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Longitudinal study of lean tools in Spanish manufacturing firms

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Abstract

Purpose – Lean management is a suitable methodology for companies that want to improve their productive performance and competitiveness. This study aims to research levels of implementation and internalisation of Lean production tools in Spanish manufacturing companies, and explores differences in behaviour between SMEs and large companies based on data gathered over three time periods. The correlation between Lean adoption and company performance is also analysed.

Design/methodology/approach – Company survey data for the years 2012, 2015 and 2018 collected from 354 respondents were used to conduct a longitudinal study on the level of lean tool adoption and internalisation in manufacturing companies.

Findings – Over the years, the use of Lean tools has increased, whereas levels of internalisation have remained stable. Lean tool use in SMEs and large companies show significant differences in 2012 and 2015, but this is no longer the case 2018. Results also show that higher Lean tool use helps increase return on sales (ROS), and higher levels of internalisation of tools helps reduce the number of products rejected.

Originality/value – To date, there are no known studies on the use and internalisation of Lean tools or their correlations with business performance indicators in Spanish manufacturing companies.

Keywords Lean tools, Implementation, Internalisation, Cultural requirements, Technical requirements

Paper type Article

1. Introduction

Lean manufacturing methodology was developed in the 1950s by Taiichi Ohno and encompasses a set of manufacturing techniques that seek to improve production processes by reducing waste (Womack and Jones, 1996). This waste, known as "muda" in Japanese, adds no value to the product and is not aligned with what the client is willing to pay (Ohno, 1988; Womack *et al.*, 1990; Womack and Jones, 1997). Seven types of waste have been identified: transport, inventory, movement, waiting, overprocessing, overproduction and defects (Ohno, 1988; Muthukumaran *et al.*, 2019).

Lean methodology originating from the Toyota Production System (TPS), helps manufacturing companies improve their productive performance and competitiveness (Netland, 2013; Belekoukias *et al.*, 2014; Dora *et al.*, 2013; Durakovic *et al.*, 2018; Garza-Reyes

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Should data be required, contact the authors via email.

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et al., 2012; Kumar *et al.*, 2018a,b; Zahraee *et al.*, 2014) through waste disposal, reducing cycle time and cost of components (Godinho Filho *et al.*, 2016; Henrique *et al.*, 2016; Muthukumaran *et al.*, 2019; Anand and Kodali, 2009; Forno *et al.*, 2014; Mazzocato *et al.*, 2010; Jasti and Sharma, 2015).

This study investigated whether Spain is indeed evolving towards a progressive implementation of Lean production systems in its manufacturing companies, which is a theory supported by previous studies (Bonavia and Marin, 2006; Moyano-Fuentes and Sacristán-Díaz, 2012; Marin-Garcia and Bonavia, 2015;Hernandez-Matias *et al.*, 2020).

Thus, this research aims to evaluate new trends in the world of manufacturing in Spain, focussing on Lean tools that are mainly related to the human capital factor. The study explores the importance of Lean culture within organisations, where the aim is to make the most of the tools implemented and improve production and organisational performance. This study also addresses the concept of internalising Lean tools. According to Nair and Prajogo (2009) and Allur *et al.* (2014), internalisation refers to daily, active use of Lean tools in all areas and processes of the company, rather than on an ad hoc basis.

Conducting a longitudinal study in a non-academic environment means that purely theoretical views can be contrasted with the practical, long-term reality of real organisations. In this context, the relationship between operators and manufacturing managers is often an organisational challenge, especially when a Lean tool implementation process is underway. There are few longitudinal studies in the literature analysing the evolution of Lean tool use and its impact on company performance. This topic is worth investigating further as many studies have alerted companies of the multiple benefits of using Lean tools, which include organisational and production system improvements, cost reduction and better business performance. These improvements are of paramount importance to the Spanish manufacturing sector, which accounts for 12% of GDP (European Commission, 2021). Furthermore, new laws promoting sustainability, the circular economy and corporate social responsibility oblige companies to minimise waste that may harm the environment. It is also worth mentioning that higher energy costs are forcing companies to consider less costly production processes. This study contributes to closing this gap by surveying Spanish manufacturing industries during the years 2012, 2015 and 2018 to observe growth of use and internalisation of Lean tools in companies, and determine whether this relates to greater business performance, and if differences in the use and internalisation of Lean tools between SMEs and large companies exist.

The remainder of this document is structured in five sections. Section 2 reviews the previous literature on concepts related to Lean manufacturing and proposes the hypotheses and theoretical model used. Section 3 outlines the methodology. Section 4 presents the findings of the study and section 5 outlines the discussion. Section 6 sets out the main conclusions, study limitations and proposed future research.

2. Overview of research context

2.1 Lean concept

Lean manufacturing is a complex concept and has fuelled an ongoing debate amongst scholars regarding terminology used for referring to strategy, methodology and other Lean concepts. Dorval *et al.* (2019) and Hopp and Spearman (2021) defined Lean as an organisational culture. Later, Åhlström *et al.* (2021) concluded that although the concept of Lean has many theoretical foundations, it is not in itself a theory. "'Methodology"', is a term proposed by renowned scholars such as Womack and Jones (1996) and appears to generate the least controversy. For businesses, implementing Lean concepts is crucial as it generates a culture of continuous improvement based on communication and teamwork. The Lean method can be adapted to all types of industries with the aim of finding new ways of doing things in a more agile, flexible, and economical way (De Steur *et al.*, 2016; Durakovic *et al.*, 2018; Sumant and Patel, 2014; Salonitis and Tsinopoulos, 2016).

