more Lean oriented" there are more medium enterprises than expected whereas in cluster 2 "enterprises less Lean oriented" we count more small companies than expected. These results on dimension are predictable as several other authors have found a tendency for Lean practices to be more adopted in larger firms (Bonavia & Marin, 2006; Shah & Ward, 2003 USA; White *et al.*, 1999).

| | | Medium | Small | Total |
|---|---|---|---|---|
| **Cluster 1** | Count | 42 | 65 | 107 |
| | Expected count | 30.2 | 76.8 | |
| **Cluster 2** | Count | 51 | 171 | 122 |
| | Expected count | 62.8 | 159.2 | |
| **Total** | | 93 | 236 | 329 |

**Table 13 –** Cross table between cluster and dimension

### 4.3. PLS-SEM

To test the hypotheses H1, H2, H3 and H4 we resorted to the packages "pls-pm" and "matrixpls" in R estimating the PLS-SEM. In our specific case we included a higher-order structural equation model (Figure 1 included in Section 2.8) in which both Lean manufacturing and Performance were second-order constructs. This came from the fact both second order constructs had their first order constructs highly correlated. Indeed Table 14 shows the Spearman's correlations between the 10 constructs proposed by Shah and Ward (2007) and Table 15 displays the Spearman's correlations between the 3 constructs measuring performance. By observing both tables it is clear that the majority of correlations are significant and, therefore, it is corroborated the existence of second order latent variables. In addition, using higher order structural models allows simplifying the relationships, which facilitates its interpretation (Hair Jr *et al.*, 2016). Furthermore, the model is a reflective-reflective higher order type, which means that both the relations are reflective and thus, the causality flows from the second order latent variable to the first order latent variable and from the first order latent variable to its items.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| (1)SupFeed | 1,00 | - | - | - | - | - | - | - | - | - |
| (2)SupJIT | 0,36 | 1,00 | - | - | - | - | - | - | - | - |
| (3)SupDvt | 0,32** | 0,47** | 1,00 | - | - | - | - | - | - | - |
| (4)CustInv | 0,53** | 0,51** | 0,38** | 1,00 | - | - | - | - | - | - |
| (5)Pull | 0,29** | 0,46** | 0,26** | 0,44** | 1,00 | - | - | - | - | - |
| (6)Flow | 0,24** | 0,42** | 0,30** | 0,36** | 0,60** | 1,00 | - | - | - | - |
| (7)Setup | 0,11* | 0,18** | 0,02 | 0,20** | 0,19** | 0,17** | 1,00 | - | - | - |
| (8)SPC | 0,25** | 0,38** | 0,29** | 0,42** | 0,40** | 0,46** | 0,10 | 1,00 | - | - |
| (9)Empinv | 0,18** | 0,30** | 0,20** | 0,30** | 0,32** | 0,33** | 0,21** | 0,42** | 1,00 | - |
| (10)TPM | 0,23** | 0,32** | 0,23** | 0,39** | 0,41** | 0,41** | 0,13** | 0,59** | 0,31** | 1,00 |

** Correlation is significant at 0,01 * Correlation is significant at 0,05

**Table 14 -** Spearman correlations between Lean manufacturing first-order constructs

| | OpePerf | FinPerf | MktPerf |
|---|---|---|---|
| OpePerf | 1,00 | - | - |
| FinPerf | 0.34** | 1,00 | - |
| MktPerf | 0,29** | 0.71** | 1,00 |

** Correlation is significant at 0,01

**Table 15 -** Spearman correlations between performance first-order constructs

### 4.3.1. Measurements reliability and validity – Lean manufacturing

The first step in PLS-SEM assessment is to examine whether the latent variables are being properly measured by the manifest variables in terms of internal consistency reliability, convergent validity and discriminant validity. Consistency reliability is the extent to which a set of items are consistent in measuring the same construct, convergent validity involves the degree to which the measures of the same construct correlate positively and discriminant validity concerns how much items of one construct are different from the ones of other construct (Hair *et al.*, 2011; Hair Jr *et al.,* 2016; Urbach & Ahlemann, 2011). In order to examine this, we considered specific criteria which differ depending on the measurement model being reflective or formative (Hair *et al.*, 2011).

Previously to any analysis, it was mandatory to eliminate the items with loadings lower than 0.4 (Hair *et al.*, 2011). These values indicate that the latent variable is explaining a small part of the items' variance and therefore should be automatically eliminated. This has led to the removal of the item "Our key suppliers are located in close proximity to our plants" (SupDvt5) related with the construct Supplier Development and "Production employees undergo cross functional training" (Setup1) that is a measure of Setup Time Reduction.

In the following table (Table 16) are presented the rules for reflective measurements validation proposed by certain authors as well as the values for each first order latent variable associated with the second order latent variable Lean manufacturing. Firstly, it is immediately noticeable from the table that the construct Setup has, in every criterion, the value 1. This is a result of the previous elimination of one of its two items whose loading was inferior to 0.4. In fact, it made it become a construct with a single-item measure which according to Diamantopoulos *et al.* (2012) should not be considered with sample sizes higher than 50 which is this study's situation. Therefore, the construct Setup was removed from the model.

| | Consistency Reliability | | Convergent Validity | | |
|---|---|---|---|---|---|
| | **CA** | **CR** | **AVE** | **Outer Loadings** | |
| **Criteria** / **Constructs** | ≥0.60 in exploratory research (Hair Jr *et al.*, 2016) | | ≥0.5 (Hair *et al.*, 2011; Hair Jr *et al.*, 2016; Urbach & Ahlemann, 2011) | ≥0.7 | |
| SupFeed | 0.5886* | 0.7607 | 0.4473* | SupFeed1<br>SupFeed2<br>SupFeed3<br>SupFeed4 | 0.6348*<br>0.6379*<br>0.8057<br>0.5746* |
| SupJIT | 0.3046* | 0.6772* | 0.4175* | SupJIT1<br>SupJIT2<br>SupJIT3 | 0.7802<br>0.5532*<br>0.5802* |
| SupDvt | 0.6311 | 0.7814 | 0.4724* | SupDvt1<br>SupDvt2<br>SupDvt3<br>SupDvt4 | 0.7419<br>0.6868*<br>0.6593*<br>0.6578* |
| CustInv | 0.7552 | 0.8324 | 0.4585* | CustInv1<br>CustInv2<br>CustInv3<br>CustInv4<br>CustInv5<br>CustInv6 | 0.5983<br>0.6719<br>0.7243<br>0.7828<br>0.7530<br>0.4873* |
| Pull | 0.5861* | 0.8282 | 0.7069 | Pull1<br>Pull2 | 0.8577<br>0.8234 |
| Flow | 0.6366 | 0.8051 | 0.5855 | Flow1<br>Flow2<br>Flow3 | 0.8462<br>0.8379<br>0.5819* |
| Setup | 1.0000 | 1.000 | 1.000 | Setup2 | 1.0000 |
| SPC | 0.8280 | 0.8798 | 0.5956 | SPC1<br>SPC2<br>SPC3<br>SPC4<br>SPC5 | 0.8321<br>0.8178<br>0.7973<br>0.6786*<br>0.7216 |
| Empinv | 0.5151* | 0.7482 | 0.5075 | Empinv1<br>Empinv2<br>Empinv3 | 0.7524<br>0.8291<br>0.5186* |
| TPM | 0.7432 | 0.8539 | 0.6609 | TPM1<br>TPM2<br>TPM3 | 0.8084<br>0.8456<br>0.7839 |

