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Lean implementation and its relationship with operational responsiveness, failure factors and resilience

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Abstract

Lean Management (LM) is a multi-faceted socio-technical approach that requires organizations to strive along several dimensions simultaneously.
Initially, a conceptual model has been proposed for investigating the network of influences among lean practices, operational responsiveness and company growth performances in Italian companies. A structural equation modelling and a second order confirmatory factor analysis have been used to test the hypothesized relationships in the structural models.
Secondly, including manufacturing firms belonging to 23 different countries, the factors influencing the success of LM and human, cultural, economic, strategic and supply chain integration barriers during the start-up and the sustainment phase of lean projects have been analysed.
Thus, taking an organizational network view, this thesis provides a definition for Resilience and a model able to calculate the resilience of a lean organization taking into account both the organizational topology as well as the attitude and the learning curves of operators. Nodes have been modelled using the Hidden Markov Model and characterized by a learning curve. The resilience is calculated as the area included between the KPI trend during the time of the disruption event and the straight line parallel to the time axes. A case study has been analysed to explain the proposed model.
Results of this thesis highlights that the operational responsiveness is only partially connected to a Lean strategy of a company and there is no direct relationship between lean bundles and firm's performances. In addition the results revealed that some cultural aspects such as Performance Oriented and Gender Egalitarianism help to maintain a lean culture. Finally, results from this study will have a practical implication assisting human resource managers and production managers in predicting and evaluating global and local effects of the personnel relocation and possible reduction in performance of the workstations.

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Chapter 1.

Introduction

1.1 Project Background

The current landscape in manufacturing leads to an intensified competition, where old methods can no longer reach the same results nor can they respond to the fast changing situation (World Economic Forum, 2015).

Indeed in the last few years, organizations have been forced to respond to a complexity of several factors in a context of ever-changing dynamics and competition on a global scale (Simchi-Levi et al., 2012). New markets are continually emerging in different areas of the world and are making the way to satisfy the need for closeness to customers, which always becomes more complex in terms of product-service requirements. In order to survive in the present world turmoil, companies must seek to improve their processes, systems and technologies to be able to be dynamic and flexible to meet the on-going changes in the market.

Driven by the success performed by Toyota and several other organizations worldwide, a growing number of firms have begun a Lean journey to fulfil market needs and improve their processes (Bevilacqua et al., 2016).

Lean Management (LM) is a multi-faceted socio-technical approach with the aim of reducing or eliminating non-value-added activities throughout a product's entire value stream, within an organization and along its supply chain network (Bortolotti et al., 2015a; Holweg, 2007; Narasimhan et al., 2006).

But, although Toyota has had amazing performance and a number of cases reporting large benefits from lean implementation (Moyano- Fuentes and Sacristán- Díaz, 2012), a lot of scepticism still remains regarding results that could be really achieved and the possibility to apply Lean approach outside high volume manufacturing.

As this topic is particularly significant in countries like Italy, where SMEs are a dominant portion of the manufacturing industry and mainly compete on large variety and high customization products the first part of this thesis developed a conceptual model for investigating the network of influences among lean practices, operational responsiveness (product mix variety, product innovation and time effectiveness) and company growth performances in Italian companies.

In addition, as attractive as the lean philosophy might initially seem, there are numerous barriers that hinder the adoption of LM and it is quite difficult to implement it correctly and successfully. Indeed LM is a multi-faceted socio-technical approach that requires organizations to strive along several dimensions simultaneously. Thus, the second part of this thesis aims to join recent researches about lean barriers, studying the combined effect of factors influencing the success of LM and human, cultural, economic, strategic and supply chain integration barriers during the start-up and the sustainment phase of lean projects.

Finally, the complexity associated with the dynamics in organizational processes in the 21st century such as mobility of the workforce, ever-changing product portfolios and their related value stream adjustments are some of the obstacle that Lean Leaders may face when implementing and sustaining Lean in their organizations. Thus, taking an organizational network view, the third part of this work provides both a definition for Resilience as well as a coherent criteria to quantify the Lean Structural Network Resilience (LSNR) to the lean transformation associated with the mentioned changes in the organization.

1.2 Lean practices, operational responsiveness and company performances in Italy

The first part of this thesis has been carried out with three objectives in mind.

The first objective is to establish the theoretical associations between lean best practices and the operational responsiveness of manufacturing companies. Indeed, in a dynamic context, the ability to be reactive to changing market demand and meeting requests rapidly and effectively is a prerogative (Abdolvand et al., 2015; Gligor et al., 2015; Narasimhan et al., 2006).

The second objective regards the analysis of the impact of operational responsiveness latent variables on company performance.

Thirdly, the direct impact of different Lean best practices on company growth performances is studied.

Moreover, we checked if the omission of concept such as sector, company size and market share lead to endogeneity bias.

In order to achieve these objectives, we developed some specific research hypothesis and a survey where LM best practices implementation (supplier management, human resource management, just in time and total quality management practices), operational responsiveness (Product mix variety, Product innovation, and Time effectiveness) and company performances have been considered. Hence, even if this study is limited to the Italian manufacturing firms, it could be representative for all companies that are operating in a context of economic instabilities and market changes. At the European Union level, companies are facing many obstacles due to macroeconomic instability. Europe is facing the so-called "anemic growth": a slow growth of the labour force and total factor productivity and a slow rate of innovations (Salvatore, 2015). The Italian industrial situation well represents this European condition. In particular, since 2008, the Italian economy has experienced two consecutive recessions, characterised by a decline in exports between 2008 and 2009, and a decline in the domestic demand from 2011 onwards which hit the SMEs harder than the large enterprises ("Enterprise and Industry ITALY 2014 SBA Fact Sheet.," 2015).

1.3 Lean barriers

Literature reveals numerous barriers hindering the adoption of Lean. Ringen and Holtskog (2013) sustained that of every three Continuous Improvement initiative projects in general, two fail to attain the expected results. In 2006, research conducted in the UK organizations implementing Lean showed that fewer than 10% of the organizations have implemented it successfully (Bhasin and Burcher, 2006). Moreover, the organizations are usually reluctant to even admit that the Lean implementation has failed, not to mention giving an exact reason for the failure.

Hence, due to the many challenges or barriers faced during the lean deployment, recent studies present analyses of research on lean barriers' identification through literature reviews (Albliwi et al., 2014; Jadhav et al., 2014), surveys (Bhasin, 2012a; Laureani and Antony, 2012) or specific case studies (Dora et al., 2016; Souza and Pidd, 2011).

These studies are definitely a precious contribution to the current knowledge. Indeed, while many studies have delved into lean constructs and tools, far fewer have explored the critical aspects. Some of them are limited to a single case study, and others consider lean barriers differently on country location, industries sector, size of the organization, and context, lacking a complete overview.

Studies proved that the environment context may affect the outcome of lean implementation. Indeed a lot of scepticism still remains regarding results that could be achieved in environments with high demand variability (Azadegan et al., 2013; Bruce et al., 2004; James- Moore and Gibbons, 1997).

Several studies demonstrated that even company size is a factor that affects a successful lean implementation (Achanga et al., 2006; Kull et al., 2014; Yang et al., 2011a). But, company size is just one of the numerous factors that affect the level of lean implementation.

Operational performance differences come up when organizations in different cultural contexts invest in identical practices (Wiengarten et al., 2011). Kull (2014) demonstrated that aside from company size, a nation's culture moderates the LM's effect on operational performance. Moreover, in their study they tried to explain why the national culture impacts LM effectiveness. Many scholars tried to formalize the ideal culture for a successful LM implementation (Kull et al., 2014; Wincel and Kull, 2013). A limit of these studies is that they do not examine how facility culture interacts with national culture to influence LM effectiveness.

The search of the reviewed papers illustrated that there is a limitation in the publication of the factors that lead to lean failure. Indeed, although researches have addressed lean barriers from different points of view, they neglected that all these aspects could be inter-correlated and influence each other. Understanding how these factors condition each other will enable managers starting the lean journey in their companies, or managers sustaining the gains, to be aware of aspects that may damage or enhance lean success.

Moreover, implementing a change is hard for many individuals, but sustaining it is even harder. Frequently, after the initial enthusiasm where change occurs, people will revert back to their old habits where they feel comfortable. Maintaining a sense of urgency and a significant level of interest is difficult over time (Sabri and Shaikh, 2010). Although the sustaining phase is the most difficult phase in any transformation project, there is relatively little research concerning sustaining phases of changes in organizations (Sabri and Shaikh, 2010).

The second part of the thesis addresses the above research gaps, joining all the aspects mentioned and differentiating the initial and the sustaining phases of a lean implementation. Thus, a combined effect of country culture, company environment, lean effectiveness and difficulties in different stages of the lean project will be analysed and discussed in the next chapters.

1.4 Lean structural network resilience

LM is more than redesigning some production processes, knowledge flows between different roles in organization need to be taken into account and analysed (Dombrowski, Mielke, & Engel, 2012). Indeed organizations, as communicating entities, require people to communicate and exchange information. Diez et al. (2015a) proposed a standardized technical formal communication through an evolution of Deming cycle: $(CPD)_nA$ (Check , Plan, Do n times, Act). They have demonstrated that it brings enormous benefits in value stream performance, in sustaining knowledge creation, by learning faster and continuously improving. Moreover, using $(CPD)_nA$ is a way to represent communication and knowledge interchange by means of the interrelationship between its processes according to its related KPIs.

Focusing the attention on the growing number of organizations that are starting or sustaining a Lean journey, the concept of resilience takes on the meaning of being efficient with stabilized processes, reduced supply chain variability and being resilient with low inventory levels (Martin & Rutherford, 2004; Pal, Torstensson, & Mattila, 2014; Puchkova, Srinivasan, McFarlane, & Thorne, 2015). Several authors recognize that such companies are probably developing a better resilience than very stable groups (Kamalahmadi & Parast, 2016; Pal et al., 2014; Reggiani, Graaff, & Nijkamp, 2002).

Holling (1973) was one of the pioneers to conceptualize resilience 'as the ability of a system to absorb changes'. Since then, many authors echoed the concept of resilience as a system's ability to bounce back, that is, its ability to recover quickly and continue to perform its task after occurrence of a disruption event (Ponomarov & Holcomb, 2009). Therefore being resilient and hence capable of surviving, adapting, sustaining the business and responding rapidly to changes in the business environment is becoming a perquisite for today firms (Ates & Bititci, 2011; Sheffi, 2005a). However, regarding the metrics of an organization's resilience, literature mainly focuses on metrics that take into account KPIs' trend against their stated objectives, omitting the interconnection between the processes of the value stream (Brunsdon, Seville, & Vargo, 2007; Dalziell & McManus, 2004).

Although literature underlines the important role of people communication, coalition and training as crucial in building a resilient firm (Lengnick-Hall, Beck, & Lengnick-Hall, 2011; McElroy, 1996; Pal et al., 2014), there is a lack of consideration of resilience for lean organizations.

Enterprise's resilience metrics focusing on networks have been used mainly for analysing supply chain configurations. Therefore, the network's metrics consider the disruptive event mainly as an interruption of the connection between two nodes, omitting the possibility of a disruption event that primarily affects the node and does not compromise the linkages.

Instead, in this third part of the thesis the interest is to assess the resilience of the company, regarding its intrinsic structure defined by the processes it implements, against two major effects:

- The local instability at process level, represented by unexpected shortages in the KPIs describing the performance of such a process.
- The relocation of process owners, which can be described not as only replacing a specific process owner and having different individual characteristics but also as a different learning curve and different attitude.

Hence, through this research we address these literature gaps developing and testing a model able to calculate the resilience of a lean organization taking into account both the organizational topology as well as the attitude and the learning curves of operators.

Results from this study will have a practical implication assisting human resource managers and production managers in predicting and evaluating global and local effects of the personnel relocation and possible reduction in performance of the workstation in organizations that are facing a Lean Journey.

1.5 Description of Tasks

The organization of this thesis is as follows.

After this introduction, in Chapter 2 a literature review has been carried out to investigate Lean practices implementation and their relationship with operational responsiveness and company performances, the main Lean barriers faced by companies and the concept of resilience and knowledge sharing in Lean organizational networks. The research models used for developing these research topics has been presented in Chapter 3. Chapter 4 reports the results of the statistical analysis carried out. A discussion regarding the results obtained and has been developed in Chapter 5. Finally, some concluding remarks and future development are presented in Chapter 6 and 7.

Chapter 2.

Literature Review

A literature review about the main concept debated in this thesis will be developed in the following sections.

2.1 Literature review of lean practices, operational responsiveness and firms' growth performances.

The first phase of our research consisted in defining a theoretical framework supporting the network of influences among lean practices (supplier management, human resource management, just in time and total quality management practices), operational responsiveness (Product mix variety, Product innovation and Time effectiveness) and company growth performances in Italian companies. Through the result of this section we developed a survey analysis and the questionnaire to be submitted to the Italian companies.