Lean methodology is basically a workplace management methodology that helps improve the work environment and human capacity, thus increasing productivity in a world with dynamic, changeable customer requirements where rapid response, quality and cost effectiveness in the supply chain are the key to business leverage. Senior management's commitment to the implementation of Lean philosophy is key, as the concept needs to be introduced and fostered amongst staff, together with investment in training and structural changes (Henrique *et al.*, 2016; Hernandez-Matias *et al.*, 2020).

Applying a single Lean production system is challenging for any company as each has its own characteristics (Salonitis and Tsinopoulos, 2016). However, the wide variety of Lean tools available means that each company can choose those that best suit their needs when adopting to the Lean system (Hu *et al.*, 2015). These systems are therefore often referred to as "xPS" (x = whatever company) in allusion to the Toyota Production System (TPS). Although many companies share similarities in terms of Lean implementation methods, and to some extent the methodology used to apply the tools or concepts (Netland, 2013), those differing from each other operationally can find tools to suit their specific production systems. To identify the most relevant research on the Lean production system, a research protocol was conducted (Appendix 1).

Based on this, Table 1 was drawn up, listing the most relevant studies on the Lean production system.

2.2 Classification of lean tools

The various Lean tools found in the studies analysed include Total Productive Maintenance (TPM), Kanban, Value Stream Mapping (VSM), Single-Minute Exchange of Die (SMED), 5S, Continuous improvement (CI).

The Lean tools employed can be either internal to the organisation and related to manufacturing processes and equipment, production planning and control and human resource management; or they can be external, and linked to the relationship companies have with suppliers and customers (Moyano-Fuentes and Sacristán-Díaz, 2012; Salonitis and Tsinopoulos, 2016; Shah and Ward, 2007).

Lean transformation should be seen as a methodology that can be approached from several different perspectives and taking various aspects of the company, as a whole, into consideration. The "technical requirements" of adopting a Lean system mainly consist of applying technological tools to production processes, and "cultural requirements" emphasise the importance of human resources, people, and leadership (Bhasin and Burcher, 2006).

Indeed, over the years the concept of Lean has evolved from the original set of so-called "hard" tools, designed for the production area, to a human-centred approach that is universally applicable to any process and context where "hard" tools are complemented by "soft" tools (Dabhilkar and Åhlström, 2013; Danese *et al.*, 2017; Shah and Ward, 2007). Lacerda *et al.* (2016) and Wong *et al.* (2014) concluded that combining soft and hard tools through technology generates operational improvements.

Hard tools correspond to the technical requirements described above, and soft tools to the cultural requirements associated with the performance of workers within an organisation.

Knol *et al.* (2018) argue that any Lean implementation has success factors that correspond to soft tools such as "teamwork", "leadership", "participation and empowerment of workers" and "employee training". This theory is supported by authors such as Danese *et al.* (2017), Losonci *et al.* (2011), Netland *et al.* (2015), Netland and Ferdows (2016), Salonitis and

Author	Methodology	Results
Shah and Ward (2003)	Questionnaire: 1757 answers	Operational performance increase
Bonavia and Marin (2006)	Questionnaire: 76 answers	Main tools: TPM, TQM, standardised work
Shah and Ward (2007)	Exploratory study	Correlation of 10 factors
Jezierski and Janerka (2013)	Survey: 300 plants	64% don't understand lean tools
Netland (2013)	Exploratory study	Main tools: standardised work, kaizen, TQM
Losonci and Demeter (2013)	Study: 453 companies	"Advanced lean": higher operational performance
Belekoukias *et al.* (2014)	Correlations study: 140 organisations	JIT and jidoka: operational performance increase
Netland *et al.* (2015)	Survey: 36 plants	Relation between control practices and lean implementation
Piercy and Rich (2015)	Longitudinal study: 5 companies	Correlation between lean tools and sustainability performance
Lacerda *et al.* (2016)	"VSM" tool study	Operators, inventory and cycle time reduction. Bottleneck eliminated
Netland (2016)	Survey: 432 professionals	CSFs: managerial and worker engagement
Antosz and Stadnicka (2017)	Questionnaire: 49 SMEs	Not implementing lean: 55% of SMEs
Tezel *et al.* (2018)	Questionnaire: 20 managers	7 motivational factors, 20 lean techniques and 16 barriers
Sahoo and Yadav (2018)	Survey: 121 SMEs	Inadequate knowledge of lean tools in "Lean beginners" and "In-transition lean"
Hernandez-Matias *et al.* (2020)	"SEM" study: 202 companies	Correlation between HRLP and lean implementation
Rajagopalan and Solaimani (2020)	Longitudinal survey	Increased lean tools adoption
Rajagopalan (2020)	Longitudinal survey. Method: "TSREP"	10% improvement in lean tools adoption
Singh and Kumar (2021)	Survey: 153 companies	Main tools: 5S, BIM
Garcia-Garcia *et al.* (2022)	"SMED" tool study	Reduction: time (30%), costs (10%). Increase: (70%) OEE
Shahriar *et al.* (2022)	"5S" tool study	Time reduction: internal processes
Gebeyehu *et al.* (2022)	"VSM" and "kaizen" tools study	Reduction: time (23%), WIP (8%), wait time (38%), distance (61%)

Source(s): Authors work

Table 1. Studies of the lean production system

Tsinopoulos (2016), Shah and Ward (2007) and Sundar *et al.* (2014). Table 2 summarises the Lean tools and techniques mentioned in the models and previous studies reviewed.