Where AVE: Average Variance Extracted; CR: Composite reliability; CA: Cronbach's Alpha.
*Do not achieve criteria suggested by the authors

**Table 16 -** Validation for Lean manufacturing measures

Observing the criteria presented in Table 16 for the remaining constructs it is clear that, regarding Consistency Reliability, Supdvt, CustInv, Flow, SPC and TPM are above the limit suggested by authors for both CA and CR. As for Convergent Validity, one can observe that Pull, Flow, SPC, Empinv and TPM fulfil the criteria for AVE, meaning each of them is explaining more than half of the variance of its items. Still, many outer loadings are below the suggested limit of 0.7. Nonetheless, for Hair Jr *et al.* (2016) weaker values for the loadings are frequent in certain domains and should not be automatically eliminated. Instead, they should only be removed if that leads to an improvement in CA, CR and AVE above the standards proposed. So, for all the constructs that failed at least one of the criteria of reliability and validity, we investigated the impacts of eliminating gradually its items lower than 0.7, starting by the one with lowest loading. Regarding the three constructs, SupFeed, SupJIT and Supdvt, the progressive removal of the items lower than 0.7 did not improve the values of CA, CR and AVE above the suggested thresholds and all these constructs ended up as single item-measure. So, analogously to what happened to Setup they were eliminated. In the case of Empinv, the removal of its only item lower than 0.7 "Production employees participate actively in product/process improvement efforts" (Empinv3) with a loading of 0.5126 did not improve Cronbach's Alpha sufficiently for it to achieve the limit of 0.7, leading to its elimination. However, in the case of the constructs Custinv the elimination of the item with lowest loading has made improvements in its convergent validity. Indeed, the elimination of the item "We conduct customer satisfaction surveys" (CustInv6) has led to an increase of AVE to 0.5272524 and thus above the limit of 0.5, so we kept it in the structural model. The changes in these two constructs are illustrated in the following Table 17.

| | | CA | AVE |
|---|---|---|---|
| Customer | With CustInv6 | 0.7551562 | 0.4584734* |
| | Without CustInv6 | 0.7735755 | **0.5272524** |
| Empinv | With Empinv3 | 0.5150823* | 0.5071164 |
| | Without Empinv3 | **0.5285194*** | 0.6792063 |

Where AVE: Average Variance Extracted; CA: Cronbach's Alpha.
*Do not achieve criteria suggested by the authors (Table 16)

**Table 17 –** Measures after item removal

Table 18 presents all indicators cross loadings and, hence, conclusions regarding discriminant validity can also be extrapolated. In fact, it can be admitted acceptable discriminant validity since in no case the items' loadings are overcome by its cross loadings.

| | Sup Feed | Sup Jit | Sup dvt | Cust | Pull | Flow | Setup | SPC | Empinv | TPM |
|---|---|---|---|---|---|---|---|---|---|---|
| Supf1 | **0.6348** | 0.3137 | 0.2977 | 0.3271 | 0.1786 | 0.1091 | 0.0562 | 0.0730 | -0.0139 | 0.1519 |
| Supf2 | **0.6379** | 0.1465 | 0.2242 | 0.3255 | 0.1583 | 0.1214 | 0.0193 | 0.2133 | 0.0832 | 0.1670 |
| Supf3 | **0.8057** | 0.3152 | 0.2450 | 0.4213 | 0.2959 | 0.2620 | 0.0892 | 0.2570 | 0.2398 | 0.2063 |
| Supf4 | **0.5746** | 0.2667 | 0.0988 | 0.2462 | 0.1684 | 0.0934 | 0.1577 | 0.0860 | 0.1439 | 0.0495 |
| SupJ1 | 0.3921 | **0.7802** | 0.3880 | 0.4529 | 0.3561 | 0.2577 | 0.1053 | 0.2743 | 0.1930 | 0.2240 |
| SupJ2 | 0.1536 | **0.5532** | 0.3329 | 0.2075 | 0.2553 | 0.2445 | -0.1189 | 0.0673 | 0.1149 | 0.1190 |
| SupJ3 | 0.1621 | **0.5802** | 0.1920 | 0.3023 | 0.3087 | 0.3222 | 0.0075 | 0.3619 | 0.2507 | 0.3045 |
| Supd1 | 0.3388 | 0.4211 | **0.7419** | 0.3732 | 0.2654 | 0.2503 | -0.0347 | 0.1853 | 0.1422 | 0.1711 |
| Supd2 | 0.2347 | 0.2874 | **0.6868** | 0.2362 | 0.1917 | 0.2307 | 0.0117 | 0.2047 | 0.2156 | 0.1694 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Supd3 | 0.1391 | 0.2576 | **0.6593** | 0.2342 | 0.1397 | 0.1456 | 0.0357 | 0.2046 | 0.1192 | 0.1797 |
| Supd4 | 0.1527 | 0.2918 | **0.6578** | 0.2237 | 0.1457 | 0.1723 | -0.0483 | 0.2054 | 0.0316 | 0.1588 |
| Cust1 | 0.2701 | 0.2946 | 0.2051 | **0.5983** | 0.3018 | 0.2642 | 0.0912 | 0.1369 | 0.1800 | 0.2112 |
| Cust2 | 0.4567 | 0.3180 | 0.2742 | **0.6719** | 0.2832 | 0.1809 | -0.0648 | 0.3029 | 0.1076 | 0.3056 |
| Cust3 | 0.4727 | 0.3475 | 0.3018 | **0.7243** | 0.3185 | 0.2431 | 0.0563 | 0.2567 | 0.1952 | 0.2424 |
| Cust4 | 0.3567 | 0.3587 | 0.2947 | **0.7828** | 0.2934 | 0.2302 | 0.0983 | 0.2500 | 0.1884 | 0.2426 |
| Cust5 | 0.3174 | 0.4312 | 0.3855 | **0.7530** | 0.3266 | 0.2813 | 0.0740 | 0.3491 | 0.3049 | 0.2323 |
| Cust6 | 0.1382 | 0.3487 | 0.1069 | **0.4873** | 0.3055 | 0.2456 | -0.0131 | 0.4044 | 0.2113 | 0.3486 |
| Pull1 | 0.2565 | 0.3962 | 0.2075 | 0.3865 | **0.8577** | 0.5675 | -0.0367 | 0.4029 | 0.3249 | 0.3845 |
| Pull2 | 0.2665 | 0.4140 | 0.2638 | 0.3710 | **0.8234** | 0.4931 | -0.0166 | 0.2847 | 0.2243 | 0.3344 |
| Flow1 | 0.2249 | 0.4460 | 0.2824 | 0.3676 | 0.6042 | **0.8462** | -0.0711 | 0.3305 | 0.2646 | 0.3348 |
| Flow2 | 0.1919 | 0.3242 | 0.2227 | 0.2835 | 0.5298 | **0.8379** | -0.0365 | 0.4346 | 0.2622 | 0.3993 |
| Flow3 | 0.1087 | 0.1533 | 0.1622 | 0.1258 | 0.2613 | **0.5819** | -0.0808 | 0.3263 | 0.3386 | 0.3108 |
| Setup2 | 0.1142 | 0.0278 | -0.0145 | 0.0608 | -0.0322 | -0.0781 | **1.0000** | -0.0446 | 0.1800 | -0.0531 |
| SPC1 | 0.2499 | 0.3284 | 0.3219 | 0.3743 | 0.2863 | 0.3767 | -0.0726 | **0.8321** | 0.3357 | 0.5295 |
| SPC2 | 0.1991 | 0.2943 | 0.1723 | 0.3473 | 0.3381 | 0.3212 | 0.0439 | **0.8178** | 0.3100 | 0.4677 |
| SPC3 | 0.1362 | 0.2967 | 0.2137 | 0.2870 | 0.3092 | 0.3424 | 0.0282 | **0.7973** | 0.3333 | 0.4035 |
| SPC4 | 0.2030 | 0.2751 | 0.1601 | 0.2651 | 0.3285 | 0.4148 | -0.0557 | **0.6786** | 0.3504 | 0.4526 |
| SPC5 | 0.1771 | 0.3101 | 0.2294 | 0.3481 | 0.3329 | 0.3737 | -0.1143 | **0.7216** | 0.2945 | 0.4261 |
| Empi1 | 0.1258 | 0.1912 | 0.1552 | 0.2276 | 0.1770 | 0.2530 | 0.1511 | 0.3829 | **0.7524** | 0.2660 |
| Empi2 | 0.1683 | 0.2827 | 0.1612 | 0.2481 | 0.3331 | 0.3419 | 0.0752 | 0.3321 | **0.8291** | 0.2570 |
| Empi3 | 0.0898 | 0.1389 | 0.0726 | 0.1405 | 0.1769 | 0.1416 | 0.2121 | 0.1329 | **0.5186** | 0.0744 |
| TPM1 | 0.1769 | 0.2921 | 0.2354 | 0.3182 | 0.3526 | 0.3946 | -0.0849 | 0.5078 | 0.2902 | **0.8084** |
| TPM2 | 0.2019 | 0.2793 | 0.1401 | 0.3505 | 0.3832 | 0.3778 | -0.0345 | 0.4719 | 0.2462 | **0.8456** |
| TPM3 | 0.1735 | 0.2744 | 0.2261 | 0.2732 | 0.3068 | 0.3307 | -0.0065 | 0.4662 | 0.1955 | **0.7839** |