To that end, a literature review was conducted in order to identify the main lean practices and the characteristics in order to describe the operational responsiveness and company performance.

A systematic literature search was conducted according to the steps explained in table 1. The analysis of these articles allowed us to define for each main variable (Responsiveness and Lean best practices) the factors to take into account.

Step	Activity	Description
Step 1	Database identification for literature review	Database: Emerald, Metapress, Science Direct, Scopus and Web of Science
Step 2	Keywords definition	Keywords: "Lean Practices", "Lean Tools", "Lean Manufacturing", "Just in Time Practices", "Lean Bundles", "Lean Production" and "Lean management", "Responsiveness", "Operational Responsiveness", "Manufacturing Flexibility", "Firm Performance" and "Company Performance"
Step 3	- Filter 1. Articles must contain the keyword search in the title, abstract or keywords; - Filter 2. Consider only English language articles.	Filters application for ensuring the papers adequacy: 158 papers were identified
Step 4	- Filter 3. Abstracts have been read for analysing article relevance. - Filter 4. Remaining full articles should be read for substantive relevance.	Filters application for ensuring the papers relevance: 46 papers were defined as relevant for this literature review study.

Table 1 Systematic literature review steps

2.1.1 Responsiveness

Operational responsiveness means responding immediately to events, changing conditions, and customer actions with a minimum of extra steps or mistakes, so business gets done quickly and effectively (Choi and Krause, 2006).

In literature, several factors have been used to measure the company operational responsiveness. Hallgren and Olhager (2009) consider responsiveness as the simultaneous achievement of flexibility and delivery performance. Analysing a large sample of manufacturing companies, these authors highlighted that delivery and flexibility (i.e. flexibility to change product mix, and flexibility to change volume) are the most important operational responsiveness factors. Danese (2013) used four factors for measuring company and supply chain responsiveness: on-time delivery, fast delivery, flexibility to change product mix, and flexibility to change volume. While some researchers (Mark Stevenson and Martin Spring, 2007; Reichhart and Holweg, 2007) address "delivery flexibility", other researchers ignore this dimension. Also the concept of product flexibility is not generally accepted. Reichhart and Holweg (2007) define "product flexibility" as the ability both to introduce new products and to make changes to existing products whereas Koste and Malhotra (1999) make a distinction between "new product flexibility" and "product modification flexibility". Regarding the product innovation Sisodiya et al. (2013)

investigated relationships among these factor and network spillovers, the industry context and responsiveness. Williams et al. (2013) measured responsiveness as external flexibilities rather than internal resource flexibilities. External flexibilities pertain to operating responses, rather than to specific resource characteristics such as labour flexibility or machine flexibility.

Many studies focus on the speed of response aspect in addition to the flexibility in order to reach operational responsiveness (Martin Christopher and Helen Peck, 2004; Matthias Holweg, 2005; Meehan and Dawson, 2002; Towill and Christopher, 2002). Prater et al. (2001) maintain that as the levels of speed and flexibility in a supply chain increase, the level of supply chain responsiveness increases.

In order to provide an analysis that will cover the main aspects of the operational responsiveness, we shift it into 3 impact areas: Product mix variety, Product Innovation and Time effectiveness.

Different reasons led us to select these impact areas. First of all, we had to choose impact categories that could be referred to internal responsiveness of the company and not connected to the company supply chain, since the survey we carried out in this work referred to a single company.

Moreover, these three impact areas have been frequently connected to the implementation of lean practices. Finally these impact areas allowed us to collect quantitative data and not only qualitative opinions (i.e.

using Likert scales) from the companies' sample. In particular, some observed variables have been connected to the three impact areas according to a literature review. These observed variables are shown in table 2 (see also section 2a of Appendix 1) and explained below.

Product mix variety

Responding to wide ranges of quantities demanded and handling large variety of standard and innovative products are some of the characteristics included in the definition of operational responsiveness (Chopra and Meindl, 2004). Indeed, operational responsiveness is an advanced level of flexibility to meet customer and market requirements. Volume flexibility enables firms to satisfy customer requests by producing the exact amount of product ordered. It enables firms to increase production volume quickly in response to unanticipated needs and to reduce volume quickly to avoid high inventory level (Jack and Raturi, 2002; Zhang et al., 2003). A high batch size variation means that the manufacturing process is affected by uncertainty and variation of the demand and it demonstrates the ability to reconfigure the production system. Moreover, in order to be competitive in today's increasingly globalized context, having a wide range of new finished products produced each year is particularly relevant for the economy of enterprises (Lewellyn and Bao, 2015).

Product Innovation

Markets today are increasingly volatile and therefore less predictable. So, building innovative products satisfying customer requests is included in the characteristics of operational responsiveness in order to be a competitive and a successful organisation (Chopra and Meindl, 2004; Kisperska-Moron and de Haan, 2011). Investing in R&D processes to create knowledge and generate innovation is particularly relevant for firms competing in today's increasingly competitive globalized knowledge-based economy (Lewellyn and Bao, 2015). Consequently, R&D investment was considered as one of the key aspects to be evaluated.

Time effectiveness

Meeting short lead time is even one of the key characteristics included in the definition of operational responsiveness (Chopra and Meindl, 2004). Indeed, for some customers, delivery reliability is not enough; delivery speed is also necessary to win the order. The speed of the product processing time and delivery has been recognized as a competitive priority in many studies (Arnas et al., 2013; Devaraj et al., 2004; Wang and Cao, 2008; Ward et al., 1996). So, in order to evaluate the importance that respondents place on time category, the inventory turnover has been evaluated. Moreover, for improving company responsiveness, response time to Warranty claim plays a fundamental role (Evangelos Psomas et al., 2014; Wheeler, 2013).

Main Factor	Impact Area	Observed variables	Source
Responsiveness	Product mix variety	Different Finished Product managed by the company.	(Chopra and Meindl, 2004);
		New finished products produce each year.	(Chopra and Meindl, 2004; Lewellyn and Bao, 2015)
		Batch size variation	(Chopra and Meindl, 2004);
	Product Innovation	Annual percentage invested in R&D.	(Lewellyn and Bao, 2015)
		Percentage of customizable products.	(Chopra and Meindl, 2004; Kisperska-Moron and de Haan, 2011).
	Time effectiveness	Mean time of stock in the warehouse	(Arnas et al., 2013; Devaraj et al., 2004; Wang and Cao, 2008; Ward et al., 1996) .
		Inventory turnover	(Arnas et al., 2013; Devaraj et al., 2004; Wang and Cao, 2008; Ward et al., 1996).
		Speedy response time to Warranty claim	(Evangelos Psomas et al., 2014; Wheeler, 2013).

Table 2 Responsiveness observed variables

2.1.2 Lean practices and bundles of lean practices

LM is an integrated social-technical system comprised of highly inter-related practices that targets waste elimination, overall operational performance improvement, and strategic human resources management.

In order to identify the most important lean practices and bundles, a literature review has been carried out, taking into account not only the manufacturing practices but even the human aspect inside the firm and the supplier collaboration. In literature the lean practices were frequently associated to lean bundles. Different authors performed data reduction techniques to reduce multiple items into a smaller number in order to refer to each of them as a latent variable or a factor. Sakakibara (1997) describe infrastructure practices (quality management, workforce management, manufacturing strategy, organizational characteristics, product design) and JIT practices (set-up time reduction, schedule flexibility, maintenance, equipment layout, kanban and JIT supplier relationships). Flynn et al. (1995) studied Just in Time (JIT) and Total Quality Management (TQM) practices and their common infrastructure; similarly, Cua et al. (2001) analysed JIT, TQM and Total Productive Maintenance (TPM) as specific practices, as well as their infrastructure. Other authors such as Koufteros and Vonderembse (1998) and Mackelprang and Nair (2010) did not distinguish between different groups of practices.

Many authors referred to Shah and Ward (2003) classification of lean practices. Shah and Ward (2003), using performance dimensions same as McLachlin (1997), reported that LM is a collection of practices that work together synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste. For them, practices commonly associated with LM include procedures for creating JIT flows, HRM and empowerment practices, equipment management and TPM, and various TQM practices. Two major forms of waste can be addressed by JIT through the associated practices: work-in-process inventory and unnecessary delays in flow time. TPM helps to maximize equipment effectiveness throughout its entire life, and TQM is aimed at continuously improving and sustaining quality products and processes (Cua et al., 2001). The fourth bundle, HRM, shows the work organization practices in LM. Always Shah and Ward, in a further work (Shah and Ward, 2007a), highlight that their four bundles account for only internally related lean practices and suggest the need for a model of lean that also includes supply chain related practices. According to this suggestion some authors introduced new bundles such as Supplier Management, Customer Management and Strategy Integration. In this context, Doolen et al. (2005), Nordin et al. (2010) and Abdul Wahab et al. (2013) incorporated new impact areas (manufacturing equipment and processes, shop floor management, product design, supplier management, customer management and workforce management) in their survey, with representative and supporting practices and activities associated with each impact area. Their survey provides an instrument to assess both the number and level of implementation of a broad range of lean practices by different organizations.

Using Shah and Ward's (2003) bundles of lean practices as a starting point, Bortolotti et al. (2015a) argued that their four lean bundles actually serve two different purposes. In particular, they proposed that HRM and TPM bundles are part of a firm's general fitness, laying the foundation for the more specific capabilities.

It is possible to highlight that in literature some practices changed their classification over time. For instance, the practice "lean management training" has been classified as JIT bundle by Sakakibara et al. (1993), as TQM bundle by Dow et al. (1999), as TPM bundle by McKone and Weiss (1999), while more recently there is an unanimously consensus to classify this practice as HRM (Arnas et al., 2013; Doolen and Hacker, 2005; Nordin et al., 2010; Wahab et al., 2013);

Moreover, some practices modified their classification due to the development of new bundle of lean practices. For instance, the practice "preventive maintenance" has been classified as JIT bundle in the early researches (Koufteros and Vonderembse, 1998; Sakakibara et al., 1993) while in recent works it is grouped as Total Productive Maintenance bundle (Gusman Nawanir et al., 2013).

The literature review, carried out according to the method proposed in section 2.1 (Table 1), provided 47 lean practices and 26 different bundles of lean practices (Table 3).

We could not use all these practices and bundles in our questionnaire since the length of the survey could have affected the likelihood of obtaining an incomplete questionnaire from the companies interviewed. In order to reduce such a likelihood, the present research focused only on the most important bundles and practices. Thus, a Pareto analyses was developed on lean bundles and practices (Figure 1; Figure 2). Results showed in Figure 1 highlight that four bundles are the most used: Just in Time (JIT), Total Quality Management (TQM), Supplier Management (SM) and Human Resource Management (HRM). These four bundles were used as latent variables in the construct model. Moreover, in Figure 2 all practices were linked to a specific bundle according to the frequency that bundle have been used for classifying that practice. For instance, the practice "Quick changeover techniques (SMED)" have been grouped as JIT bundle because eleven out of eighteen authors (62%) used this classification. No bundle has been assigned to the practices that had not a clear classification.