The 18 lean tools observed in the literature are related to companies' internal side, and are the focus of the research presented in this paper.

Several studies on the growing use of Lean tools in industry (Bonavia and Marin, 2006; Jezierski and Janerka, 2013; Singh and Kumar, 2021) link Lean tool use to higher business performance (Shah and Ward, 2003; Olhager and Prajogo, 2012; Belekoukias *et al.*, 2014; Hernandez-Matias *et al.*, 2020). Other link a high degree of Lean tool implementation with higher production performance within companies (Losonci and Demeter, 2013; Sahoo and Yadav, 2018), and yet other studies have reported the effects of specific Lean tools on the production system (Garcia-Garcia *et al.*, 2022; Shahriar *et al.*, 2022; Gebeyehu *et al.*, 2022). Other research includes longitudinal studies on the growing use of Lean tools in manufacturing companies (Piercy and Rich, 2015; Rajagopalan and Solaimani, 2020;

Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Shah and Ward (2003)	X	X	X	X									X					
Bonavia and Marin (2006)		X	X		X				X		X			X				
Shah and Ward (2007)			X		X	X	X	X	X	X	X	X	X	X				
Jezierski and Janerka (2013)	X		X		X				X	X			X					
Netland (2013)	X	X			X	X		X			X		X	X				
Losonci and Demeter (2013)	X	X	X		X							X	X	X				
Belekoukias *et al.* (2014)	X		X			X							X		X			
Netland *et al.* (2015)	X	X	X	X									X					
Piercy and Rich (2015)	X	X	X			X	X	X		X			X					
Lacerda *et al.* (2016)						X			X							X	X	
Netland (2016)	X	X	X	X		X				X		X						
Antosz and Stadnicka (2017)		X	X		X	X		X	X	X	X	X	X		X			
Tezel *et al.* (2018)						X		X		X	X		X			X		X
Sahoo and Yadav (2018)			X			X		X	X	X			X		X		X	
Hernandez-Matias *et al.* (2020)				X	X	X		X	X	X	X		X					
Rajagopalan and Solaimani (2020)	X				X	X			X							X		
Rajagopalan (2020)	X	X								X			X					
Singh and Kumar (2021)					X					X							X	X
Garcia-Garcia *et al.* (2022)									X									
Shahriar *et al.* (2022)										X								
Gebeyehu *et al.* (2022)						X							X					

Note(s): Lean Tools used: 1. Just-In-Time, 2. Total Quality Management, 3. Total Productive Maintenance, 4. Human Resource Management, 5. Kanban, 6. Value Stream Mapping, 7. Specific Lines, 8. Visual Control, 9. Single-Minute Exchange Die, 10.5s, 11. Standardised Work, 12. Six Sigma, 13. Continuous Improvement, 14. Task Integration, 15. Jidoka, 16. Takt-Time, 17. Poka-Yoke, 18. Building Information Modelling
Source(s): Authors work

Table 2.
Lean tools and techniques in previous studies

Rajagopalan, 2020). In addition, research by Kumar *et al.* (2018a, b) and Gupta *et al.* (2018) proposes future longitudinal studies aimed at gaining further insight into the implementation of Lean tools in companies. We also found that longitudinal studies base their analysis on the internal application of Lean tools in firms (Piercy and Rich, 2015; Rajagopalan and Solaimani, 2020; Rajagopalan, 2020).

Taking the above into account, and with the knowledge that no longitudinal study on the use and internalisation of Lean tools has been conducted in Spain to date, the following hypotheses are proposed.

H1. Spanish manufacturing companies have witnessed an increased uptake of Lean tools over the years analysed.

H2. Spanish manufacturing firms have adopted a higher level of internalisation of Lean tools over the years analysed.

According to studies by Olhager and Prajogo (2012) and Hernandez-Matias *et al.* (2020) the deployment of Lean tools leads to an improvement in the performance of companies. Furthermore, this study aims to test whether a similar situation is observed in Spanish manufacturing companies. Thus, two further hypotheses are put forward.

H3. Spanish manufacturing companies with a higher use of Lean tools have a higher business performance.

H4. Spanish manufacturing companies with a higher degree of internalisation of Lean tools have a higher business performance.

2.3 Challenges of lean implementation

One of the main challenges of adopting a Lean production system is getting the workforce to accept and adapt to the change. There is often an inherent resistance to new practices and production routines, especially amongst workers with a lower level of education, and this severely affects the speed of Lean implementation (Mathur *et al.*, 2012; Sahoo and Yadav, 2018). Other factors affecting the pace of Lean implementation are lack of support from senior management and lack of knowledge amongst employees regarding the benefits of Lean management (Behrouzi and Wong, 2011; Dorval *et al.*, 2019; Durakovic *et al.*, 2018). Reda and Dvivedi (2022) and Tezel *et al.* (2018) point out that added barriers to Lean implementation are the absence of quality standards, budget limitations (risk aversion), lack of planning and coordination during implementation, and inadequate control of the entire value stream.