**Table 18 –** Cross loadings for Lean manufacturing measures

### 4.3.2. Measurements reliability and validity – Performance

As for the higher-order construct Performance the statistical rules for validity and reliability are equally applied and the values are illustrated in Table 19.

| | Consistency Reliability | | Convergent Validity | | |
|---|---|---|---|---|---|
| | **CA** | **CR** | **AVE** | **Outer Loadings** | |
| **Criteria** / **Constructs** | ≥0.60 in exploratory research | | ≥0.5 | ≥0.7 | |
| OpePerf | 0.628 | 0.798 | 0.573 | MC<br>Defects<br>CT | 0.814<br>0.649*<br>0.791 |
| FinPerf | 0.855 | 0.932 | 0.873 | NI<br>ROA | 0.934<br>0.935 |
| MktPerf | 0.812 | 0.914 | 0.841 | MS<br>SG | 0.917<br>0.918 |

Where AVE: Average Variance Extracted; CR: Composite reliability; CA: Cronbach's Alpha.
*Do not achieve criteria suggested by the authors

**Table 19 -** Validation for Performance Measures

The item "Stocks level (raw material/unfinished products/finished products)" (Stocks) is not presented in the table as it has been automatically removed because of its loadings being lower than 0.4 (Hair *et al.*, 2011). An interpretation analogous to the one completed to the first order latent variables measuring Lean manufacturing is made to the ones measuring Performance. Following the same criteria suggested it is evident that for all of these constructs the Internal Consistency Reliability and Convergent Validity are acceptable. The cross loadings in Table 20 equally showed acceptable discriminant validity.

| | OpePerf | FinPerf | MktPerf |
|---|---|---|---|
| MC | **0.814** | 0.3611 | 0.2595 |
| Defects | **0.649** | 0.1591 | 0.1402 |
| CT | **0.791** | 0.2348 | 0.2665 |
| NI | 0.283 | **0.9343** | 0.6884 |
| ROA | 0.343 | **0.9349** | 0.6431 |
| MS | 0.264 | 0.6518 | **0.9171** |
| SG | 0.265 | 0.6550 | **0.9175** |

**Table 20 -** Cross loadings for Performance measures

### 4.4. Model Validation and Hypothesis Testing

Once the all measurement models that did not fulfil the validity and reliability criteria were eliminated, the higher order structural model was again estimated with the retained constructs and items. In this last stage analysis, the assumed relationship between the endogenous (Lean manufacturing) and Exogenous (Performance) was estimated. Table 21 and 22 show the measures of Reliability and Validity for this final model and it can be inferred that all criteria suggested by authors were met. In fact, from Table 21 one can see that all first-order constructs, measuring each of the second order constructs, were statistically significant as the confidence interval in any case contains the value 0.

| First order constructs | Indicators | Construct Loading | Confidence Interval 95% |
|---|---|---|---|
| LM | CustInv | 0.6746724 | [0.5916888; 0.7457698] |
| | Flow | 0.6986974 | [0.6318992; 0.7596411] |
| | SPC | 0.8520033 | [0.8144853; 0.8830662] |
| | TPM | 0.7787832 | [0.7304287; 0.8221272] |
| Performance | OpePerf | 0.6397811 | [0.5463505; 0.7220545] |
| | FinPerf | 0.8838601 | [0.8558451; 0.9089151] |
| | MktPerf | 0.8628617 | [0.8260064; 0.8937050] |

**Table 21 –** Validation of the final PLS structural equation model

| | CA | CR | AVE |
|---|---|---|---|
| Criteria / Constructs | ≥ 0.60 in exploratory research | | ≥0.5 |
| LM | 0.866 | 0.888 | 0,569 |
| Performance | 0.798 | 0.854 | 0,645 |
| CustInv | 0.774 | 0.847 | 0.527 |
| Flow | 0.637 | 0.806 | 0.586 |
| SPC | 0.828 | 0.880 | 0.596 |
| TPM | 0.743 | 0.854 | 0.661 |
| OpePerf | 0.628 | 0.798 | 0.573 |
| FinPerf | 0.855 | 0.932 | 0.873 |
| MktPerf | 0.812 | 0.914 | 0.841 |

**Table 22 –** First-order constructs loadings

Moreover, Figure 3 shows the results of the structural model along with path coefficients and the coefficient of determination ($R^2$). Examining the paths coefficients in the figure one can admit that these are all positive which is indicative of positive relationships (Hair Jr *et al.*, 2016). These should also be significant at a minimum 0.05 level (Urbach & Ahlemann, 2011) and therefore a bootstrapping was used to estimate the statistical significance of these relationships.