Practices	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Quick changeover techniques (SMED)	JIT	JIT	JIT	TBC	PE	JIT			JIT	JIT	JIT		MPE	PE	JIT	JIT	Setup	Setup	MPE	JIT	JIT	
Pull production / Kanban implementation	Flow	JIT	JIT	TBC	MPC	JIT			JIT	JIT	JIT	JIT	SFM	MPC	JIT	JIT	Pull	Pull	MPE	JIT	JIT	JIT
Total production maintenance			JIT						TPM				MPE		JIT		TPM	TPM			Fitness	TPM
Production smoothing/ Heijunka/Mixed model	JIT	JIT			MPP		TPM		JIT	JIT			SFM	MPP	JIT	JIT	UPL	Pull	MPE	JIT	JIT	JIT
Mistake-proofing/Poka-Yoke					PE								MPE	PE						TQM		
Total quality control (TQC) implementation																				TQM		
Standardized operating procedures																						TPM
Sharing information					SM								SM				SM	SM				

with suppliers																						
Involvement of supplier in the lean journey	SM			TBC	SM		TQM						SM	SM			SM	SM	SM			
Reducing the number of suppliers					SM												SM	SM				
Supplier partnership		IN	TQM		SM					TQM		SM	SM	SM			SM	SM			Fitness	
Lean Management training	JIT				HRM		TQM	TPM					HRM	HRM				HRM	HRM	HRM		
Create a multi-skilled Workforce/ Job Rotation		IN			HRM		TQM	TPM	IN	HRM	HRM	HRM	HRM	HRM			FR			HRM	Fitness	HRM
Employers' involvement (Suggestion schemes)		IN		TBC	HRM				IN		HRM			HRM		HRM		HRM	HRM	HRM	Fitness	HRM
Goal oriented teams																						HRM
Supplier quality involvement	SM		TQM		SM				TQM	TQM				SM			SM	SM			TQM	
Customer involvement		TQM			CM		TQM		TQM	TQM							TQM	CM	CM		TQM	

in product offerings																						
Top management leadership for quality		IN	TQM						IN												TQM	
Process feedback			TQM		CM				IN	TQM		TQM					TQM	CM		TQM	TQM	
Flow-oriented layout	Flow		JIT		PE				JIT	JIT	JIT	JIT		PE	JIT	JIT	CL	Flow			JIT	
Manufacturing-business strategy linkage		IN							IN			SI										
Small Group problem solving	JIT	IN			HRM							HRM				HRM	FR				Fitness	CI
Customer involvement in product design					CM									CM				CM				
Statistical process control		TQM	TQM						TQM	TQM	TQM	TQM				TQM	TQM	SPC			TQM	TQM
Cycle time reduction					PE								MPE						MPE			CI
Continuous improvemen				TBC							TQM	TQM				HRM			MPE		Fitness	

t																						
Shop-floor organization													MPE				CL	HRM	MPE			
Lot size reduction	Flow				MPP								SFM				SLP			WIF		
New Product Development: Design For-X					PD																	
technology ring)				TBC	PE	JIT							MPE	PE			CL	Flow				
Preventive maintenance	JIT			TBC	PE	JIT								PE			TPM	TPM				
New Product Development: Parts standardization					PD								PD									
New Product Development: Variability reduction	Flow				PD								PD									
Self-directed work team					HRM									HRM			FR					

Concurrent Engineering					PD								PD									
Work Time flexibility					HRM												FR					
few levels of management					HRM																	
Supplier involvement in design					SM									SM				SM				
Supplier proximity					SM													SM				
Rewards and recognition					HRM								HRM									
Process mapping																				VM		
Total cost supplier evaluation					SM								SM					SM				
Visual Information system					MPC												TQM		VM	VM		
Cleaness and organization /5S		IN			PE				TPM							TQM			MPE	VM	Fitne ss	
Supplier training and developmen					SM													SM				

t																						
Value Stream Mapping (VSM)													MPE						MPE			
Use of EDI with Suppliers					SM																	

Table 3 Lean practices classification

(1) Sakakibara et al. (1993); (2) Flynn et al. 1995; (3) Sakakibara et al. (1997); (4) Koufteros et al. (1998); (5) Panizzolo R. (1998); (6) Koufteros and Vonderembse (1998); (7) Dow et al. (1999); (8) McKone and Weiss (1999); (9) Cua et al. 2001; (10) Ahmad et al. (2003); (11) Shah and Ward (2003); (12) Swink et al. (2005); (13) Doolen and Hacker (2005); (14) Nordin et al. (2010); (15) Mackelprang and Nair (2010); (16) Furlan et al. (2011); (17) Nawanir et al. 2012; (18) Hofer et al. (2012); (19) Abdul Wahab et al. (2013); (20) Arnas et al. 2013; (21) Bortolotti et al. (2015a); (22) Netland et al. (2015)

Acronyms: JIT = Just In Time; TQM = Total Quality Management; HRM = Human Resource Management; TBC = Time Based Competition; TPM = Total Productive Maintenance; PE = Process & Equipment; MPE = Manufacturing Process & Equipment; MPC = Manufacturing Planning & Control; SFM = Shop Floor Management; UPL = Uniform Production Level; SM = Supplier Management; IN = Infrastructure; FR = Flexible resources; CM = Customer Management; CL = Cellular Layout; SI = Strategy Integration; CI = Continuous Improvement; SPC = Statistical Process Control; SLP= Small Lot Production; WIF = Work in Flow; PD = Product Design; VM = Visual Management

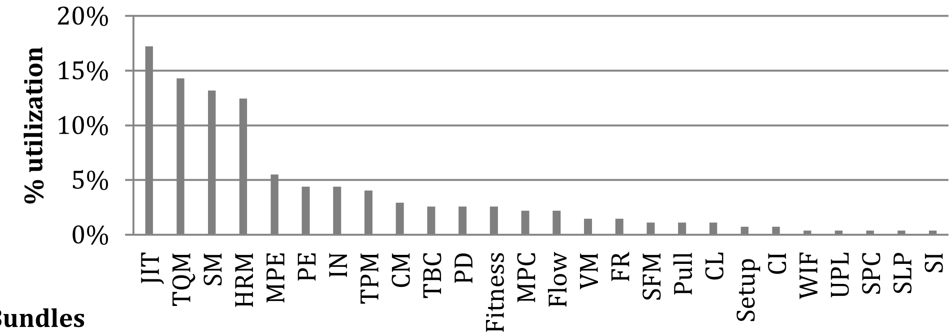

Figure 1 Pareto analysis of lean bundles

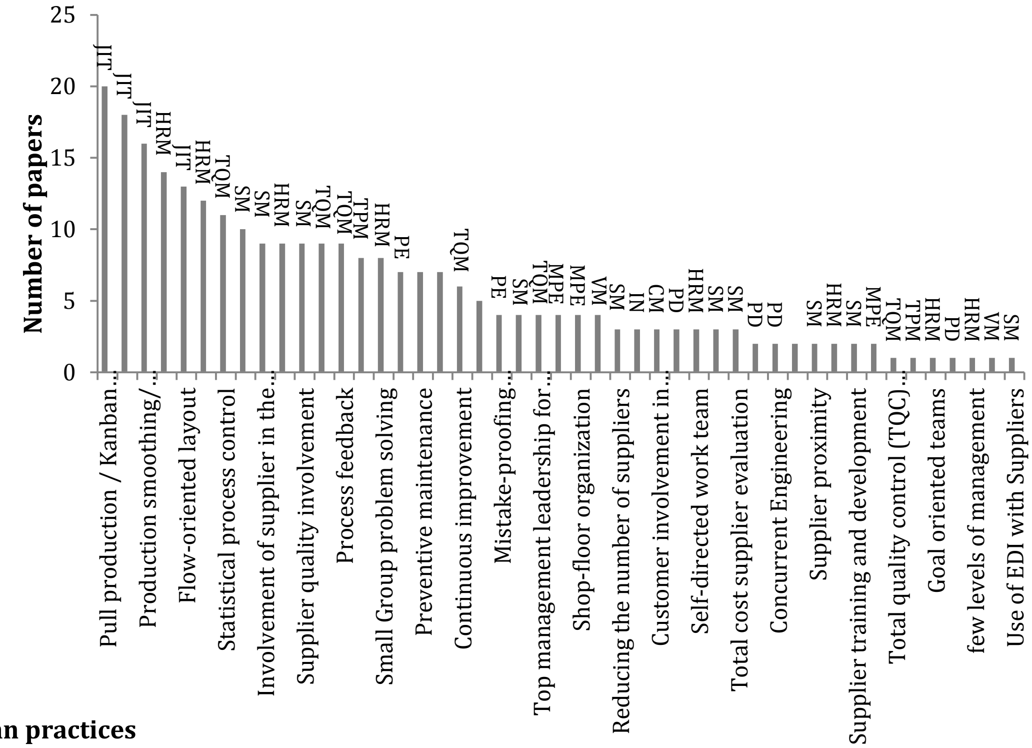

Figure 2 Pareto analysis of lean practices

2.1.3 A model of lean practices responsiveness: Theoretical foundation

Having reviewed the most relevant literature on LM and operational responsiveness, a research model was then developed with the aim to investigate the possible relationships between the following factors: 1) Lean Practices and bundle of lean practices, 2) Product Mix variety, 3) Product Innovation, 4) Time Effectiveness and 5) company growth performance.

In literature, there are many studies demonstrating that LM implementation has a positive influence on company performance (Bortolotti et al., 2015a, 2015b; Evangelos Psomas et al., 2014; Shah and Ward, 2003). Lean practices can be evaluated as noteworthy, based on the significant returns they generate via operational effectiveness and cost savings (Mackelprang and Nair, 2010). Cost efficiency and time effectiveness are the primary performance outcome associated with leanness (Narasimhan et al., 2006; Rachel Mason- Jones et al., 2000; Shah and Ward, 2003; Towill and Christopher, 2002). Indeed, according to Womack et al. (1990), most lean programs focus on reducing waste and non-value adding activities, emphasizing performance improvements in the areas of cost efficiency, conforming quality and productivity, and reducing inventory and throughput time. Instead, the operational responsiveness emphasizes the capacity to respond to a wide ranges of quantities demanded, to meet short lead time, to handle a large variety of products, to build highly innovative products and to meet a very high service level (Chopra and Meindl, 2004).

Considering the ever-changing dynamics, competition on a global scale (Simchi-Levi et al., 2012) and the increasing interests of companies in lean practices, it is essential to analyse the relationship between lean best practices implementation and the operational responsiveness. Indeed, the study of Qrunfleh and Tarafdar (2013) analyses the relation of lean and agile supply strategies and the supply chain responsiveness in USA manufacturing firms. The results of this analysis demonstrate that a company that focuses only on waste elimination without considering the deployment of appropriate resources would not achieve benefits in terms of responsiveness (Sufian Qrunfleh and Monideepa Tarafdar, 2013). In that case the supply chain responsiveness has been considered through a unique variable.

In a context of increasing volatility, global competitiveness and sales crisis, it would be essential to define the reason of the discordance between the techniques focus on waste reduction and the operational responsiveness requested by the market.

Hence, through the Italian sample the aim of this thesis is to analyse the reason of this failure relation. The goal is reached splitting the variable responsiveness, as illustrated in section 2.1, into 3 factors (Product Mix variety, Innovation, Time Effectiveness).

Leanness requires elimination of all forms of waste, including time, and allows enhancing manufacturing and management productivity (Narasimhan et al., 2006; Shah and Ward, 2003). Indeed a time-compression strategy allows companies to effectively compete on waste elimination reducing manufacturing time and inventory (Narasimhan et al., 2006; Ugarte et al., 2016). In consequence, a reduction of the mean time to stock and response time to customer and, a growth in the Inventory turnover is obtained.

Moreover lean practices are useful even for providing support to solve some innovative problems in the business process (such as new product development), in order to fulfill customer expectations (Camacho-Miñano et al., 2013; Johnstone et al., 2011; Yang et al., 2011a). Indeed waste in innovation and in new product development processes can be detected and reduced in the same way as waste in manufacturing, creating enormous potential savings. Reinertsen and Shaeffer (2005) highlight how low-cost, rapid cycles of learning achieved through lean improvements can directly reduce risk aversion and enhance innovation because the cost and consequences of a negative outcome are reduced. Byrne et al. (2007) examined the innovation performance of several firms that had adopted a lean strategy and come across that the most successful companies were those that had deliberately extended lean principles into their innovation agenda and had used it to enable breakthrough innovations and, importantly, change the culture towards one that supported continual innovation.

But if time effectiveness and innovation are commonly associated with lean (Narasimhan et al., 2006; Rachel Mason- Jones et al., 2000; Shah and Ward, 2003; Towill and Christopher, 2002) we considered the product mix variety as a possible critical factor in the research model.

Indeed, Just-In-Time practices were firstly developed in Toyota in a high repetitive production system, and for years researchers considered this methodology applicable only in contexts with repetitive manufacturing systems. Moreover in literature the majority of successful lean application came from repetitive contexts, where products are standardized and customer demand is stable and predictable (Jay Jina et al., 1997; Lander and Liker, 2007). Indeed non-repetitive contexts, with demand fluctuations, dynamic takt time and a high product variety inhibit production smoothing and make lean implementation critical (Andreas Reichhart and Matthias Holweg, 2007; Lander and Liker, 2007).

But some authors have denied this view, providing descriptive and anecdotal case studies where Lean practices have been implemented successfully also in non-repetitive contexts (Crute et al., 2003; Lander and Liker, 2007; White and Prybutok, 2001).

Prybutok and White (2001), demonstrated that JIT is applicable in repetitive and non-repetitive companies, even if some techniques are less frequently applied in non-repetitive manufacturing systems, and that performance improvements are more evident in a repetitive environment.

Crute et al. (2003) describe an example of Lean application in the aerospace sector, characterized by low volumes and Make to Order production systems. The authors affirmed that low volumes facilitate the implementation of Lean practices because the production system is naturally closer to the concept of one piece flow, and Make to Order systems follow a pull logic.

But, more recently, Bortolotti et al. (2013) identified a gap in literature, where there is the lack of studies based on a large sample, which analyse Just-In-Time impact on performance at varying degrees of repetitiveness. Data from a sample of 244 plants, analysed using a structural equation modelling (SEM) procedure, demonstrated that demand variability reduces (negatively moderates) the positive effect of Just-In-Time on operational responsiveness.

Therefore, we assume that lean practices implementation has a positive relationship with Innovation and Time effectiveness, but a negative relationship with product mix variety. Hence hypothesis H1a, H1b and H1c have been developed:

H1a: Lean practices implementation has a negative impact on product mix variety.

H1b: Lean practices implementation has a positive impact on product innovation.