In addition to the obstacles to Lean adoption already mentioned, most companies attempting to implement Lean manufacturing only use two or three tools, which brings unsatisfactory results, as optimising implementation requires adopting as many available Lean tools as possible in a coordinated way (Durakovic *et al.*, 2018; Sundar *et al.*, 2014).

Company size is another influential factor in Lean implementation (Sahoo and Yadav, 2018; Shah and Ward, 2003). Authors such as Netland *et al.* (2015) and Tezel *et al.* (2018) argue that SMEs show a significantly lower acceptance of Lean manufacturing compared to large companies.

For SMEs, both internal and external factors influence the shift from traditional manufacturing practices to a Lean system challenging (Godinho Filho *et al.*, 2016).

Some authors have pointed out that SMEs should opt for less expensive tools such as 5s or Visual Control given their economic constraints (Sahoo and Yadav, 2018). A study carried out in Poland on 49 SMEs found that 55% of companies had not implemented Lean philosophy in their organisations due to budget limitations (Antosz and Stadnicka, 2017).

Regarding Lean tool internalisation levels for SMEs, Achanga *et al.* (2006) pointed out that many SMEs are not yet familiar with Lean implementation, even though higher levels of implementation and internalisation leads to higher productive performance in companies. Thus follows the final hypothesis.

H5. There are differences between SMEs and large companies in Spain regarding the use of Lean tools over the years analysed.

2.4 Description of the theoretical model used

This research is based on a model proposed by Shah and Ward (2007), accepted in previous literature by scholars such as Danese *et al.* (2018), Knol *et al.* (2018), Netland *et al.* (2015) and Pettersen (2009).

The model is based on a set of Lean tools grouped into underlying internal and external (supplier and customer related) constructs. As mentioned previously, internal tools relate to the organisational aspect of companies and external tools relate to the company's relationship with customers and suppliers (Moyano-Fuentes and Sacristán-Díaz, 2012; Panizzolo, 1998; Salonitis and Tsinopoulos, 2016). In this model, Lean production is conceptualised holistically, bringing together both philosophical and practical perspectives.

Shah and Ward (2007) proposed a ten-component operational model divided into three groups: 1) Supplier related, 2) Customer related, 3) Internally related. The number of Lean operational measures making up each group is specified in parentheses.

1- Supplier related: supplier feedback (3), JIT delivery (3), supplier development (6)

2- Customer related: customers involved (5)

3- Internally related: pull (4), flow (4), low setup (3), controlled processes (5), productive maintenance (4), involved employees (6)

The first two groups are related to customers and suppliers and correspond to the external aspect of the model. The third group, on the other hand, collects together 6 operational constructs specific to the internal vision of the organisation and linked to a number of lean tools. This study only focuses on tools related to internal aspects of organisations, as Losonci and Demeter (2013) point out that external factors are usually difficult to control.

3. Materials and methods

This section describes the methodology used to test the hypotheses.

3.1 Sample

The study data was extracted from the European Manufacturing Survey (EMS), which is coordinated by the Fraunhofer Institute for Systems Research and Innovation (ISI), Karlsruhe, Germany. EMS seeks to standardise information on organisational and technological issues related to manufacturing companies, and includes other countries in addition to Spain, such as Slovenia, Germany, Austria, and the Netherlands.

To meet survey requirements, data from manufacturing companies must have a NACE code 15–37 and at least 20 workers. According to the Spanish National Institute of Statistics, more than 15,000 companies meet these requirements every year. A questionnaire was sent by post and online to the top managers of 4,000 of these companies for each year studied, which was followed by a telephone call after one week. In addition to the initial email, two further follow-up emails were sent after one and three months, and survey responses were collected at the end of the process. The response rate was 4.22% in 2012, 2.5% in 2015 and 2.12% in 2018.

From the time periods analysed, 354 valid responses were obtained. With these results, a 95% confidence interval was obtained with a margin of error of 5%.

Regarding the respondent profile, we selected top-level respondents such as manufacturing managers, industrial managers and CEOs with a clear global perspective or access to information on industrial and commercial requirements, as these tend to be more reliable sources of information than lower-level management (Sartal *et al.*, 2017).

It was not possible to ensure that the companies surveyed were the same over the years, as the survey was conducted anonymously. Nevertheless, it was decided emphasis should be placed on the longitudinal phenomenon of Lean tool implementation in Spanish manufacturing companies, regardless of whether the companies were the same or not. Although the number of responses decreased, it was considered that there were sufficient annual samples collected to carry out the study effectively.

3.2 Variables and encodings

The model proposed by Shah and Ward (2007) is taken as a reference to measure the evolution of Lean tools from an organisation's internal perspective. This model has been widely used in previous studies, as noted above (see Table 1).