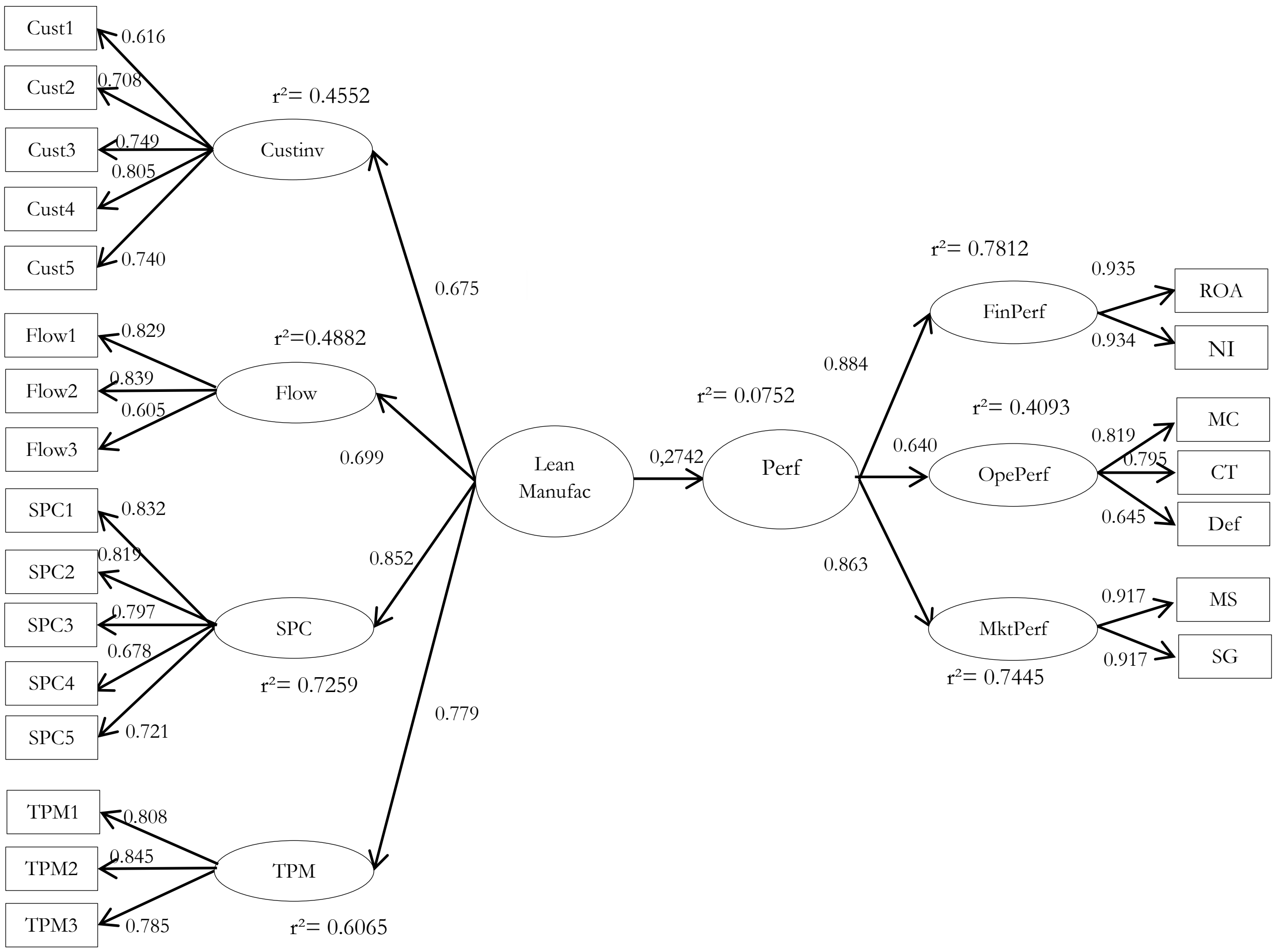


**Figure 3 –** Final PLS-SEM Model

The results of the effects and bootstrapping (5000 subsamples) for the hypothesis that this study proposes to test are illustrated in Table 23.

| **Hypothesis/structural relation** | **Original path coefficients** | **Mean bootstrapping** | **Standard Error** | **Confidence Interval 95%** |
|---|---|---|---|---|
| LM -> Performance | 0.2742124 | 0.2758306 | 0.05230887 | [0.1757930; 0.3757988] |
| LM -> OpePer | 0.1754359 | 0.1771611 | 0.03720881 | [0.1083231; 0.2532823] |
| LM -> FinPer | 0.2423654 | 0.2439154 | 0.04661640 | [0.1543092 0.3334934] |
| LM -> MktPer | 0.2366074 | 0.2381285 | 0.04612363 | [0.1496573 0.3263757] |

**Table 23 -** Bootstrap parameter estimation of the structural model

The findings show support for the all hypotheses (H1, H2, H3 and H4). As a matter of fact, all the paths have the expected positive sign and the effects are all statistically significant since the confidence intervals do not contain zero. Therefore, we have enough statistical evidence to state that Lean impacts positively overall performance and all its sub-types (operational, financial and market performances).

### 4.5. Discussion of Results and implications

The first results provided by the cluster analysis are indicative that the majority of Portuguese manufacturing SMEs are implementing Lean practices discreetly and therefore it can be inferred that Lean is still on its infancy in Portugal. These results cannot be directly compared with any other study since none has used a Lean measurement instrument to measure Lean practices implementation in Portugal. The closest study is the one by Silva *et al.* (2010) and the authors conclude that Portuguese companies are still behind countries such as UK, USA and Italy, and believe that Lean practices implementation in Portugal have potential to increase significantly in short-run. Additional analysis allowed us to identify that there is a positive association between Lean implementation and companies' dimension, yet no association of Lean between sectors and companies perception of self-Leanness. Regarding the former conclusion, we were not surprised as many scholars had already suggested that association (Bonavia & Marin, 2006; Shah & Ward, 2003; White *et al.*, 1999). As for the no association between Lean and sectors, possibly it may be due to the debility of the sample with some sectors counting with less than 10 responses. Regarding the lack of association between Lean and perception of self-Leanness, it is indicative that there is still a great deal of unawareness and, therefore, we suggest the need of stimulating consciousness on Lean and its benefits so that its presence increases.

As for the hypotheses (H1, H2, H3 and H4) the results are the expected and consistent with the great majority of authors (Cua et *al.*, 2001; Fullerton & Wempe, 2009; Furlan *et al.,* 2011; Godinho Filho *et al.*, 2016; Hofer *et al.*, 2012; Rahman *et al.,* 2010; Shah & Ward, 2003; White *et al.*, 1999; Yang *et al.*, 2011). The main findings are that the aggregated implementation of Lean practices, namely Customer Involvement, Statistical Process, Continuous Flow and Total Productive Maintenance leads to improvements in global performance measured by market, financial and operational measures, and also improves each of these measures individually. This study innovates by using performance as a second order construct measured by not exclusively operational performance as done by Godinho Filho *et al.* (2016), but also by financial and market performance measures.

The results of this study provide some valuable academic and managerial insights. To begin with, they enrich the literature on Lean implementation in countries. These studies are important to understand how different contexts affect Lean implementation. Moreover, while testing this hypothesis, the 10 constructs proposed by Shah and Ward (2007) to measure Lean were narrowed to 4 constructs for meeting model's validity criteria. In our perspective a reason for this can be the fact that the questionnaire proposed by these authors might not be well-adjusted to the reality of the inquired companies or may be out of date. In fact, the instrument was validated by using a sample of only U.S. enterprises, an industrial context fairly different from the Portuguese, and neglected companies with less than 100 employees, which, in this study, represented around 88 % of the sample. Additionally, this instrument has been developed 11 years ago. Therefore, from an academic perspective, arises the need for reviewing this instrument or developing a new one that follows the evolution of the concept all over these years.

Also, the results suggesting a positive impact of Lean on performance have several managerial implications. First, have implications for leaders, has it shows they should invest all their efforts in trying to implement a Lean culture in their company. Secondly, employees, as they should be open to advance their knowledge and expertise. Finally, for the government and/or economic decision makers, who have all interest in seeing national firms growing, and should therefore be ready to give incentives and finance all these efforts mentioned above.