H1c: Lean practices implementation has a positive impact on time effectiveness.

Markets today are increasingly volatile and therefore are less predictable. Many authors sustain that to be competitive and successful organisations need to be agile in response to market demand (Kisperska-Moron and de Haan, 2011). A lot of previous research exposed significant evidence related to lean practices and companies performance (Bortolotti et al., 2015a; Evangelos Psomas et al., 2014; Narasimhan et al., 2006; Shah and Ward, 2003). Indeed, the application of LM practices increases the manufacturing productivity by reducing setup times and work in process inventory improving throughput times, and thus improving market performance (sales and market share variation in the last 3 years) (Tu et al., 2006).

The use of bundles of manufacturing practices (e.g. JIT or TQM) in the manufacturing strategy framework represents both decisions and actions and many empirical articles investigate relationships involving different practices. Konecny and Thun (2011) find that while the adoption of TQM and TPM bundles individually improves plant performance, their conjoint implementation does not provide additional performance benefits. Furlan et al. (2011) detect synergy between JIT and TQM bundles for firms that also implement human resources related lean practices. Bortolotti et al. (2015b) argued that TQM lean practices is indirectly related to cost performance because there is less of a need for inventories to protect the production system against external variance (Khim Ling Sim and Anthony P. Curatola, 1999) and less invested in scrap and rework.

Moreover, involving supplier management lean practices in company strategy improves raw material quality conformance, thus reducing the time dedicated to quality inspections (Romano, 2002) and rework.

LM positively influences even the firm's financial performance (returns on sales and returns on investments) through improving organizational processes, cost efficiencies (Christopher and Towill, 2000; Fullerton et al., 2003; Rosemary R. Fullerton and William F. Wempe, 2009) and labour and asset productivity (Kinney and Wempe, 2002).

Furthermore, LM achieves better customer service levels and higher profit margins increasing customer responsiveness, reducing customer lead time, improving customer value in terms of lower prices and quality products and innovating problem solving in business processes (e.g., new product development, order fulfilment, customer services) (Camacho-Miñano et al., 2013; Shah and Ward, 2003; Yang et al., 2011a; Zhou, 2012).

Thus, having described the firm growth performances through the Employee growth variation in the last 2 years, the Sales growth variation in the last 2 years and the Customer Retention in the last 2 years, we hypothesize a positive relationship between the four impact areas of lean best practices and the company's growth performance.

H2a: HRM Lean practices positively influence the company's growth performance.

H2b: TQM Lean practices positively influence the company's growth performance.

H2c: SM Lean practices positively influence the company's growth performance.

H2d: JIT Lean practices positively influence the company's growth performance.

Company performance refers to how well a company achieves its market-oriented and financial goals (Li et al., 2005; Sufian Qrunfleh and Monideepa Tarafdar, 2013; Yamin et al., 1999). Wu et al. (2006) argue that higher levels of capabilities (responsiveness, information exchange, coordination and interfirm activity integration) can potentially improve a firm's market and financial performance. Furthermore, Birkinshaw et al. (2008) advocate how “management innovation” can improve the future productivity unlike product or process innovation. Indeed, investing in R&D processes to create knowledge and generate innovation is particularly relevant for firms competing in today’s context of ever-changing dynamics and competition on a global scale (Lewellyn and Bao, 2015).

Moreover, in a study of Inman et al. (2011) they demonstrated how agile manufacturing positively influences the financial performance of a firm. Indeed, using an agile manufacturing business becomes more flexible in terms of product models and configurations by quickly responding to change in customers and the capacity to get new products to market quickly. As sustained by Goodman et al. (1995) and Choi and Krause (2006) responsiveness is an advanced level of flexibility to meet customer and market requirements. Liao et al. (2010) through a structural equation modelling suggest that the higher the flexibility of the firm, the better it is at enabling the focal firm to adapt to changes in the market.

So, in light of the previous consideration we linked responsiveness factors to company growth performance and, in particular, we assume that *Product Innovation, Time effectiveness* and *product mix variety* have a positive effect respectively on company growth performance. Hence hypothesis 3a, 3b and 3c have been developed:

H3a: The company growth performance is positively influenced by the Product mix variety latent variable.

H3b: The company growth performance is positively influenced by the Product *innovation latent variable.*

H3c: The company growth performance is positively influenced by the Time effectiveness latent variable.

The hypothesized research model is shown in Figure 3.

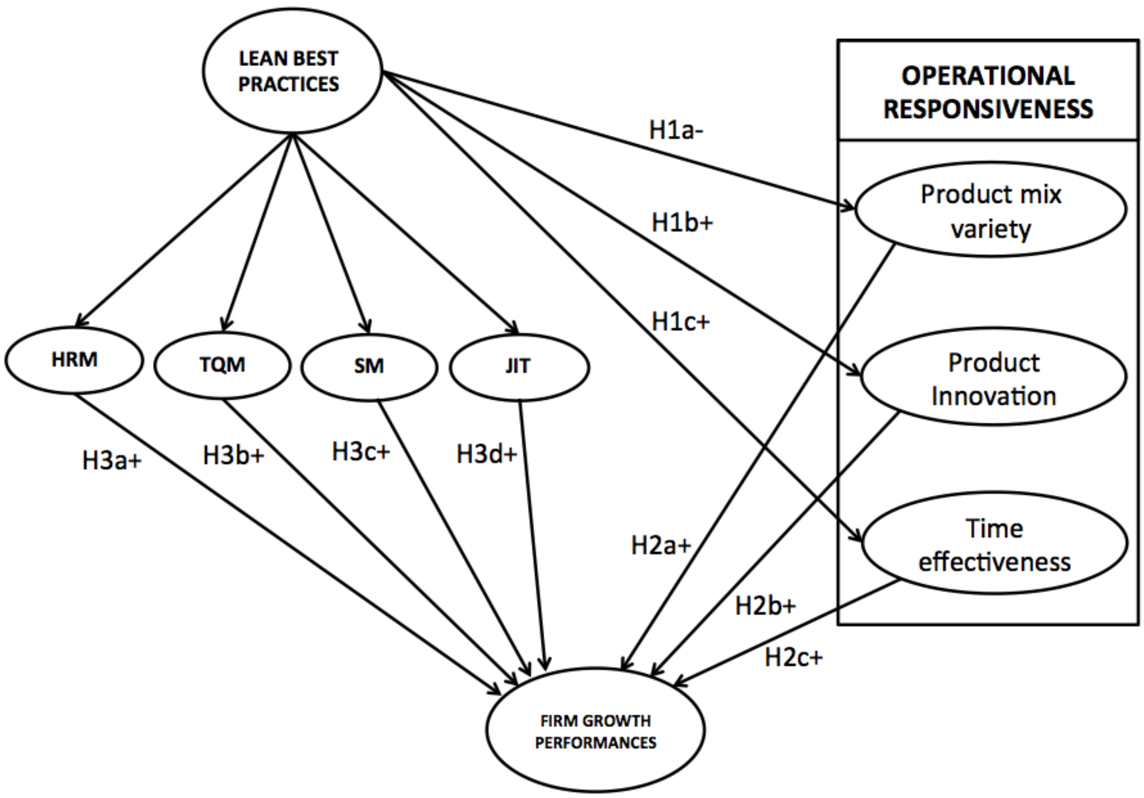

Figure 3 Research model linking lean best practices, operational responsiveness and firm growth performances.

2.2 Lean difficulties review

Literate lacks of a synthetic and efficient classification of Lean barriers. Indeed the limited number of articles that face the Lean barriers topic do not classified them in an efficient way. Recently Albliwi et al. (2014) analysed 34 common failure factors for Lean Six Sigma implementation. Bhasin (2012) classified 15 categories of lean difficulties in UK companies like so Jadhav et al. (2014) that identified 24 groups of barriers. Hence, due to the multi-disciplinary aspect that LM involves, barriers in literature have been traced back to 4 categories: Strategic, Economic, Supply Chain integration, Human and Cultural Barriers.

To that end, a systematic literature search was conducted according to the steps explained in table 1. Keywords such as: “Lean Difficulties”, “Lean barriers”, “Lean Manufacturing obstacles”, “Just in Time barriers”, “Just in Time difficulties”, “Just in Time obstacles”, “Lean management”, “Lean start-up/ sustaining phase”, “Strategic barriers/ difficulties/ obstacles”, “Economic barriers/ difficulties/ obstacles”, “Supply Chain integration barriers/ difficulties/ obstacles”, “Human barriers/ difficulties/ obstacles”, “Cultural barriers/ difficulties/ obstacles” and “national culture barriers/ difficulties/ obstacles” were used for the step 2 of the structured literature review. At the end of step 4, 40 papers were defined as relevant for this literature review study.

The analysis of these articles allowed us to define for each barrier (strategic, economic, supply chain integration, human and cultural) the factors to take into account. Moreover, we’ll consider lean barriers in the first phase of the LM journey and on the sustaining phase.

2.2.1 Strategic Barriers

The development of a detailed strategic planning is a critical issue for LM. It's unthinkable to implement and sustain big changes without a strategic planning (Jadhav et al., 2014). In the study of Albliwi et al.(2014), a weak link between the continuous improvement projects and the strategic objectives of the organization has been allocated as the fourth critical failure factor. Indeed, an effective roadmap, to start a lean project and to guide its implementation in the successive steps, is fundamental (Bhasin, 2012b; Kwak and Anbari, 2006; Saja Albliwi et al., 2014). In the preparation phase of a lean project, department, division, and processes should be selected and the goals of the project formulated (Pedersen and Huniche, 2011). Lack of awareness about the benefits and the need of lean projects leads managers to set unclear goals and strategic plans for the new improvements (Anand and Kodali, 2009; Saja Albliwi et al., 2014).

Another strategic barrier that may lead to lean failure is the possible incompatibility of lean with the organizational bonus, rewards or incentive system (Upadhye et al., 2010). Poor incentive and rewards systems fail to motivate employees to implement and sustain lean (Jadhav et al., 2014; Upadhye et al., 2010).

Moreover, some authors (Karim and Arif-Uz-Zaman, 2013; Saja Albliwi et al., 2014) observed that many firms have failed to obtain any benefits from Lean implementation due to the unclear managers' understanding of Lean performance and how to measure the performances.

2.2.2 Economic Barriers

Cost and time required for LM programs could be another reason for the low level of LM implementation (Jadhav et al., 2014). A survey conducted by Pinto et al. (2008) in 1,000 large Brazilian organizations showed that the most common reason for quality improvement programs' failure is a shortage of financial resources, especially for the large investment needed for white-collared and blue-collared workers' training. If there are economic problems in large organizations, these are even more evident in SME (Achanga et al., 2006). Indeed, financial, technical, and human resources are required for an effective and successful LM implementation (Jagdish R. Jadhav, Shankar S. Mantha, and Santosh B. Rane 2014; Eswaramoorthi et al. 2010; Alessandro Laureani and Jiju Antony 2012).

A study made by Chakrabarty and Chuan (2009) in service organizations explains that companies are frequently forced to hire part-time employees due to lack of resources, which makes sustainability of improvement programs much more difficult to achieve. Indeed, it is widely recognized that if starting a lean project requires a considerable financial effort, the sustaining phase is even more critical (Eswaramoorthi et al., 2010; Jadhav et al., 2014; Sabri and Shaikh, 2010; Saja Albliwi et al., 2014).

Moreover, companies often find that lean changes are so significant that it's necessary to hire outside experts to successfully shift to lean (Jadhav et al., 2014; Tracey and Jamie, 2006). A lean sensei helps managers in the first phase to develop their own lean thinking through practical hands-on exercises on the shop floor and to monitor the correct lean shifting in the successive phases (Jones, 2014; Womack et al., 1990).

In addition, another financial effort that firms should face in the LM program is the improvement of facility layout and the modernization of plants and equipment. Preventing the executive managers from modifying plant configuration and investing in new necessary machinery will bring about many deteriorating effects, such as high material handling costs, excessive work-in-process inventories and low or unbalanced equipment utilization (Helena Boarin Pinto et al., 2008; Jadhav et al., 2014; Wong and Kuan, 2011).

2.2.3 Supply Chain integration Barriers

Supplier chain integration also plays a vital role in supporting LM (Bortolotti et al., 2016; Chavez et al., 2015; Shah and Ward, 2007a). It is important to establish clear and effective channels for communication upstream (suppliers) and downstream (customers) (Bhasin, 2012b; Chavez et al., 2015; Jiju Antony et al., 2007; Saja Albliwi et al., 2014; Scherrer-Rathje et al., 2009; Worley and Doolen, 2006). Poor information flow with stakeholders is one out of ten reasons for poor lean sustainability identified by Hines et al. (2011). Even the firms' structure can contribute to creating barriers in communication, as supplier management department may have no or little interaction with the rest of the organization (Cudney and Elrod, 2010; Jadhav et al., 2014). A cooperation between suppliers and manufactures allows companies to reduce inventory level, improve lead time reliability, scheduling flexibility, quality and customer satisfaction (Jadhav et al., 2014; Shah and Ward, 2007a).