This model, which comprises 6 operational constructs, is taken as a basis to link the 11 lean tools listed in the EMS survey (see Appendix 2). The tools in the EMS survey used for the study are as follows: kanban (PULL), Value Stream Mapping, specific lines and visual control (FLOW), Single-Minute Exchange of Die and 5S (SET UP), Total Productive Maintenance and standardised work (TPM), six sigma Statistical Process Control (SPC), Continuous Improvement (CI) and task integration (EMPINV).

Three indicators were used to measure business performance: (1) "the percentage of orders delivered on time", (2) "the percentage of products rejected or in need of reprocessing" and (3) "the percentage of return on sales (ROS)".

First, a longitudinal study was conducted on the use and internalisation of Lean tools in Spanish manufacturing companies over the years 2012, 2015 and 2018, based on an analysis of tool use at both aggregate and individual levels (H1 and H2). Following this, a study was carried out on whether a certain degree of Lean tool implementation (internalisation) could be correlated with better business performance (H3 and H4). Finally, the same longitudinal study was carried out, but this time the results of SMEs and large companies were separated to observe whether there were differences in the use and internalisation of Lean tools over the years (H5).

For this purpose, descriptive statistics were used to analyse the variables and a statistical study was carried out to validate the hypotheses. For the first two hypotheses, the results obtained on Lean tool implementation and internalisation within companies were analysed and comparisons made to ascertain whether there were differences between 2012 and 2018. To validate the third and fourth hypotheses, a correlational analysis was carried out between the selected business performance indicators and use, and internalisation of the Lean tools selected.

To contrast the last hypothesis (H5), a comparison was made using the same procedure employed in (H1) to verify whether there are differences in Lean tool implementation between SMEs and large companies in the same year.

The coding system "yes" or "no" was used to answer the question related to whether the companies surveyed use Lean tools in their manufacturing processes or not.

Regarding measuring the internalisation variable, companies were asked a direct question, as indicated in previous studies (e.g. Naveh and Marcus, 2005), and answers rated on a Likert scale from 1 to 3, where 1 = low use, 2 = medium use and 3 = high use of the tool.

Two new variables were created as an aggregation of Lean tools. One variable relates to the use of the tool and the other to the level of internalisation of the tool. The first variable is the percentage of Lean tools implemented in the company, which is calculated as the sum of the tools used out of the total number of possible tools used. Companies could answer "NS" (no sense) if this tool made no sense in their company.

The second variable is the percentage of a company's level of internalisation of Lean tools. This is calculated from the sum of the level of internalisation of each tool divided by the maximum level (calculated as the number of tools used and multiplied by 3, which is the high level of internalisation). In this case, this variable ranges from 33 to 100%.

4. Results

The results obtained on the combined use of Lean tools confirm a longitudinal growth for the 11 tools studied, as shown in Table 3. However, the use of Lean tools offers mixed results if each tool is analysed separately.

Firstly, the Lean tools “specific lines”, “visual control” and “SMED” showed a steady and statistically significant growth over the years. Other tools such as “VSM” and “5S” also showed a significant increase in use between 2012 and 2015 but stagnated between 2015 and 2018. The Lean tools “kanban” and “task integration” also show longitudinal growth, although this is not statistically significant. A similar case occurred with “continuous improvement”, as the tool showed increased use between 2012 and 2018, although this decreased between 2012 and 2015.

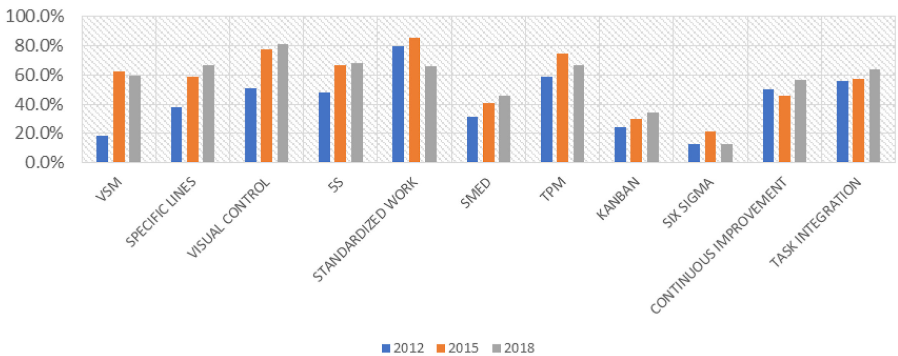
It is worth highlighting that the tools in the “TPM” group displayed irregular growth in usage; for example, “standardised work” was used extensively between 2012 and 2015, but this decreased in 2018 in a statistically significant way. The “TPM” tool, in the same TPM group, also showed a significant increase in use between 2012 and 2015, but a decrease in use in 2018. Finally, it is worth mentioning the least used tool of all, which is “six sigma”. This tool experienced a slight increase in use between 2012 and 2015, but in 2018 it decreased, returning to its initial values.

Figure 1 illustrates an upward trend in Lean manufacturing over the years, showing that some tools have a greater tendency to be implemented than others. These results support the theories of Netland (2013) and Hu *et al.* (2015).