## 5. Conclusion

Lean has been attracting attention from all over the world and has been used as an asset by many companies to improve performance and gain competitive advantage. Little was known on its presence in Portugal. This study intended to study the diffusion of Lean practices in Portuguese manufacturing SMEs. The results suggest that some Portuguese companies have been adopting Lean practices, yet Lean is still an unknown concept for many companies. Moreover, it reinforces the idea that Lean manufacturing practices help companies achieving better performance in an operational, financial and market level. However, there is still lack of understanding on the concept and lack of awareness of the benefits that come from its implementation. Therefore, we advocate the need of creating incentives, and fostering education and research on Lean in association with Portuguese industries. We hope that with our results, obtained from a relatively large sample, we contribute in a robust way to enrich and clarify the knowledge on this concept.

This study, analogously to all investigations, has certain limitations which provide avenues for future research. We consider a limitation of this study the fact that some sectors were not well represented and therefore the sample was not as much representative of the Portuguese industry as we desired. Additionally, despite our efforts, several respondents were not directly inserted in production or quality departments which may suggest that some may not be familiar with the production processes in the company. Also, the use of Likert type scales might have introduced subjective bias. For further research we would recommend the introduction of fuzzy logic as made by authors such as Susilawati *et al.* (2015) as to remove the vagueness of subjective human judgement. Finally, the instrument measure developed by Shah and Ward (2007) is not adapted to SMEs. The aim of researchers in the future should be to develop a Lean measure specifically for SMEs.

## References


Abdulmalek, F. A., Rajgopal, J., & Needy, K. L. (2006). A classification scheme for the process industry to guide the implementation of lean. *Engineering Management Journal, 18*(2), 15-25.

Achanga, P., Shebab, E., Roy, R., & Nelder, G. (2006). Critical Sucess factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management, 17*(4), 460-471.

Alcaraz, J. L., Maldonado, A. A., Iniesta, A. A., Robles, G. C., & Hernández, G. A. (2014). A systematic review/survey for JIT implementation: Mexican maquiladoras as case study. *Computers in Industry, 65*(4), 761-773.

Alsmadi, M., Almani, A., & Jerisat, R. (2012). A comparative analysis of Lean practices and performance in the UK manufacturing and service sector firms. *Total Quality Management & Business Excellence, 23*(3-4), 381-396.

Belekoukias, I., Garza-Reyes, J. A., & Kumar, V. (2014). The impact of lean methods and tools on the operational performance of manufacturing organisations. *International Journal of Production Research, 52*(18), 5346-5366.

Bhamu, J., & Singh Sangwan, K. (2014). Lean manufacturing: literature review and research issues. *International Journal of Operations & Production Management, 34*(7), 876-940.

Bhasin, S. (2008). Lean and performance measurement. *Journal of Manufacturing Technology Management, 19*(5), 670-684.

Bonavia, T., & Marin, J. A. (2006). An empirical study of lean production in the ceramic tile industry in Spain. *International Journal of Operations & Production Management, 26*(5), 505-531.

Büyüközkan, G., Kayakutlu, G., & Karakadılar, İ. S. (2015). Assessment of lean manufacturing effect on business performance using Bayesian Belief Networks. *Expert Systems with Applications, 42*(19), 6539-6551.

Cezar Lucato, W., Araujo Calarge, F., Loureiro Junior, M., & Damasceno Calado, R. (2014). Performance evaluation of lean manufacturing implementation in Brazil. *International Journal of Productivity and Performance Management, 63*(5), 529-549.

Comm, C. L., & Mathaisel, D. F. (2000). A paradigm for benchmarking lean initiatives for quality improvement. *Benchmarking: An International Journal, 7*(2), 118-128.

Commission, E. U. (2003). Commission recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises. *Official Journal of the European Union, 46*, 36-41.

Cua, K. O., McKone, K. E., & Schroeder, R. G. (2001). Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. *Journal of Operations Management, 19*(6), 675-694.

Dennis, P. (2016). *Lean Production simplified: A plain-language guide to the world's most powerful production system.* Crc press.

Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P., & Kaiser, S. (2012). Guidelines for choosing between multi-item and single-item scales for construct measurement: a predictive validity perspective. *Journal of the Academy of Marketing Science, 40*(3), 434-449.

Dora, M., Van Goubergen, D., Kumar, M., Molnar, A., & Gellynck, X. (2014). Application of lean practices in small and medium-sized food enterprises. *British Food Journal, 116*(1), 125-141.

Eswaramoorthi, M., Kathiresan, G. R., Prasad, P. S., & Mohanram, P. V. (2011). A survey on lean practices in Indian machine tools industries. *The International Journal of Advanced Manufacturing Technology, 52*(9-12), 1091-1101.

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

Furlan, A., Vinelli, A., & Dal Pont, G. (2011). Complementarity and lean manufacturing bundles: an empirical analysis. *International Journal of Operations & Production Management, 31*(8), 835-850.

Gebauer, H., Kickuth, M., & Friedli, T. (2009). Lean management practices in the pharmaceutical industry. *International Journal of Services and Operations Management, 5*(4), 463-481.

Gelei, A., Losonci, D., & Matyusz, Z. (2015). Lean production and leadership attributes– the case of Hungarian production managers. *Journal of Manufacturing Technology Management, 26*(4), 477-500.

Ghosh, M. (2012). Lean manufacturing performance in Indian manufacturing plants. *Journal of Manufacturing Technology Management, 24*(1), 113-122.

Godinho Filho, M., Ganga, G. M., & Gunasekaran, A. (2016). Lean manufacturing in Brazilian small and medium enterprises: implementation and effect on performance. *International Journal of Production Research, 54*(24), 7523-7545.

Hair Jr, J. F., Hult, G. T., Ringle, C., & Sarstedt, M. (2016). *A primer on partial least squares structural equation modeling (PLS-SEM).* Sage Publications.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing theory and Practice, 19*(2), 139-152.

Herzog, N. V., & Tonchia, S. (2014). An instrument for measuring the degree of lean implementation in manufacturing. *Strojniški vestnik-Journal of Mechanical Engineering, 60*(12), 797-803.

Hines, P., Holweg, M., & Rich, N. (2004). Learning to evolve: a review of contemporary lean thinking. *International journal of Operations & Production Management, 24*(10), 994-1011.

Hofer, C., Eroglu, C., & Hofer, A. R. (2012). The effect of lean production on financial performance: The mediating role of inventory leanness. *International Journal of Production Economics, 138*(2), 242-253.

Hofer, C., Eroglu, C., & Hofer, A. R. (2012). The effect of lean production on financial performance: The mediating role of inventory leanness. *International Journal of Production Economics, 138*(2), 242-253.

Holweg, M. (2007). The genealogy of lean production. *Journal of Operations Management, 25*(2), 420-437.

INE (2016). Pordata: Report on Portuguese small and medium enterprises in percentage of total enterprises. Retrieved from https://www.pordata.pt/en/Portugal/Small+and+medium+sized+enterprises+as+a+percentage+of+total+enterprises+total+and+by+size-2859, accessed in 9 of January, 2018

INE (2016). Pordata: Report on enterprises' gross value added: total and by size. Retrieved from https://www.pordata.pt/en/Portugal/Enterprises%27+gross+value+added+total+and+by+size-2916, accessed in 9 of January, 2018

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

Jasti, N. V., & Kodali, R. (2015). Lean production: literature review and trends. *International Journal of Production Research, 53*(3), 867-885.

Jayaram, J., Vickery, S., & Droge, C. (2008). Relationship building, lean strategy and firm performance: an exploratory study in the automotive supplier industry. *International Journal of Production Research, 46*(20), 5633-5649.

Karlsson, C., & Ahlström, P. (1996). Assessing changes towards lean production. *International Journal of Operations & Production Management*, 24-41.