Some other factors should be included in the supply chain integration barriers. The distance between the facility and the supplier may impact the level of inventories (Harris et al., 2010). New suppliers and short-standing relationships may be another barrier in implementing and sustaining LM (Comm and Mathaisel, 2000). In the sustaining phase of a lean project, providing material on-time-in-full delivery in the right place and at the right price plays a vital role (Harris et al., 2010; Jadhav et al., 2014; Shah and Ward, 2007a).

Moreover, in order to ensure efficient delivery and pick-ups in the start-up and sustaining phase of a lean project, partnership or closer relations with carriers and logistics providers are advisable (Hines et al., 2011; Jadhav et al., 2014).

2.2.4 Human Barriers

LM is not just about tools and technique, but it is above all about people (Bhasin, 2012b; Jadhav et al., 2014; Wincel, 2013) and changing the workers' mind-set. Indeed, the Lean Enterprise Institute web surveys (Wroblewski, 2007) stated that backsliding to the old ways of working was the most important factor contributing to the lean failures. Resistance to change is a natural tendency of human beings, and very few people dare to come out of their comfort zone (Eswaramoorthi et al., 2010; Jadhav et al., 2014).

A study made by Sohal and Egglestone (1994) shows that human resistance arises at every company level, including senior managers, middle managers and shop floor personnel. However, in order to successfully start a lean project and to avoid its failure in the successive steps, managers should support the Lean teams (Jadhav et al., 2014; Saja Albliwi et al., 2014). Managers should also be perseverant in supporting changes, contrasting the natural propensity to revert to original practices (Wong and Kuan, 2011). Scherrer-Rathje et al. (2009), by describing in detail two lean implementation projects, stress the importance of management commitment and highlight the necessity of starting project top-down. Indeed, if it is initiated bottom-up, it needs too many resources to achieve goals, and the goals will not be noticed. The lack of senior management commitment and interest in lean also means that employees who take part in the lean changes are not motivated and consider this project as only one out of many projects going on at the same time (Scherrer-Rathje et al., 2009). Moreover, employees' reluctance to LM projects might depend on fear factor. LM is about eliminating non-added-value activities, so employees are scared that it could lead to staff reduction (Jadhav et al., 2014; Wong and Kuan, 2011).

Antony et al. (2007) believe that a lack of communication is one of the major problems facing organizations and leading to LM failure. It is important to establish clear and effective channels for communication at all organizational levels to ensure the engagement of all the team members in the improvement projects (Bhasin, 2012b; Jiju Antony et al., 2007; Saja Albliwi et al., 2014; Scherrer-Rathje et al., 2009; Worley and Doolen, 2006). Villalba-Diez and Ordieres-Merè (2015), in order to foster efficient and effective communication between processes in a manufacturing organization, proposed a standardization model of inter-process communication that increases manufacturing operational performance.

Management should motivate and involve people in the lean journey, empowering them to make decision without having to follow the normal decision-making procedure (Bortolotti et al., 2015a; Jadhav et al., 2014). Scherrer-Rathje et al. (2009) affirmed that lack of team autonomy and lack of organizational communication lead to the termination of lean project. Indeed, employees' empowerment improves performance because it fosters communication and openness. It allows employees to make independent decisions irrespective of their hierarchical level in the organization, and it improves motivation and morale (Jadhav et al., 2014; Naor et al., 2010; Saja Albliwi et al., 2014; Scherrer-Rathje et al., 2009). Management domination and control of the workplace does not help to sustain a lean transformation (Jadhav et al., 2014). Strong cooperation and mutual trust between the employees and management is a prerequisite to creating an atmosphere suitable for sustaining LM (Wincel, 2013).

2.2.5 Cultural Barriers

Other challenges are related to the cultural aspects. It is not easy to change the culture in any organization, and it could take years to do so. Changing the culture of an organization means changing workers' habits, attitude, and mentality to build a culture of confidence and trust (Saja Albliwi et al., 2014). Moreover, many problems may occur in early phases, while others may remain unnoticed and may manifest themselves in later phases (Xue et al., 2005). Hence, sustaining lean initiatives through intellectual support and physical engagement is fundamental (Eswaramoorthi et al., 2010; Jadhav et al., 2014; Saja Albliwi et al., 2014; Wroblewski, 2007). Even if participating in training courses seems tedious as they are considered as time-wasting (Anand and Kodali, 2009; Saja Albliwi et al., 2014; Uche Nwabueze, 2012), an adequate education and training is vital for motivating individuals to overcome resistance, and educating senior managers, employees, and customers on the benefits of the lean concept (Kwak and Anbari, 2006; Laureani and Antony, 2012). Poor lean concept education is one of the reasons for low level lean implementation (Eswaramoorthi et al., 2010; Jadhav et al., 2014; Saja Albliwi et al., 2014).

Moreover, it is important to develop a training roadmap in order to determine who in the organization needs to know what, to establish how the training will be delivered, how facilitators can turn training into true learning, and where to find necessary resources (Houshmand and Jamshidnezhad, 2006). Indeed, lack of training road map hinders the improvement process (Jadhav et al., 2014).

As mentioned earlier, sometimes it is necessary to employ outside experts to successfully shift to lean (Jadhav et al., 2014; Tracey and Jamie, 2006). Sometimes, though, it is difficult for employees to accept external experts, thus posing another barrier to take into account in the start-up and sustaining phase.

The formation of cross functional groups, where people with different functional expertise work toward a common goal, it's absolutely critical to implement and maintain a lean culture ("Articles On Lean Manufacturing, Lean Management, & More," 2016; Jadhav et al., 2014)**.** It has been recognized that in order to effectively reduce wastes and improve overall equipment effectiveness (OEE), cross-functional team working and hence a combination of skills and knowledge, is necessary (Bamber et al., 2003). Many other authors (Bortolotti et al., 2015a; Cua et al., 2001; Shah and Ward, 2007a, 2003) emphasize the importance of human-related practices in conducting continuous improvement programs, such as small group problem-solving, and employee training. LM encourages teamwork and promotes collaborative relations between individuals (Naor et al., 2010), whereas lack of teamwork promotes individual goals and interests and neglects group goals (Wincel, 2013). Moreover, although benefits are reached, they are frequently not communicated effectively at all levels of the organization. Thus, employees in manufacturing and other functional areas are not aware of the success of the project and, as a result, little support is given to them (Scherrer-Rathje et al., 2009; Worley and Doolen, 2006).

2.2.6 National Culture

Kull et al. (2014) support the theory that a nations culture may moderate LMs effect on operating performance. In their works, they show which specific cultural values are incongruent with LM's practices. Indeed, national culture values lead members in different cultural contexts to implement and use management practices differently (Ferreira et al., 2012; Xue et al., 2005), sometimes in ways that support the practice and sometimes not. Data from the GLOBE national culture study have been used. GLOBE (Global Leadership and Organizational Behavior Effectiveness Research Project) is an international group of social scientists and management scholars who study cross-cultural leadership (House et al., 2004). This international team collected data from 17,300 middle managers in 951 organizations and grouped 62 countries into ten geographic clusters (Anglo, Latin Europe, Nordic Europe, Germanic Europe, Eastern Europe, Latin America, Middle East, Sub-Saharan Africa, Southern Asia, Confucian Asia). They analyze similarities and differences between cultural groups and make meaningful generalizations about culture and leadership. Moreover, the research identified nine cultural competencies that distinguish approaches to leadership: Assertiveness (A), Future orientation (FO), Performance Orientation (PO), Human Orientation (HO), Gender Egalitarianism (GE), In Group Collectivism (GC), Institutional Collectivism (IC), Power Distance (PD), and Uncertainty Avoidance (UA).

A is defined as the degree to which individuals in organizations or societies are assertive, confrontational, and aggressive in social relationships (House et al., 2004).

FO refers to the level of importance a society attaches to future oriented behaviors, such as planning and investing in the future, and delaying gratification (House et al., 2004). Cultures with high FO prefer strategic thinking, encourage knowledge acquisition, develop long-term objectives, and accept flexible organizational structures (Kull and Wacker, 2010).

PO refers to the extent to which an organization or society encourages and rewards group members for performance improvement and excellence (House et al., 2004).

HO means the degree to which an organization or society encourages and rewards individuals for being fair, altruistic, friendly, generous, caring, and kind to others (House et al., 2004).

GE is the degree to which a society resorts to role differentiation and gender discrimination (House et al., 2004).

GC refers to the degree to which individuals express pride, loyalty, and cohesiveness in their organizations or families (House et al., 2004).

IC means the level to which a society encourages institutional or societal collective action(House et al., 2004).

PD is the degree to which members of an organization or society expect and agree that power should be unequally shared (House et al., 2004).

UA is the level to which a nation relies on given procedures and establishes norms to reduce unpredictable events.

Moreover, GLOBE study assigns different values of cultural competencies to the ten geographic clusters (House et al., 2004). Anglo countries are competitive and result-oriented. Confucian Asia is result-driven and encourages groups working together over individual goals. Eastern Europe is forceful and supportive of co-workers. Germanic Europe values competition and is more result-oriented. Latin America's society is loyal and devoted to their families and similar groups. Even Middle East is devoted and loyal to its own people but women are given a lower status. Latin Europe values individual autonomy. Nordic Europe gives high priority on long-term success and women are treated with greater equality. Southern Asia has a strong sense of the family and deep concern for their communities. Sub-Sahara Africa is sensitive to others and demonstrates strong family loyalty.

Even if in other studies, HO, GD, GC, and IC are supposed to positively influence the lean effectiveness (Yauch and Steudel, 2002), Kull et al. (2014) found them irrelevant. Indeed, they found that high UA, low A, low FO, and low PO are the four cultural conditions where lean is most effective.

2.2.7 Lean Management: Hard and Soft Lean practices

In section 2.1.1 a literature review has been carried out in order to identify the most important lean practices and bundles. After, we reduce multiple items into a smaller number in order to represent each of them as a latent variable or a factor (HRM, TQM, SM, JIT).

Using the lean practices selected in section 2.1.2 for this second part of the analysis we decided to describe the lean implementation through 2 latent variables: the human aspects, such as leadership and people management; and the technical system or into the "soft" and "hard" parts.

In literature, there is a general agreement on the need to measure practices related to people management and customer focus as soft factors and on the use of practices related to measurement, process management, tools and techniques as hard factors. Bortolotti et al. (2015a) presented a collection of lean practices and, in line with previous studies, they classified practices into hard (HLP) and soft lean practices (SLP). These include the technical and analytical tools introduced in the firm to improve production systems (e.g., statistical process control, Kanban, SMED etc..) in the HLP, and, practices related to principles, managerial concepts, people and relations in SLP (e.g., continuous improvement, training employees, customer and supplier involvement).

Bortolotti et al. (2015a) stressed the importance of applying SLP for a successful LM implementation. Indeed, companies frequently make an extensive use of HLP and they don't pay particular attention to SLP. The reason may lie in the fact that companies have not fully understood what LM exactly means or, in order to conform with competitors, they adopt tools that are clearly "visible" (such as hard practices) disregarding the importance of SLP, which are intangible and apparently don't modify the facade of the company. Another reason could be that companies are pressured by customers to adopt LM because they want to receive JIT deliveries by their suppliers. Thus, they don't care about SLP because these practices are perceived as something not fundamental to comply with customer requirements (Danese et al., 2012). However, according to several authors (Bhasin, 2012b; Jadhav et al., 2014; Wincel, 2013), Lean is not just about the tools and techniques; at its heart there are the people.

Hence the national culture and the main lean barriers in the start up and sustaining phase will be related to two latent variables representing the level of hard and soft lean practices.

2.2.8 Lean barriers research model

Hence, through this second part of the thesis we want to investigate the inter-correlation between all the aspect that could influence and affect a successful LM implementation in the start up and sustaining phase of a lean project.

In addition to lean barriers, the level of Hard and Soft lean practices implementation and the national culture, other aspect should be taken into account as mentioned in the introduction.

Company size is a factor that could affect a successful lean implementation.

Achanga (2006) identified critical factors that determine the success of implementing the concept of lean within SMEs. Indeed, large firms are more prone to implementing new operational practices than smaller ones. Even if large organizations suffer from structural inertial forces (Hannan and Freeman, 1984) that negatively affect LM, the availability of both capital and human resources facilitates the adoption and the implementation of lean practices as well as returns to scale for investments associated with lean practices (Shah and Ward, 2003). In addition to company size some studies sustained that the environmental complexity and dynamism undermines the effectiveness of lean operations, making it difficult to synchronize the production process and reduce the inventory (Azadegan et al., 2013; Bruce et al., 2004; James- Moore and Gibbons, 1997).