“Shah and ward” model Group	Lean tools	2012 (169) Use	2015 (100) Use	2018 (85) Use	Use significance
Pull	Kanban	24%	30%	37%	0.11
Flow	VSM	18%	62%	61%	0.001*
	Specific lines	38%	59%	67%	0.001*
	Visual control	51%	77%	82%	0.001*
Setup	SMED	31%	41%	48%	0.02*
	5S	48%	67%	68%	0.001*
TPM	TPM	59%	74%	67%	0.03*
	Standardised work	80%	86%	67%	0.007*
SPC	Six sigma	13%	22%	13%	0.13
EMPINV	Continuous improvement	50%	46%	57%	0.3
	Task integration	56%	58%	65%	0.34

Note(s): *Statistical significance
Source(s): Authors work

Table 3.
Evolution in the use of lean tools



Source(s): Authors’ work

Figure 1.
Level on implantation of lean tools

Regarding internalisation, when each tool was studied separately, no significant differences in the evolution of internalisation levels for any of the tools analysed were found (Table 4).

After presenting the results of each tool separately, Table 5 shows the results obtained from the three time periods regarding the use and internalisation of Lean tools, considering the new variables calculated on the basis of the set of tools and their level of internalisation.

A hypothesis contrast was carried out through a statistical test comparing mean values of the variable significance, both for the results of each tool separately (Tables 3 and 4) and for the variables calculated for aggregated tools (Table 5). The findings validate (H1) for all 11 tools as a whole, but not for the individual tools. The individual results (Table 3) indicate that the Lean tools "kanban", "specific lines", "visual control", "SMED", "5S" and "task integration" also validate (H1). In contrast, (H1) cannot be validated for the tools "VSM", "TPM", "standardised work", "six sigma" and "continuous improvement".

Regarding (H2), this is completely rejected as there are no significant differences between the values across the different periods.

Regarding the impact of Lean tools on performance, findings on correlations between the use and level of internalisation of the Lean tools and the business performance indicators mentioned previously are shown in Table 6.

Findings show that of the three business performance indicators selected for the study, the only one that correlates positively and significantly with the use of Lean tools is (3) "ROS". This indicates that companies implementing more Lean tools in their manufacturing

"Shah and ward" model		2012 (169)	2015 (100)	2018 (85)	
Group	Lean tools	Internalisation level: 1-2-3	Internalisation level: 1-2-3	Internalisation level: 1-2-3	Internalisation significance
Pull	Kanban	2.28	2.07	2.11	0.59
Flow	Value stream mapping	2.07	2.17	2.27	0.63
	Specific lines	2.45	2.46	2.52	0.68
	Visual control	2.45	2.37	2.45	0.88
Setup	SMED	2.16	2.13	2.34	0.29
	5S	2.24	2.25	2.13	0.051
TPM	TPM	2.26	2.29	2.39	0.23
	Standardised work	2.57	2.51	2.41	0.53
SPC	Six sigma	2.1	1.95	1.7	0.9
EMPINV	Continuous improvement	2.24	2.2	1.84	0.14
	Task integration	2.41	2.44	2.31	0.25

Source(s): Authors work

Table 4. Evolution in the level of internalisation of lean tools

Group	Year	N (respondents)	Mean (%)
Use of tools	2012	169	42,56
	2015	98	56,64
	2018	84	58,79
	Total	351	50,38
Internalisation of tools	2012	146	77,93
	2015	87	76,32
	2018	78	75,76
	Total	311	76,76

Source(s): Authors work

Table 5. Global results of lean tools use and internalisation as a result from new variables

processes have a better ROS. This result allows us to partially validate (H3), as this correlation is not observed for (1) "the percentage of orders delivered on time", nor (2) "the percentage of products rejected or in need of reprocessing".

With regard to the variable "level of internalisation", this only correlates significantly with indicator (2) "products rejected or in need of reprocessing"; however, in this case the correlation is negative. In short, the greater the degree to which companies internalise Lean tools in their manufacturing processes, the lower the number of rejected products or products that need to be reprocessed. In this case, (H4) is also partially validated, as companies with a higher degree of internalisation have a better business performance, as measured by the indicator (2), "products rejected or in need of reprocessing"; but, not by (3) "ROS", or (1) "percentage of orders delivered on time".

However, Table 7 highlights the fact that business performance indicators (1) and (2) have a negative and significant correlation with each other. This means that the more orders that are delivered on time, the lower the proportion of products rejected.

Finally, to validate (H5), a significance study was conducted between SMEs and large companies for the years 2012, 2015 and 2018. Findings showed differences between SMEs and large companies for all the years analysed, including 2012 and 2015, which showed statistically significant differences. Therefore, (H5) can be validated.

Table 8 shows differences in the implementation of Lean tools between SMEs and large companies.