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of Children With A utism S pectrum D isorder by Sensory Subtype: A Case for Sensory-Based Phenotypes. *Autism Research, 7*(3), 322-333.

Ndaita, P. M., Gachie, T., & Kiveu, C. W. (2015). The implementation of Lean Six Sigma concept at national bank of Kenya-operation division. *The TQM Journal, 27*(6), 683-690.

Negrão, L. L., Godinho Filho, M., & Marodin, G. (2017). Lean practices and their effect on performance: a literature review. *Production Planning & Control, 28*(1), 33-56.

Nordin, N., Deros, B. M., & Wahab, D. A. (2010). A survey on lean manufacturing implementation in Malaysian automotive industry. *International Journal of Innovation, Management and Technology, 1*(4), 374.

Ohno, T. (1988). *Toyota Production System: beyond large-scale production.* crc Press.

Panizzolo, R. (1998). Applying the lessons learned from 27 lean manufacturers: The relevance of relationships management. *International Journal of Production Economics, 55*(3), 223-240.

Pavnaskar, S. J., Gershenson, J. K., & Jambekar, A. B. (2003). Classification scheme for lean manufacturing tools. *International Journal of Production Research, 41*(13), 3075-3090.

Pettersen, J. (2009). Defining lean production: some conceptual and practical issues. *The TQM Journal, 21*(2), 127-142.

Rahman, S., Laosirihongthong, T., & Sohal, A. S. (2010). Impact of lean strategy on operational performance: a study of Thai manufacturing companies. *Journal of Manufacturing Technology Management, 21*(7), 839-852.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management, 21*(2), 129-149.

Shah, R., & Ward, P. T. (2007). Defining and Developing measures of lean production. *Journal of Operations Management, 25*(4), 785-805.

Silva, C., Tantardini, M., Staudacher, A. P., & Salviano, K. (2010). Lean Production Implementation: A survey in Portugal and a comparison of results with Italian, UK and USA companies. *17th International Annual EurOMA Conference–Managing Operations in Service Economics, R. Sousa, C. Portela, SS Pinto, and H. Correia, eds.*

Singh, B., Garg, S. K., & Sharma, S. K. (2010). Development of index for measuring leanness: study of an Indian auto component industry. *Measuring Business Excellence, 14*(2), 46-53.

Staudacher, A. P., & Tantardini, M. (2007). Lean Production implementation: a survey in Italy. *XI Congreso de Ingeniería de Organización*, 1269-1279.

Sundar, R., Balaji, A. N., & Kumar, R. S. (2014). A review on lean manufacturing implementation techniques. *Procedia Engineering, 97*, 1875-1885.

Susilawati, A., Tan, J., Bell, D., & Sarwar, M. (2015). Fuzzy logic based method to measure degree of lean activity in manufacturing industry. *Journal of Manufacturing Systems, 34*, 1-11.

Urbach, N., & Ahlemann, F. (2011). Structural equation modeling in information systems research using partial least squares. *Journal of Information technology theory and application, 11*(2), 5-40.

Wahab, A. N., Mukhtar, M., & Sulaiman, R. (2013). A conceptual model of lean manufacturing dimensions. *Procedia Technology, 11*, 1292-1298.

White, R. E., Pearson, J. N., & Wilson, J. R. (1999). JIT manufacturing: A survey of implementations in small and large U.S. manufacturers. *Management Science, 45*(1), 1-15.

Womack, J. P., & Jones, D. T. (1996). *Lean thinking: Banish waste and create wealth in your corporations* (1st ed.). Simon & Shuster, Inc., The Free Press, New York.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world* (1st ed.). Simon & Schuster, Inc., The Free Press, New York.

Wong, Y. C., & Wong, K. Y. (2011). A lean manufacturing framework for the Malaysian electrical and electronics industry. *In Proceedings of the 3rd International Conference on Information and Financial Engineering, 12*, 30-34.

Yang, M. G., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics, 129*(2), 251-261.

# Annex 1 – Questionnaire translated

## *Quão próximas do sistema de produção Lean estão as PME portuguesas?*

O presente questionário pretende estudar o grau de implementação das práticas Lean* e o seu impacto no desempenho da empresa.

Todos os dados recolhidos serão tratados com TOTAL ANONIMATO e confidencialidade, de forma agregada e apenas serão usados para efeitos deste estudo.

Ao responder a este inquérito, lembre-se de que apenas queremos saber a sua opinião, pelo que não existem respostas certas ou erradas. Por favor responda ao questionário de acordo com a realidade da vossa empresa. Obrigada pela disponibilidade e colaboração.

**O Lean é um sistema/filosofia de gestão das operações que pretende, essencialmente eliminar todas as fontes de desperdício.*

**I. Informação geral**

NIF da empresa: ________________________________

CAE: ______________________________________________________

Nº de Vendas (2017): __________________________________________

Nº de Trabalhadores: __________________________________________

O seu cargo na empresa: ________________________________________

**II. Práticas correntes no planeamento da produção**

Indique, por favor, a dimensão de uso de cada uma das seguintes práticas na empresa.

(1)nunca (2)raramente (3)às vezes (4)bastante frequente (5)muito frequente, se não sempre

| | Relacionadas com Fornecedores | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1. | Our suppliers visit our plants | | | | | |
| 2. | Visitamos as fábricas dos nossos fornecedores | | | | | |
| 3. | Damos aos nossos fornecedores feedback sobre a qualidade e o desempenho da entrega | | | | | |
| 4. | Esforçamo-nos para estabelecer um relacionamento de longo prazo com os nossos fornecedores | | | | | |
| 5. | Os fornecedores estão diretamente envolvidos no processo de desenvolvimento de novos produtos | | | | | |
| 6. | Os nossos principais fornecedores entregam na fábrica numa base just in time (na altura agendada - nem adiantado, nem atrasado – e na quantidade solicitada) | | | | | |
| 7. | Temos um programa formal de certificação de fornecedores | | | | | |
| 8. | Discutimos questões estratégicas da nossa empresa com fornecedores chave | | | | | |
| 9. | Tomamos medidas ativas para diminuir o número de fornecedores em cada categoria de produto/consumíveis | | | | | |
| 10. | Os nossos principais fornecedores gerem o nosso inventário (relativo ao componente que fornecem) | | | | | |
| Por favor, considere agora uma escala diferente para responder às próximas perguntas:<br><br>(1)nenhum (2)muito poucos (3)alguns (4)muitos (5)quase todos, se não todos | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11. | Os nossos fornecedores estão contratualmente comprometidos a reduções anuais de custos | | | | | |
| 12. | Os nossos principais fornecedores estão localizados nas proximidades da nossa fábrica | | | | | |

(1)nunca (2)raramente (3)às vezes (4)bastante frequente (5)muito frequente, se não sempre

| | Relacionadas com Clientes | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 13. | Estamos em contacto estreito com os nossos clientes | | | | | |
| 14. | Os nossos clientes visitam as nossas fábricas | | | | | |
| 15. | Os nossos clientes providenciam feedback sobre a qualidade e o desempenho de entrega | | | | | |
| 16. | Os nossos clientes estão direta e ativamente envolvidos nas ofertas atuais e futuras de produtos da nossa empresa | | | | | |
| 17. | Os nossos clientes partilham informações com o departamento de marketing sobre as procuras atuais e futuras | | | | | |
| 18. | Realizamos questionários de satisfação do cliente | | | | | |