Finally the wealth of the country where the company is located, and the sector of the firm are other 2 factors that should be analysed (Dahlman, 2007).

Thus, a research model reported in Figure 4 has been developed, taking into account the following aspects: the national culture, the level of Hard and Soft

Lean practices implementation, the lean difficulties in the sustaining and start-up phase, the firm dimension, the firm environmental variability, the firm environmental complexity, the sector and the richness of the country where the firm is located.

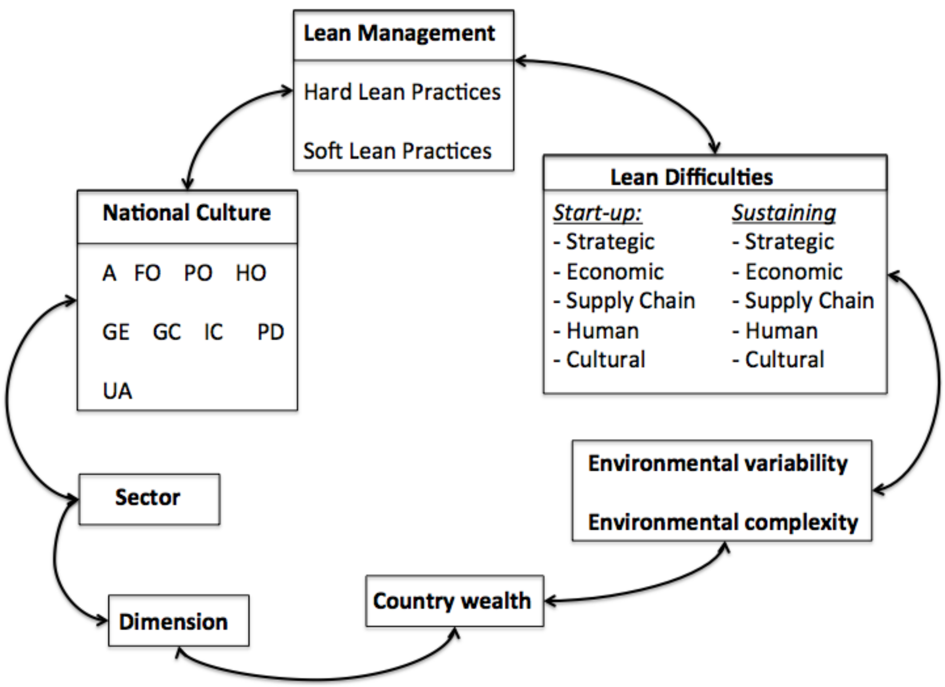

Figure 4. Lean difficulties research model.

2.3 Knowledge sharing in Lean organizational network

A growing complexity of value chain network due to pressing product life cycle cost, time-to-market requirements and rising product complexity are some of the environmental forces acting upon manufacturing organizations. When structural complexity increases, organizations tend to develop interfaces between processes in order to make information readily available for process owners (Durugbo et al., 2013). Indeed knowledge sharing between the personnel is the fundamental means through which employees can contribute to knowledge application, innovation, and ultimately to the competitive advantage of the organization (Susan E. Jackson et al., 2006; Wang and Noe, 2010). A research developed by Wang and Noe (2010) has shown that knowledge sharing is positively related to reductions in production costs, faster completion of new product development projects, team performance, firm innovation capabilities, and firm performance including sales growth and revenue from new products and services. Villalba-Diez and Ordieres-Merè (2015) stressed the importance of an effective and efficient communication between processes. They defined a standardized way of interchange information between processes through an evolution of Deming cycle ($(CPD)_nA$ - Check Plan Do n times and Act).

The $(CPD)_nA$ is composed by 5 main phases where the current state of processes are first understood, in order to systematically eradicate the biggest constraint that hinders the process achieve better performance (Villalba-Diez and Ordieres-Meré, 2015). In the Check phase, the process at Gemba is studied, a key performance indicator (KPI) for the sender Process Owner that measures process performance is decided and the current state of this KPI is measured. After in the Plan phase the current state of the process is understood through a process-mapping tool, the main sources of MUDA, MURA, and MURI are prioritized and finally, the main source of wastes within the process boundaries are analysed. The first 3 phases are repeated as often as is necessary. Finally, the Act phase is where fixing and transforming the active learning into organizational learning. Indeed, if the actions taken upon the process brought a positive effect in the KPI, these changes in the process will be incorporated into the new current state, becoming the new standard, understood as the best-known way to perform the process. If the action upon the process delivered no results, then the standard is not changed. It is the responsibility of the receiver process owner to ensure that the sender process owner performs the process following the standard.

Villalba-Diez and Ordieres-Meré (2015) demonstrated how the implementation of a standardized way of interchange information ($(CPD)_nA$) impacts on manufacturing operational performances.

Indeed, the use of formal and informal social networks in an organization, has received growing attention in the last years (Chiu et al., 2006; Cross and Parker, 2004) as the information flow and having a good organizational network has several positive effects on firms' productivity. Good local interactions create a global outcome that no one could accomplish alone (Greve et al., 2010).

As a direct consequence, organizations are interested in using social networks to promote collaborative working groups, to diffuse innovations, to foster the sharing of information and knowledge and to meet their business needs.

The interest in working with Lean oriented organizations is mainly because, as described in important studies (Shah and Ward, 2007), they have the "main objective of minimizing internal organizational variability." Therefore, this objective is rather coherent with the resilience property we are interested in. It is relevant to highlight the focus is resilience, neither robustness nor responsiveness.

Robustness is a structural performance requirement in most designs. While robustness enables system to cope with accidental actions, resilience appears to be a broader concept seeking the system to address/mitigate the consequences of failure and recover its former capabilities (Wang et al., 2012). Obviously, responsiveness is a quality of system because of which the resilience matters, but as it is, the interest here is regarding the broader concept, i.e. the resilience.

2.3.1 Resilience in Lean organizational network

An exhaustive definition of Firm resilience in the enterprise context can be found in the study of Kamalahmadi and Parast (2016). They analysed more than 100 papers and developed the following definition: "*The dynamic capability of an enterprise, which is highly dependent on its individuals, groups, and subsystems, to face immediate and unexpected changes in the environment with proactive aptitude and thought, and adapt and respond to these changes by developing flexible and innovative solutions*".

Resilience can be built in firms through operational flexibility, like by building inter-operable standardized materials and processes, effective lean management, closeness of operations to demand via postponement, building efficiency through training programs, seamless integration of processes, concurrent engineering techniques, shortened lead times etc. (George & Everly, 2011; Pal et al., 2014; Sheffi, 2005b; Vogus & Sutcliffe, 2007).

In particular, Pal et al. (2014) highlighted five categories of resources (material/systems, finance, social, network, and goodwill) as essential contributors to resilience and hence to superior organizational performance. Moreover, in line with previous studies (Leiblein, 2011; Sheffi, 2005b), they affirmed that collaborative inter-organizational relationships and strategic alliances could help to transfer and exchange uniquely complementary sets of knowledge resources and relationships and hence offering greater agility and adaptability. Indeed, in accordance with other studies (Sheffi, 2005a) they emphasized the importance of human resources with requisite skills, people collaboration and proactive communication for higher organizational performance.

In addition, many other studies (Lengnick-Hall et al., 2011; McElroy, 1996) mentioned the important role of people communication, coalition and training in building a resilient firm.

But, resilience in enterprises is mainly measured by KPIs' trend against their stated objectives (Dalziell & McManus, 2004), neglecting the organizational structure and the process connection.

Otherwise when resilience is associated to network, network topology is taken into account.

Many studies developed interesting metrics for infrastructure network (Cox, Prager, & Rose, 2011; Matisziw, Murray, & Grubesic, 2008; Taylor, 2012). But even if nodes, links and network connectivity is taken into account, these quantitative approaches are limited in their usability and thus are not applicable outside the discipline where they have been developed.

More general approaches to network resilience have been developed by Najjar and Gaudiot (1990), who proposed a network resilience that provides the upper bound on the number of node failures allowed, and defined the maximum number of node failures that can be sustained while the network remains connected. Even Rosenkrantz et al. (2009) identified edges and nodes resilience of a network as the largest value of edges and nodes failure that can assure the resulting sub-network to be self-sufficient. Finally another interesting application of network resilience has been developed by Henry and Emmanuel Ramirez-Marquez (2012). They proposed a generic metrics and formulae for quantifying system resilience, taking as case study the network of Seervada Park. The disruption events considered are the abolishment of connection between two nodes. Hence, resilience has been considered as a time dependent function in the context of system. Where the system experiences three distinct states: original state (S_0), disrupted state (S_d), and recovered state (S_f).

Analysing quantitative metrics for companies (Dalziell & McManus, 2004; Henry & Emmanuel Ramirez-Marquez, 2012; Hosseini, Barker, & Ramirez-Marquez, 2016) and networks (Al-Ammar & Fisher, 2006; Hosseini et al., 2016; Omer, Mostashari, & Lindemann, 2014; B. Wang, Tang, Guo, Xiu, & Zhou, 2006) we realized that these metrics are not able to evaluate the local and global effect of the personnel relocation in organizations or the decrease of performances in a specific workstation.

2.3.2 Factors affecting resilience

Focusing on the local and global effect of the personnel relocation in organizations even if literature lacks of resilience metric calculation and evaluation, it is widely recognised that when an operator start working on a new project or process the performance of a worker is not at its best and the learning phenomenon takes place (Michel J. Anzanello, Fogliatto, & Santos, 2014; Michel Jose Anzanello & Fogliatto, 2011; Wright, 1936).

Indeed according to Alamri and Balkhi (2007), workers demand less time to perform a task as repetitions take place, either due to familiarity with the task or because shortcuts to task completion are discovered. Since Wright (1936) designed the “80% learning curve”, widely applied in aeronautical sector and with the aim of reducing cumulative assembly cost, a great number of researchers have tried to model and describe the human learning process.

Indeed the Log linear model of Wright (1936) has been modified and improved during the years, inserting working prior experience, the influence of machineries or the steady state of workers performance (1936). Other researchers modified the Log linear models in exponential LC relying on a more complete set of parameters and yielding a more precise estimate of production rate (Michel Jose Anzanello & Fogliatto, 2011; Knecht, 1974). Moreover Mazur and Hastie (1978) proposed a learning curve (LC) model relating the number of conforming units to the total number of units produced, which is represented by the 2-parameter hyperbolic curve.

Mazur and Hastie (1978) also proposed the inclusion of a parameter to allow considering worker's prior experience in executing the task (3-parameter hyperbolic LC).

Anzanello and Fogliatto (2007) evaluated the different LC models in literature and found out that the 3-parameter hyperbolic model is the most robust in terms of efficiency, stability, parsimony and ability to model scenarios with negative learning (i.e. forgetting).

The 3-parameter hyperbolic model is expressed in formula 1, where y represents the number of items produced in x units of operation time, k the maximum performance level, r the learning rate expressed as the time required to achieve a production equal to k/2 and p considers the worker's prior experience in executing the task.

$$\mathbf{y = k(\frac{x+p}{x+p+r})} \quad 1$$

Uzumeri and Nembhard (1998) applied the model to data from a population of workers submitted to new tasks. The authors proposed that, as fast learners (workers presenting low values of *r*) tend to achieve lower maximum performance *k* if compared to slow learners (workers presenting high values of *r*), fast learners could be allocated to short duration tasks, while slow learners should perform tasks of long duration, given their final performance.

Moreover because organizations consist of people, and because it is people, and only people, who can reach success or failure, the success of a company is determined by employees (Cowling, 1998). Indeed many studies demonstrated that a positive employees' work aptitudes have a favourable impact on firm's performance such as productivity, benefits, or client satisfaction (Clapp-Smith et al., 2009; Harter et al., 2002). Thus, in this context, considering the operators' aptitude plays a vital role.

Sure enough, optimistic and pessimistic employees will interpret the same situation very differently. Optimistic will welcome the challenge and enjoy being able to accept recognition from their results. Pessimist, on the other hand, will be preoccupied of incidents, failures or poor performance and thus impede their own growth opportunities demanding more structure and sureness in their work lives (Luthans, Avolio, & Youssef-Morgan, 2015).

In the actual environment optimism represent a fresh opportunity for a positive healthy and productive workforce that is also independent, change-embracing, and open to new ideas and workplace developments (Luthans et al., 2015).

Without an optimistic workforce, the chances of survival are considered ably diminished (Luthans et al., 2015). If, on the one hand, operators' aptitude depend on their personality on the other could be strongly influenced by leadership.

Indeed through an authentic leadership approach, managers are able to build trust and generating enthusiastic support from their subordinates, improving individual and team performance (Clapp-Smith et al., 2009).

Tangirala et al. (2007), using data from 581 frontline nurses and 29 supervisors in a hospital, support the hypothesis that high leader-member exchange has a stronger positive effect on employees' aptitudes toward the organization and its customers. Indeed trust in management was found to mediate the relationship between positive psychological capital and performance and to partially mediate the relationship between authentic leadership and performance (Clapp-Smith et al., 2009).