Table 6. Correlation between use of tools and business performance

		(1) On time	(2) Rejected	(3) ROS
Tools	Pearson correlation coef.	0.083	−0.058	(0.134)*
	Significance	0.132	0.295	0.037
	N	329	325	243
Internal	Pearson correlation coef.	0.109	(−0.115)*	−0.011
	Significance	0.063	0,05	0.872
	N	295	290	217

Note(s): * Correlation is significant at the 0.05 level
Source(s): Authors work

Table 7. Correlation between business performance indicators

		(1) On time	(2) Rejected	(3) ROS
Rejected	Pearson correlation coef.	(−0.293)**	1	−0.033
	Significance	<0.001	–	0.62
	N	321	326	230

Note(s): ** Correlation is significant at the 0.01 level
Source(s): Authors work

Table 8. Differences in the implementation of lean tools between SMEs and large firms

Year	Group	Size	Mean	N	Significance
2012	Use of tools	SME	39,04	140	0.,001*
		Large	63,04	24	
2015	Use of tools	SME	51,54	80	0.,001*
		Large	79,29	18	
2018	Use of tools	SME	56,83	71	0.,062
		Large	72,80	7	

Note(s): *Statistical significance
Source(s): Authors work

This study on Lean tool use points out the positive finding that an increasing number of companies are using at least one Lean tool. According to the results from our survey, 14 companies (8.2%) used no Lean tools in 2012, this figure was 5 (5%) in 2015, dropping to just 1 (1.1%) in 2018.

5. Discussion

It is noteworthy that the use of "VSM", "TPM", "standardised work" and "six sigma" tools decreased from 2015 to 2018, despite having experienced an increase between 2012 and 2015. The reverse is true for "continuous improvement", which decreased between 2012 and 2015 and increased between 2015 and 2018. These variations may be due to an often-inherent resistance to new productive practices and routines, as mentioned by Mathur *et al.* (2012) and Dorval *et al.* (2019), which makes it difficult for organisations to communicate and transfer Lean concepts. In the case of the "six sigma" tool, low levels of use may be explained by the financial investment involved in its implementation, which many companies are unwilling to take on.

Also, worth noting is the fact that many studies mention the benefits of using the Lean "VSM" tool in industrial environments. For example, Salonitis and Tsinopoulos (2016) argue that it is one of the most widely implemented tools in manufacturing environments as it is easily understood and conveyed to workers. This is a highly visual tool that requires little investment to implement and produces immediate results in terms of performance. In light of the above, findings show that "VSM" is the tool with the highest percentage of growth and is also statistically significant regarding usage between 2012 and 2015, with a slight stagnation between 2015 and 2018.

Figure 1 shows that Lean tool use does not grow equally amongst companies. As suggested by Netland (2013) and Hu *et al.* (2015), each company implements the tools that best suit their organisation. It should also be noted that there are many ways of interpreting the same Lean tool. Sometimes they can be referred to and used under another name, rather than its specific Lean tool name; one such example is Just-in-time or kanban. Liker (2004) also mentioned that the terms kaizen and continuous improvement are used interchangeably.

Regarding internalisation of Lean tools, findings show a partial and constant use, although the tools examined fail to reach a high level of adoption. According to a study by Losonci and Demeter (2013), the group with the highest degree of internalisation of Lean tools has better operational performance. The present study shows a negative correlation between internalisation and rejected products, which results in improved operational performance (Table 6).

The tools showing declining levels of internalisation are "six sigma" and "continuous improvement", explained by the argument put forward by Mathur *et al.* (2012) and Dorval *et al.* (2019) regarding workers" resistance to change. There are also other factors that may affect the degree of internalisation of lean tools such as the commitment and involvement of manufacturing firms" senior management (Behrouzi and Wong, 2011; Dorval *et al.*, 2019; Durakovic *et al.*, 2018; Netland, 2016; Reda and Dvivedi, 2022; Salonitis and Tsinopoulos, 2016; Tezel *et al.*, 2018) or employee's training, participation and empowerment (Danese *et al.*, 2017; Hernandez-Matias *et al.*, 2020; Knol *et al.*, 2018; Losonci *et al.*, 2011; Netland *et al.*, 2015; Netland and Ferdows, 2016; Salonitis and Tsinopoulos, 2016; Shah and Ward, 2007; Sundar *et al.*, 2014).

Regarding the correlational study carried out on the use of Lean tools and business performance indicators, this study is in line with Olhager and Prajogo (2012), showing positive correlations between the use of "Lean internal practices" and increased "business performance". Also noteworthy is the study by Hernandez-Matias *et al.* (2020) which observed relationships between Lean practices related to human resources and operational performance. The present study shows a positive correlation between the use of Lean tools and ROS, which indicates that companies are becoming more efficient through savings in production costs resulting from the use of Lean tools. This efficiency is also visible in the negative correlation between the levels of internalisation of tools and the rejection rate of delivered products. In effect, the more Lean tools are internalised in companies, the higher the quality of the products delivered, and therefore fewer defective products, or products that require reprocessing. A negative correlation is also observed between the variables "orders delivered on time" and "rejected products", which validates the goodness of the indicators chosen.

Finally, Table 8 shows differences in Lean tool use between SMEs and large companies. Differences in 2012 and 2015 are significant; however, differences are no longer significant in 2018. This data points towards diminishing differences between SMEs and large companies regarding Lean tool implementation. However, these results cannot be compared as very few empirical longitudinal studies on differences in Lean tool implementation between SMEs and large companies were found in the literature.

6. Conclusions and future research

The literature review conducted in this study shows the paucity of longitudinal studies on the deployment of Lean tools in companies. Only Piercy and Rich (2015), Rajagopalan and Solaimani (2020) and Rajagopalan (2020) offer similar studies; thus, the present study contributes to enhancing knowledge in this area.