(1)nunca (2)raramente (3)às vezes (4)bastante frequente (5)muito frequente, se não sempre

| | Relacionadas com Trabalhadores | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 19. | Os nossos trabalhadores são treinados para reduzir o tempo necessário para o arranque (set-up) do equipamento | | | | | |
| 20. | Os trabalhadores da produção são fundamentais para as equipas de resolução de problemas | | | | | |
| 21. | Os trabalhadores da produção são responsáveis pela elaboração de programas de sugestões de melhoria dos produtos/processos | | | | | |
| 22. | Os trabalhadores da produção são submetidos a treinos multifuncionais | | | | | |

(1)nunca (2)raramente (3)às vezes (4)bastante frequente (5)muito frequente, se não sempre

| | Relacionadas com Processos | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 23. | As decisões de produção são tomadas apenas após a chegada de uma encomenda ou necessidade de produto intermédio (i.é, a produção é "puxada" pela expedição de produtos acabados) | | | | | |
| 24. | Usamos Kanbans (cartões), ou outros sinais para programação e controlo da produção | | | | | |
| 25. | Os produtos são classificados/organizados tendo em conta as semelhanças de processo produtivo | | | | | |
| 26. | O ritmo de produção está directamente ligado à taxa de procura de clientes | | | | | |

| | Relacionadas com Equipamentos | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 27. | O equipamento é agrupado para produzir um fluxo contínuo de famílias de produtos, e portanto as famílias de produtos determinam o layout da fábrica | | | | | |
| 28. | Dedicamos uma parte de cada dia para atividades de manutenção de equipamento planeadas | | | | | |
| 29. | Temos registos rigorosos de todas as atividades relacionadas com a manutenção | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | de equipamentos | | | | | |
| 30. | Afixamos os registos de manutenção de equipamentos na área de produção para partilha ativa com os empregados | | | | | |
| 31. | Utilizamos técnicas estatísticas para reduzir a variabilidade do processo produtivo | | | | | |
| 32. | Gráficos que mostram as taxas de defeitos são usados como ferramentas na área de produção | | | | | |
| 33. | Usamos diagramas do tipo espinha de peixe para identificar as causas dos problemas de qualidade | | | | | |
| 34. | Realizamos estudos acerca da capacidade dos processos produtivos antes do lançamento do produto no mercado | | | | | |
| Por favor, considere agora uma escala diferente para responder às próximas perguntas:<br><br>(1)nenhum (2)muito poucos (3)alguns (4)muitos (5)quase todos, se não todos | | | | | | |
| 35. | As máquinas na nossa fábrica apresentam baixos tempos de preparação (set-up) | | | | | |
| 36. | Os nossos equipamentos/ processos na área de produção estão atualmente a ser controlados utilizando uma ferramenta do tipo controlo estatístico da qualidade de processo | | | | | |

**III. Avaliar a performance**

Os items abaixo representam medidas de desempenho e pretendem avaliar o desempenho da empresa. Na sua opinião, qual o impacto que as práticas utilizadas nos últimos anos no planeamento e execução da produção teve ao nível de:

| | Aumentou muito (mais de 50%) | Aumentou, mas pouco | Manteve-se | Diminuiu, mas pouco | Diminuiu muito (mais de 50%) |
|---|---|---|---|---|---|
| Custo de produção | | | | | |
| Nível de stocks (matérias primas/trabalhos em processo/produtos acabados) | | | | | |
| Número de falhas/defeituosos | | | | | |
| Tempo de produção | | | | | |
| Resultado Líquido | | | | | |
| Retorno dos ativos | | | | | |
| Quota de mercado | | | | | |
| Volume de vendas | | | | | |

**IV. Percepção acerca do Lean**

Tendo em conta as práticas utilizadas nos últimos anos no planeamento e execução da produção considera a empresa Lean?

Sim ☐ Não ☐ Não sei o que é Lean ☐

# Annex 2 – Questionnaire

## *How far from Lean are Portuguese Small and Medium enterprises?*

The present questionnaire intends to study de degree of implementation of Lean practices and its impact on companies' performance.*

All collected data will be treated with TOTAL ANONYMITY and confidentiality, in an aggregated way and will be exclusively used in this study.

When responding to this questionnaire, bear in mind that only your opinion is important, and therefore there are no correct or wrong answers. Please respond to the questionnaire according to the reality of your company.
Thank you for your availability and cooperation.

* *Lean is a management system/philosophy that aims essentially to eliminate all sources of waste.*

### I. General information

NIF: ________________________________

CAE: ______________________________________________________

Sales Volume (2017): __________________________________________

Number of employees: __________________________________________

Job position: ________________________________________

### II. Current practices in production planning

Please indicate the extent of use of each of the following practices in the company.

(1)never (2)rarely (3)sometimes (4)fairly often (5)frequently, if not always

| | Related with suppliers | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1. | Our suppliers visit our company | | | | | |
| 2. | We visit our suppliers' plants | | | | | |
| 3. | We give our suppliers feedback on quality and delivery performance | | | | | |
| 4. | We strive to establish long-term relationship with our suppliers | | | | | |
| 5. | Suppliers are directly involved in the new product development process | | | | | |
| 6. | Our key suppliers deliver to plant on JIT (just-in-time) basis | | | | | |
| 7. | We have a formal supplier certification program | | | | | |
| 8. | We have corporate level communication on strategic issues with key suppliers | | | | | |
| 9. | We take active steps to reduce the number of suppliers in each category of products/consumables | | | | | |
| 10. | Our key suppliers manage our inventory (concerning the component they provide) | | | | | |
| Please, consider now a different scale to answer the following questions:<br><br>(1)none (2)very few (3)some (4)many (5)almost all, if not all | | | | | | |
| 11. | Our suppliers are contractually committed to annual costs reduction | | | | | |
| 12. | Our key suppliers are located in close proximity to our plants | | | | | |

(1)never (2)rarely (3)sometimes (4)fairly often (5)frequently, if not always

| | Related with clientes | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 13. | We are in close contact with our customers | | | | | |
| 14. | Our customers visit our plants | | | | | |
| 15. | Our customers give us feedback on quality and delivery performance | | | | | |
| 16. | Our customers are actively and directly involved in current and future product offerings | | | | | |
| 17. | Our customers share current and future demand information with marketing department | | | | | |
| 18. | We conduct customer satisfaction surveys | | | | | |

(1)never (2)rarely (3)sometimes (4)fairly often (5)frequently, if not always

| | Related with workers | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 19. | Our employees are trained to reduce set-up time required for the equipment to start up | | | | | |
| 20. | Production employees are key to problem solving teams | | | | | |
| 21. | Production employees participate actively in product/process improvement efforts | | | | | |
| 22. | Production employees undergo cross functional training | | | | | |

(1)never (2)rarely (3)sometimes (4)fairly often (5)frequently, if not always

| | Related with processes | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 23. | Production decisions are made only after the arrival of an order or need for an intermediate product | | | | | |
| 24. | We use Kanban or other signals for production control | | | | | |
| 25. | Products are classified with similar processing provision requirements | | | | | |
| 27. | Pace of production is directly linked with the rate of customer demand | | | | | |