Based on findings from the literature review, it is possible to highlight that if enterprise's resilience neglected the network's topology, the network's metrics considered the disruptive event mainly as an interruption of the connection between 2 nodes, omitting the possibility of a disruption event do not eliminate the linkages between two nodes. Even worse, there is not an easy way to estimate the internal resilience of an organization neither based on its own strategic process configuration nor by considering the effects of the attitude or skills specific process owners exhibit. Those aspects are going to be addressed in this third part of the thesis.

Chapter 3.

Research Methodology

As explained in the Introduction this thesis is mainly divided in 3 macro-areas with the common topic of Lean management. After an introduction and a literature review of the main concept involved in the research, this chapter explains in detail the methodology used for the 3 studies.

The four main steps (Data collection, model validation, model analysis, results) that constitute my researches have been illustrated in Figure 5. In particular, blue, green and yellow dotted lines highlight the tool used, for each one of the four phases, for the 3 studies: Lean implementation and operational responsiveness, Lean barriers and Lean Structural Network.

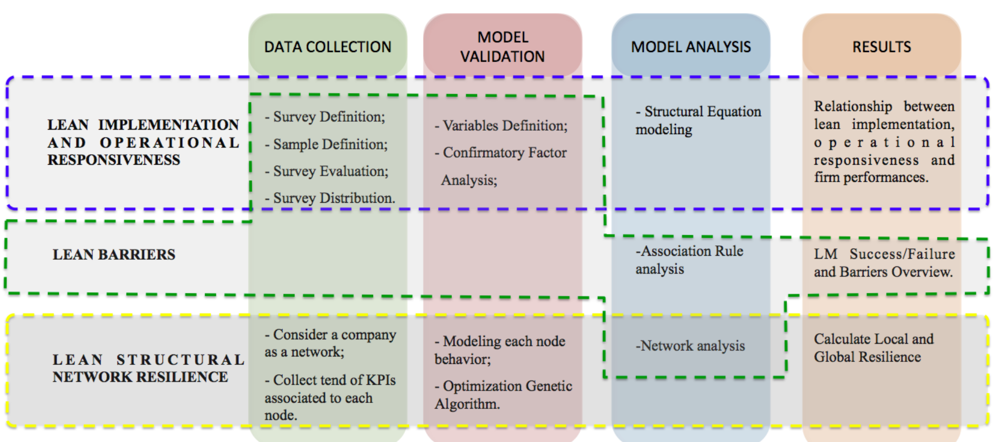

Figure 5 General methodology

3.1 Lean implementation, operational responsiveness and firms' growth performances methodology

3.1.1 Survey definition, evaluation and distribution

In order to respond to the hypotheses defined in section 2.1.3, a survey among Italian manufacturing companies has been carried out using the questionnaire reported in Appendix 1.The questionnaire was developed on the basis of the factors identified in section 2.1 and the research hypotheses explained in section 2.1.3.

It is structured in three sections; the first section is dedicated to enterprise information, the second to the operational responsiveness and growth performance and the third to lean practices implementation.

In particular, in sections 1 and 2 the internal context of the enterprise is studied. These sections include questions about the organization's size (OS_1; OS_2), company market share at European (MSE) and National level (MSN), the operational responsiveness and therefore the *time effectiveness* (TE_1;TE_2;TE_3), the *Product mix variety* (PM_1;PM_2;PM_3) and the *Product Innovation* (INN_1;INN_2), and information about the growth performance (GP_1;GP_2;GP_3).

In order to evaluate the company growth performance, its changes in both sales and employees have been evaluated. In addition to these performance values, customer retentions variation in the last 2 years has been considered an important company performance measure. The scale used for questions of the first section is a five points quantitative scale.

With reference to the third section of the questionnaire, the respondent was asked to define the implementation level of lean practices in the company belonging to the four different bundles (JIT, TQM, SM and HRM). The three most used lean practices were selected to operationalize each of the four bundles according to the analysis carried out in Figure . Section 3 of appendix 1 reports the final lean practices considered in the survey, specifying, for each practice, the related bundle.

In order to take into account the implementation levels of different possible practices, the scale adopted consists of the following seven points: (1) never heard/not implemented, (2) idea of implementation in some department, (3) start-up phase just started for some department, (4) started successfully for some department, (5) in use successfully for some department less than 1 year, (6) in use successfully for some department more than 1 year, (7) in use successfully to the whole system.

In order to evaluate the questionnaire, before distributing it, we involved some sample firms in July 2014 in order to get an early feedback. Moreover, a preliminary work was presented at the XIX Summer School Francesco Turco in order to receive suggestions from academics as well as to validate the initial survey. After these preliminary activities, the measurement items were modified, discarded or added to strengthen the construct and the content validity (Appendix 1). The distribution of the survey started in November 2014, and each individual in the sample was provided with a covering letter describing the survey and ensuring anonymity of response.

3.1.2 Sample Definition

As a sample of companies to be surveyed, the new ATECO 2007 classification of economic activities that ISTAT (Italian Statistical Authority) adopted since January 2008 has been considered. This classification is the national version of the European nomenclature, Nace Rev. 2, published in the Official Journal of 20 December 2006 (Regulation (EC) n. 1893/2006 of the European Parliament and of the Council of 20 December 2006). The analysed sample, used for the study, was extracted from the AIDA database, and the set of manufacturing companies belonging to Sector C of the ATECO 2007 Economic Classification was considered. This section includes the physical or chemical transformation of materials, substances, or components into new products, although this cannot be used as the single universal criterion for defining manufacturing. Substantial alteration, renovation or reconstruction of goods is generally considered to be manufacturing. Thus, with the aim of achieving as high a degree of generalization as possible for the results of this work, we aimed to survey companies of various sizes (small-medium-large) and those operating in all the industry fields belonging to the C sector (Burgess-Limerick et al., 1998).

The initial study sample consists of approximately 70,000 Italian manufacturing companies. Plants which have a turnover less than 5 million euros (micro enterprises) and which do not report their data have been excluded from the study. The final number of companies surveyed was 2,422. All these companies have been contacted since November 2014. In order to consider only firms that have started a Lean journey, an initial filter question in the survey asked if the company have ever applied some Lean Management/Manufacturing/production practices. If the answer was negative the survey finished and the company was excluded from the study.

Data was collected mainly from Lean Specialist and from manufacturing plant managers via e-mail and Internet-based survey methods, using a specially developed Internet-based questionnaire. Manufacturing plant managers were invited by e-mail to participate in the survey. The invitation letter contained the Internet address where the survey was hosted. Following the initial invitation, we sent two reminder e-mails at 2-week intervals. In some cases, follow-up phone calls were also made. A total of 254 completed surveys were returned.

3.1.3 Confirmatory factor analysis and structural Equation modelling

In order to validate the model a Confirmatory Factor Analysis (CFA) procedure was performed for all latent constructs using a pooled CFA. CFA models have been developed in order to check the model parameters fell within the recommended limits. Modifications were made to the models according to the guide provided by Hair et al. (2006). The modification procedure starts with a review of the factor loading of each item and removal of the items that do not exceed 0.5. It continues with a review of the standardized residual where the items with a value higher than 2.58 are dropped.

Once the latent constructs had passed the CFA stage, Structural Equation Modelling was developed which allowed researchers to explore the pattern of inter-relationships between variables through the creation of a measurement model and a structural model (Bollen, 1989; Pedhazur and Schmelkin, 2013).

There are a number of model fit indices but no single fit index seems sufficient for a correct assessment of fit in a CFA and SEM model. Indeed, researchers are advised to use a variety of fit indices from different families (Bentler, 1992; Marsh et al., 1988).

One of the most widely used fit indices is the model chi-square which tests the closeness of fit between the sample covariance matrix and the fitted covariance matrix (Jöreskog and Sörbom, 1993). A non-significant, small χ^2 value indicates that the observed data are not significantly different from the hypothesized model. However, a serious drawback is connected with this statistic. Since the formula for computing χ^2 is directly related to sample size, almost all models are evaluated as incorrect as sample size increases (Bentler, 1992). For this reason, the χ^2 is compared to the critical value from the chi-squared distribution with df degrees of freedom. If $\chi^2$is greater than critical χ^2, the model is considered to have a good fit. The χ^2 value is statistically significant only if the probability level is greater than 0.05.

Another widely used fit index is the root mean square error of approximation (RMSEA). Bryne (2013) asserts that RMSEA is one of the most informative criteria in covariance structure modelling. RMSEA is, according to MacCallum (1996), better than any other fit index where models are very parsimonious because RMSEA measures the lack of fit per degree of freedom. A value of RMSEA up to .05 indicates a good model fit; a value between .08 and 0.1 would indicate a reasonable error of approximation; and values greater than .10 indicate a poor model fit (Browne and Cudeck, 1992; Jöreskog and Sörbom, 1993) .

An additional group of fit indices that are commonly used includes the Bentler–Bonett normed fit index (NFI), the comparative fit index (CFI), the incremental fit index (IFI), and the Tucker Lewis Index (TLI). The NFI index compares fits of two different models (the hypothesized model and the null model) for the same data set; Bentler and Bonnet (1980) recommended accepting NFIs of .90 as indicative of a good fit. However Bentler (1992) revised the use of NFI and suggested the use of CFI, because NFI tends to underestimate fit in small samples. CFI takes into account sample size and should be greater than .90.

Another fit index of IFI was developed by Bollen (1989) to address the issues of sample size and parsimony. Like NFI, CFI and IFI of .90 or greater indicates an acceptable fit to the data (Bentler, 1992).

The overall model is evaluated using the above common model goodness-of-fit measures estimated by AMOS and SPSS. Table 4 Assessment of goodness-of-fit summarizes the 5 indices considered for the evaluation of model fit with the respective cut-off points: CMIN/df, CFI, IFI, TLI and RMSEA (Hair et al., 2006). A Pooled CFA, running all the latent variables simultaneously has been conducted (Zainudin, 2012).

Fit index	Recommended values	Source
$CMIN$ /df	≤ 2-5.00	Hair et al., 2006.
TLI	≥ .90	Hoyle, 1995.
IFI	≥ .90	Bollen, 1989a.
CFI	≥ .90	Bentler, 1992.
RMSEA	= .05 good model fit; .08 - 0.1 reasonable error of approximation; ≥ .10 indicates poor model fit.	Byrne, 1998; Bryne, 2010; MacCallum, 1995; Browne and Cudeck, 1993; Joreskog and Sorbom, 1993.

Table 4 Assessment of goodness-of-fit

Moreover according to Zainudin (2012), the researcher needs to assess the measurement model for all the latent constructs of unidimensionality, validity and reliability.

Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE) are the indices evaluated. A reliability scale test was carried out for all four attributes in order to assess the internal consistency of the variables. In accordance with Babbie (1992), the value of Cronbach's Alpha was classified based on a reliability index in which 0.90 - 1.00 is very high, 0.70 - 0.89 is high, 0.30 - 0.69 is moderate, and 0.00 – 0.30 is low.

Composite reliability values, which depict the degree to which the construct indicators indicate the latent construct, of all latent constructs should exceed the recommended level of 0.7 (Zainudin, 2012). Table 4 illustrates the level of acceptance of each index.

The Convergent validity is the degree to which multiple attempts to measure the same concept are in agreement. Average Variance Extracted is used as a measure of convergent validity and it should exceed 0.5 (Zainudin, 2012). Discriminant validity is assessed by comparing the shared variance (squared correlation) between each pair of constructs against the average of the AVEs for these two constructs (Bove et al., 2009; Hassan et al., 2007; Walsh et al., 2009).

With a final measurement model in place, the structural relations of the latent factors are modelled in the same way as used for path models.

	Index	Recommended values	Source
Construct Reliability	Cronbach's Alpha	≥ .6	Zainudin,2012; Babbie, 1992.
Internal Reliability	Composite Reliability	≥ .6	Zainudin, 2012
Convergent Validity	Average Variance Extracted	≥ .5	Zainudin, 2012

Table 5 Validity and Reliability

3.2 Lean barriers methodology

In order to test the combined effect of national origin, company environment, lean effectiveness and difficulties in different stages of the lean project, a methodology represented by the green dotted line in Figure 5 will be described in detail in the following paragraphs.

3.2.1 Lean Barriers survey definition

Data were collected through a questionnaire developed on the basis of the factors identified in the literature review (section 2.2) and it is structured in three main parts (A, B and C), which respectively represent: enterprise information, LM practices and LM barriers in both the start-up and sustaining phase. The full version of the survey is reported in Appendix 2.