Change towards a Lean production system must be understood as a global process that involves both senior and middle management, as well as workers. The models and studies analysed in this article point out that companies need to implement this change by combining "hard" and "soft" tools, as discussed by Dabhilkar and Åhlström (2013), Danese *et al.* (2017) and Shah and Ward (2007). "Soft" tools are becoming increasingly important as they are focused on employee performance, and therefore, companies must generate a "Lean culture" if they are to implement a Lean production system.

The data obtained verifies the Spanish manufacturing industry's growing interest in the Lean production system.

Findings show that there is no uniform growth of Lean tools in these companies, as each company implements the tools that best suit its own type of organisation. Nevertheless, over the years there is a general growth in the use of Lean tools, as well as individual growth in many of the specific tools surveyed. It is worth noting that the study on internalisation shows average levels of tool internalisation, which is still far from the high degree of internalisation sought. The failure to identify any significant change in internalisation levels suggests that there is still considerable progress to be made in the Spanish manufacturing industry regarding implementing the Lean manufacturing system.

Clearly, some tools are more difficult to implement than others. This study identified "six sigma" as the tool companies are least interested in implementing. It should be noted, however, that "six sigma" often requires the support of the "poka-yoke" tool to improve its performance and understanding within organisations, and when used alone, generally leads to implementation problems due to economic or organisational issues.

This research verifies that differences in levels of Lean adoption depend on the size of the company, and that Lean production systems are more easily implemented in large companies than SMEs; however, it should be noted that over time, this gap is closing.

Differences in the increased use of Lean tools by large companies with respect to SMEs are becoming progressively smaller. Although significant differences in the use of Lean tools between large companies and SMEs were found between 2012 and 2015, the situation in 2018 indicates that large companies continue to use Lean tools more than SMEs in their production processes, but these differences are not significant. This suggests that the use of Lean tools is gradually becoming more widespread and generalised and that their application depends less on the size of the company.

It is also possible to relate business performance indicators to Lean tool use and internalisation; for example, the positive and significant correlation between the ROS and a greater use of Lean tools; or the higher the degree of internalisation of Lean tools, the lower the rate of rejected products. These results may be of interest to managers or business organisations. It has been demonstrated that levels of internalisation in Spain have scope for further growth, however, senior management may have commitment and participation issues related to adopting the lean system. It is therefore recommended that managers maintain their interest in adopting Lean tools in their companies. In particular, it is recommended that company managers carry out training sessions aimed at understanding Lean concepts before proceeding to implement the tools in their organisations.

Future research could evaluate the variables in the model investigated using structural equation modelling, which would provide information on which tools evolve together and what conclusions can be drawn from this. Further research could also broaden the sample to provide a more up-to-date and realistic picture. Many companies remain resistant to Lean philosophy, particularly the considerable effort involved in implementing it in their sectors, which hinders its dissemination and natural evolution.

Finally, the scope of this study was limited by the analysis only focussing on companies in the manufacturing sector, which may differ from each other. Another limitation is the small sample size.

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Appendix 1

Table A1. The research protocol carried out is shown below

Search terms (Title, abstract and keywords)	"Lean tools" OR "lean longitudinal study" OR OR "lean survey" OR "lean critical success factors"
Research strategy	Boolean operator OR for terms in the same group Boolean operator AND for linking groups
Data base	Scopus (477)/ResearchGate (343)
Document type	Research/Review/Conference articles
Language	English
Temporal clipping	2003–2022

Source(s): Authors work

Appendix 2

Which of the following organisational concepts are currently used in your factory?	(No = "0"; yes = "1"; non sense = "-")
Model Dimensions	*Questions in the Survey*
PULL	Production controlling following the Pull principle (e.g. KANBAN, Internal zero-buffer principle) - Kanban
FLOW	Measures to improve internal logistics (e.g. Value Stream Mapping/Design, changed spatial arrangements of production steps) - VSM
	Customer- or product-oriented lines/cells in the factory (instead of task-/operation-structured shop floors) - Specific lines
	Display boards in production to illustrate work processes and work status (e.g. Visual Management) – Visual Control
SETUP	Fixed process flows to reduce setup time or optimise change-over time (e.g. SMED, QCO) - SMED
	Method of 5S ("work place appearance and cleanliness") – 5S
TPM	Methods of assuring quality in production (e.g. CIP, TQM, preventive maintenance) - TPM
	Standardised and detailed work instructions (e.g. standard operation procedures SOP, MOST) – Standardised work
SPC	Methods of operation management for mathematical analyses of production (i.e. Six Sigma) – Six Sigma
EMPINV	Methods of continuous improvement of production processes (quality circle, PDCA, Deming circle/cycle, etc.) – Continuous improvement
	Integration of tasks (planning, operating or controlling functions with the machine operator) – Task Integration
Extent of used potential for each organisational concept (internalisation)	(Low = "1"; Medium = "2"; High = "3")
Business performance indicators	
What percentage of orders are delivered on time? (Please reply according to confirmed delivery date)	% value
What percentage of products or semi-finished products have to be scrapped or reworked because of quality issues?	% value
Return on sales (ROS)	(Negative; 0–2%; 2–5%; 5–10%; >10%)

Source(s): Authors work

Table A2. The following are the questions of the European manufacturing survey (EMS) and the description of the internal lean tools used for the study

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