(1)never (2)rarely (3)sometimes (4)fairly often (5)frequently, if not always

| | Related with equipments | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 27. | Equipment is grouped to produce a continuous flow of families of products, and consequently families of products determine the factory layout | | | | | |
| 28. | We dedicate a portion of everyday to planned equipment maintenance related activities | | | | | |
| 29. | We maintain rigorous records of all equipment maintenance related activities | | | | | |
| 30. | We post equipment maintenance records on shop-floor for active sharing with employees | | | | | |
| 31. | We use statistical techniques to reduce production process variance | | | | | |
| 32. | Charts showing defect rates are used as tools on production | | | | | |
| 33. | We use fishbone type diagrams to identify causes of quality problems | | | | | |
| 34. | We conduct production process capability studies before product launch in the market | | | | | |
| Please, consider now a different scale to answer the following questions: | | | | | | |

| (1)none (2)very few (3)some (4)many (5)almost all, if not all | | | | | | |
|---|---|---|---|---|---|---|
| 35. | The machines in our plant have low setup times | | | | | |
| 36. | Our equipment/ processes in the production area are currently being controlled using a statistical process quality control tool | | | | | |

**III. Evaluating performance**

The following items represent performance measures and propose to evaluate the company's performance. In your opinion, what is the impact that the planning and execution of production practices used in the last few years have had in:

| | Increased a lot (more than 50%) | Increased, but little | Mantai ned | Decresead, but little | Decresead a lot (more than 50%) |
|---|---|---|---|---|---|
| Manufacturing costs | | | | | |
| Stocks levels (raw materials/work in process/finished goods) | | | | | |
| Number of defects | | | | | |
| Cycle time | | | | | |
| Net income | | | | | |
| Return on assets | | | | | |
| Market Share | | | | | |
| Sales Growth | | | | | |

**IV. Lean self-perception**

Considering the production planning and execution practices used in your company in the last years do you consider your company Lean?

Yes ☐ No ☐ Don't know what Lean is ☐

## Annex 3 – 1st E-mail

Bom dia,

Escrevo da Faculdade de Economia do Porto para solicitar o endereço de e-mail da pessoa responsável pela Gestão e Planeamento da Produção da vossa empresa. Estamos a iniciar a realização de um estudo relativo a TODAS as empresas industriais portuguesas sobre como organizam os seus processos e gostaríamos de poder contactar directamente (por e-mail) com o Diretor da Produção.

Obrigada pela disponibilidade e atenção,

Rosário Moreira

## Annex 4 – 2nd E-mail

Bom dia,

Começo por agradecer desde já o tempo dedicado a este Projecto da FEP e INESC TEC.

Após o primeiro contacto de há umas semanas, venho solicitar o preenchimento do questionário que pode ser acedido no link:

A duração expectável de preenchimento é de 15 a 20 minutos. Pedimos a sua colaboração para preencher da forma mais próxima à realidade da sua empresa – lembre-se de que apenas queres saber a sua opinião, pelo que não existem respostas certas ou erradas.

Todos os dados recolhidos serão tratados com TOTAL ANONIMATO e confidencialidade, de uma forma agregada e apenas serão usados para efeitos deste estudo.

Logo no início do questionário será solicitado o NIF da empresa (caso não o tenha consigo pedimos que o obtenha antes de iniciar o questionário)

Obrigada pela disponibilidade e atenção,

Rosário Moreira

# Annex 5 – Descriptive statistics for each item

| | *Item* | *Item Code* | *Mean* | *SD* | *Min.* | *Max.* |
|---|---|---|---|---|---|---|
| Suppliers | We strive to establish long-term relationship with our suppliers | SupFeed4 | 4,44 | ,566 | 3 | 5 |
| | We give our suppliers feedback on quality and delivery Performance | SupFeed3 | 3,80 | ,812 | 1 | 5 |
| | Our key suppliers deliver to plant on JIT (just-in-time) basis | SupJIT2 | 3,54 | ,937 | 1 | 5 |
| | Our suppliers visit our plants | SupFeed1 | 3,44 | ,832 | 1 | 5 |
| | Suppliers are directly involved in the new product development Process | SupJIT1 | 3,35 | ,902 | 1 | 5 |
| | We take active steps to reduce the number of suppliers in each category of products/consumables | SupDvt2 | 3,16 | ,938 | 1 | 5 |
| | We have corporate level communication on strategic issues with key suppliers | SupDvt1 | 2,82 | 1,012 | 1 | 5 |
| | We visit our suppliers' plants | SupFeed2 | 2,79 | ,845 | 1 | 5 |
| | Our key suppliers are located in close proximity to our plants | SupDvt5 | 2,77 | ,948 | 1 | 5 |
| | We have a formal supplier certification program | SupJIT3 | 2,37 | 1,505 | 1 | 5 |
| | Our suppliers are contractually committed to annual costs Reduction | SupDvt4 | 1,95 | 1,005 | 1 | 5 |
| | Our key suppliers manage our inventory (concerning the component they provide) | SupDvt3 | 1,62 | ,869 | 1 | 5 |
| Customers | We are in close contact with our customers | CustInv1 | 4,39 | ,640 | 2 | 5 |
| | Our customers give us feedback on quality and delivery Performance | CustInv3 | 3,99 | ,771 | 1 | 5 |
| | Our customers visit our plants | CustInv2 | 3,71 | ,860 | 1 | 5 |
| | Our customers are actively and directly involved in current and future product offerings | CustInv4 | 3,65 | ,912 | 1 | 5 |
| | Our customers share current and future demand information with marketing department | CustInv5 | 3,23 | 1,018 | 1 | 5 |
| | We conduct customer satisfaction surveys | CustInv6 | 3,06 | 1,512 | 1 | 5 |
| Processes | We use Kanban or other signals for production control | Pull2 | 4,01 | ,808 | 1 | 5 |
| | Production decisions are made only after the arrival of an order or need for an intermediate product | Pull1 | 3,56 | 1,046 | 1 | 5 |
| | Products are classified with similar processing provision Requirements | Flow1 | 3,50 | ,904 | 1 | 5 |
| | Pace of production is directly linked with the rate of customer Demand | Flow2 | 3,02 | 1,015 | 1 | 5 |
| Employees | Production employees undergo cross functional training | Setup1 | 3,89 | 1,048 | 1 | 5 |
| | Production employees participate actively in product/process improvement efforts | Empinv3 | 3,68 | 1,144 | 1 | 5 |
| | Our employees are trained to reduce set-up time required for the equipment to start up | Empinv1 | 3,65 | ,980 | 1 | 5 |
| | Production employees are key to problem solving teams | Empinv2 | 2,40 | 1,458 | 1 | 5 |
| Equipment | Equipment is grouped to produce a continuous flow of families of products, and consequently families of products determine the factory layout | Flow3 | 3,74 | 1,158 | 1 | 5 |
| | We maintain rigorous records of all equipment maintenance related activities | TPM2 | 3,60 | 1,154 | 1 | 5 |
| | The machines in our plant have low setup times | Setup2 | 3,32 | ,968 | 1 | 5 |
| | We dedicate a portion of everyday to planned equipment maintenance related activities | TPM1 | 3,04 | 1,043 | 1 | 5 |

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|---|---|---|---|---|---|
| We post equipment maintenance records on shop-floor for active sharing with employees | TPM3 | 2,78 | 1,376 | 1 | 5 |
| We conduct production process capability studies before product launch in the market | SPC4 | 2,64 | 1,375 | 1 | 5 |
| We use statistical techniques to reduce production process Variance | SPC1 | 2,50 | 1,242 | 1 | 5 |
| Our equipment/ processes in the production area are currently being controlled using a statistical process quality control tool | SPC5 | 2,46 | 1,377 | 1 | 5 |
| Charts showing defect rates are used as tools on production | SPC2 | 2,35 | 1,335 | 1 | 5 |
| We use fishbone type diagrams to identify causes of quality Problems | SPC3 | 1,96 | 1,191 | 1 | 5 |