In particular, in section A the environment context of the enterprise is studied. This section includes questions about the environmental variability and the environmental complexity that have been widely recognized to be two factors that strongly affect the outcome of lean implementation (Azadegan et al., 2013; Bruce et al., 2004; James-Moore and Gibbons, 1997). To reduce as much as possible the human perception, in accordance with Trianni et al.(2013), the environmental variability has been expressed through the demand variability reported in formula 2 (question A5.1). On the other hand, the environmental complexity has been obtained from a combination of the variety of production and the production volumes (Trianni et al., 2013). In particular, the production volume is measured through the range of different finished products managed by the company (A5.2). The variety of production on the other hand, is estimated by a combination of the percentage of customized finished products (formula 3) and the average batch size variation in the organization (formula 4).

$$\text{Demand volume variation} = \frac{\text{MAX}_{monthlydemand} - \text{MIN}_{monthlydemand}}{\text{MAX}_{monthlydemand}} * 100 \qquad 2$$

$$\text{Percentage of customization} = \frac{\text{Maximum number of parts personalizable}}{\text{Total numer of parts}} * 100 \qquad 3$$

$$\text{Batch size variation} = \frac{\text{Maximum batch size} - \text{Medium batch size}}{\text{Medium batch size}} * 100 \qquad 4$$

Secondly in accordance with previous studies we considered Lean practices as Soft (SLP) and Hard practices (HLP) and we applied Bortolotti et al. (2015a) criterion in defining the characteristics and differences between HLP and SLP. However, in discordance with Bortolotti et al. (2015a), instead of autonomous maintenance we inserted Total Productive Maintenance (TPM) as an HLP. Indeed, even if TPM places a strong emphasis on empowering operators to maintain their equipment, the autonomous maintenance is just one building block of TPM program. As evaluating the effectiveness of LMI could be difficult and extremely subject to human perception, we used a six point scale where the score respectively represents: (1) never heard/not implemented; (2)

the implementation had started and failed, (3) just started successfully for some department, (4) in use successfully for some department less than 1 year; (5) in use successfully for some department more than 1 year; (6) in use successfully in the whole system. As well as measuring the adoption of different LM practices, we also included in the survey a question concerning the percentage of lean project successfully developed in the respective companies. Five different levels of successful implementation have been defined: (1) 0%; (2) Between 0% and 20% ; (3) Between 20% and 50%; (4) Between 50% and 90%; (5) > 90%.

Finally, measuring the perception of a given barrier could be quite difficult and companies are always reluctant to admit their difficulties. Hence, in section C of the questionnaire, we formulated the barriers in the form of best practices that should be applied in the different areas (strategic, economic, supply chain integration, cultural and human) and phases (Start-up and sustaining) of a Lean project. Moreover in order to rank the responses, a Likert scale from 1 ("Very slightly/Not at all") to 5 ("Extremely") has been adopted.

But in order to reduce the risk of socially acceptable response to a specific question, the value of some barriers depends on the combination of different questions.

The unclear starting point barrier in the start-up phase (C1.A4-5) takes into account the lack of knowledge on how (C1.A4) and where (C1.A5) the Lean project starts. On the other hand, considering the supply chain integration barriers, the involvement of suppliers (C1.C2-3-4-5) could be difficult for several reasons: distance (C1.C2), short-standing relationships (C1.C3), lack of communication (C1.C4) and low incentive for suppliers (C1.C5). In the sustaining phase, supplier collaboration (C2.C5-6-7) has been evaluated in terms of time delivery (C2.C5), in the right place (C2.C6), and at the right price (C2.C7). Cost and time required for LM programs is another reason for low levels of LM implementation (Jadhav et al., 2014). Indeed concerning the lack of economic availability for lean programs (C1.B5-6), time (C1.B5) and cost aspects (C1.B6) are considered part of the same variable. Lack of time and financial availability have even been considered for the economic difficulties related to training employees and managers in the start up and sustaining phase (C1.B1-2; C1.B3-4; C2.B4-5; C2.B6-7). Hence the lack of economic availability for training courses will be considered high if the time or the cost aspect is deemed important. Finally, regarding the human aspects, the “lack of an active participation by workers” barrier (C1.D3-4), takes into account the 2 main aspects that could restrain workers’ cooperation: the fear factor (C1.D3) and the lack of interest in changing their old habits (C1.D4). As a human barrier in the sustaining phase, according to literature, we considered the importance of managers’ support (C2.D1-2-3). Indeed mangers should be perseverant in conducting lean projects (C2.D1), support changes (C2.D2) and contrast the natural propensity to revert to original practices when obstacles are faced (C2.D3). Moreover, during LM projects an effective communication (C2.D8-9) could be obstructed by the mangers’ non-acceptance of employees’ suggestions (C2.D8) and lack of communication at an organizational level (C2.D9).

3.2.2 Lean Barriers sample definition

In order to involve a sample as large as possible for the present study we used ORBIS Database (Bureau van Dijk, 2016), moreover we asked the support of a Lean Consultant Company and Lean Institutes. With the aim of achieving a high degree of generalization, we aimed to survey companies of various sizes (small-medium-large) and those operating in all the industry fields belonging to sector C of the European Economic Classification ("Statistical Classification of Economic Activities in the European Community, Rev. 2.," 2008).

3.2.3 Lean Barriers survey evaluation and distribution.

After the positive evaluation of a panel of expert surveys were distributed by mail preceded by a phone call in order to explain the project aim, ask if the company had ever applied any Lean Management/Manufacturing techniques, and obtain the contact of the most suitable person. Approximately 80% of the companies contacted that were starting or had started a lean journey, filled out the questionnaire. The questionnaire was originally developed in Italian and then translated into Spanish and English by an expert native language speaker to ensure an accurate translation.

3.2.4 Association rule analysis

Association rule analysis is also called market basket analysis to examine the issue of "what goes with what".

Following the original definition of Agrawal et al. (1993) the problem of association rule mining is defined as: let I = $\{i_1, i_2, , \ldots, i_n\}$ be a set of n binary attributes called items, and let D = $\{t_1, t_2, \ldots, t_m\}$ be a set of transactions called the data base. Each transaction in D has a unique transaction ID and contains a subset of the items in I. A rule is defined as an implication of the form A→B, where A and B are known as item sets, and A, B⊆I, A∩B = ∅. Agrawal et al. (1993) considered each rule composed by two different sets of items, called item-set (A and B). Hence, A is named the antecedent or left-hand-side (LHS) and B is the consequent or right-hand-side (RHS). Moreover in order to select rules of interest, three common metrics (support (5), confidence (6) and lift (7)) are defined for measuring association between the antecedent and the consequent.

$$Support = \frac{\{LHS \cup RHS\}}{\{allrecords\}} \quad 5$$

$$Confidence = \frac{Support\ \{LHS \cup RHS\}}{Support\ \{LHS\}} \quad 6$$

$$Lift = \frac{Support\ \{LHS \cup RHS\}}{Support\ \{LHS\}\ x\ Support\ \{RHS\}} \quad 7$$

Thus, the "Support" indicates how frequent combination of item-sets occurs in the dataset for an alternative. In contrast, the confidence is equivalent to the conditional probability, the probability of finding the RHS of the rule in transactions under the condition that these transactions also contain the LHS. Furthermore, the lift tells us whether the antecedent and the consequent are independent (zero), positively correlated (above unity), or negatively correlated (below unity).

Firstly we will impose different level of Lean success and Lean implementation as a right-hand-side (RHS) item-set, in order to investigate which factors mainly influence these two aspects. Secondly different level of lean barriers (strategic, cultural, human, economic and supply chain integration) in the start-up and sustaining phase will be imposed as RHS item-set, so that aspects influencing the implementing and sustaining phase will be pointed out. Finally, in order to consider the most significant results, only groups of rules that have a confidence level greater than 0.7 will be taken into account.

3.2.5 Network Analysis

Once the association rules between variables are found out, in order to have a complete overview of the variables' interaction, they will be represented as a weighted directed network.

A network is conceived as an ordered pair G = (V, E) comprising a set V of vertices or nodes or points together with a set E of edges or arcs or lines, which are 2-element subsets of V.

In this study, each ranked variable (i.e. HLP=1; HLP=2; etc..) will represent a node and the associations sequence of items will be the edges between the variables of the network. Moreover, the lifts of the association rules have been considered as the weights of the edges.

The free source visualization tool Gephi is used to map and analyse the network (Bastian et al., 2009). Each group of association rules, with different RHS item-set imposition, will be reported in a different network. Three networks will be realized with the aim of providing an overview of the combined effects of the factors that allow an effective lean implementation and the factors that affect different levels of start-up and sustaining lean barriers in different areas (economic, supply chain, strategic, human and cultural).

Furthermore, studying the network properties, we are able to identify numerically and visibly the most influential nodes and therefore aspects that affect lean success and lean difficulties. Moreover, the main inter-combined and interrelated factors will be grouped in different clusters and will be visualized in a really fast and intuitive way.

The relative importance of a node, and hence of a specific factor could be quantified using various metrics. In this study the approach taken into account to identify the most influential nodes within a network is made through the calculation of the degree centrality. For a binary networks (connected-disconnected), it represents the number of nodes that the focal node is connected to (Freeman, 1978). In literature some contributions tried to generalize centrality measures for weighted networks by taking the sum of weights instead of the number ties (Barrat et al., 2004; Newman, 2004; Opsahl et al., 2008). But, these generalizations do not take into account the number of ties, which is the key aspect of the original measure (Freeman, 1978).

As such, a second set of generalization was proposed by Opsahl et al. (2010) that incorporates both the number of ties and the tie weights by using a tuning parameter. The tuning parameter (α) determines the relative importance of the number of ties compared to tie weights. Hence, according to Opsahl et al.

(2010) the degree centrality (C) is computed as the product of the number of nodes (k) that a focal node (i) is connected to, and the average weight to these nodes adjusted by the tuning parameter. The degree centrality for a focal node i is expressed by formula 8.

$$C(i) = k_i \times \left(\frac{w_i}{k_i}\right)^{\alpha} \qquad 8$$

Where w_i is the sum of the tie weights that are connected to the focal node and α is a positive tuning parameter (between 0 and 1) that can set according to the research setting and data. For this study a value of 0.5 will be considered. Indeed α sets on 0.5 would positively value both the number and the weights of ties (Opsahl et al., 2010).

Moreover the different number of outgoing and incoming ties is another aspect that should be considered in a directed network. But in our specific analysis, differentiating the degree into out-degree (outgoing ties) and in-degree (incoming ties) of the node doesn't have relevance, as we chose a direct representation of the graph for a better graphic understanding of the association rules direction. Indeed all the RHS factors, even if connected by oriented arrows, are not consequential, because all parts of the RHS are item-set.

3.3 Lean Structural Network Resilience Methodology

Firstly, it is needed to adopt an uniform way of describing the organization. In terms of Lean oriented organizations, they looks to systematically empowering value stream owners (VSOs) along the value stream (VS) to continuously improve their processes.

In order to analyse corporate structural properties, the organizational network paradigm (Cross et al., 2010a), in which corporations can be understood as networks has been adopted. This paradigm can be used to describe physical networks, such as networks of organizational power (Castells, 2011).

Among all the possible network representation for organizations, the netwok linking the VS concepts for related processes is adopted, where the links follows the criteria promoted in (Villalba-Diez & Ordieres-Meré, 2015), considering the organization as a Lean Structural Network. Lean because they seek the standardization of all sort of process, knowledge sharing and internal variability reduction (Shah & Ward, 2007).

The advantage of such representation is that it manages both, product flows but also information flows and it enables feedback coaching that contributes to the process owner empowerment.

A research developed by Wang and Noe (2010) has shown that knowledge sharing is positively related to reductions in production costs, faster completion of new product development projects, team performance, firm innovation capabilities, and firm performance including sales growth and revenue from new products and services.

Moreover, Villalba-Diez and Ordieres-Meré (2015) demonstrated how the implementation of a standardized way of interchange information ($(CPD)_nA$) impacts on manufacturing operational performances. Therefore, in order to take into account the whole value stream and consequently the information flow, we considered manufacturing organizations as network, where nodes (N) represent individuals (PO), within the network and edges (E) represent associations between those individuals (Cross et al., 2010b). In particular, in accordance with Villalba-Diez & Ordieres-Meré (2015) we took into account firms through inter-process product and information exchange networks composed by a set of nodes formed by the processes, represented by their related process owner (POs) of the organization and a set of edges formed by $(CPD)_nA$s that are reported from several POs to others and we will call them Lean Structural Network (LSN) representation of the organization.

In order to estimate and compute the Resilience of a LSN affected by an unexpected event, personnel relocation or a process owner decreasing of performances, this research has developed a methodology represented in Figure 5.

The methodology is mainly composed by 4 macro-steps:

- Data collection: and hence the identification of a LSN and the KPIs associated to each node;
- Model validation: nodes' modelling and characterization through a genetic algorithm;

- Model Analysis: Network analysis object of different disruption event;

- Results: Resilience analysis.

Figure 6 represents the identification, nodes modelling, characterization, and network and resilience analysis phase in detail. The following paragraphs of this section will describe each stage.

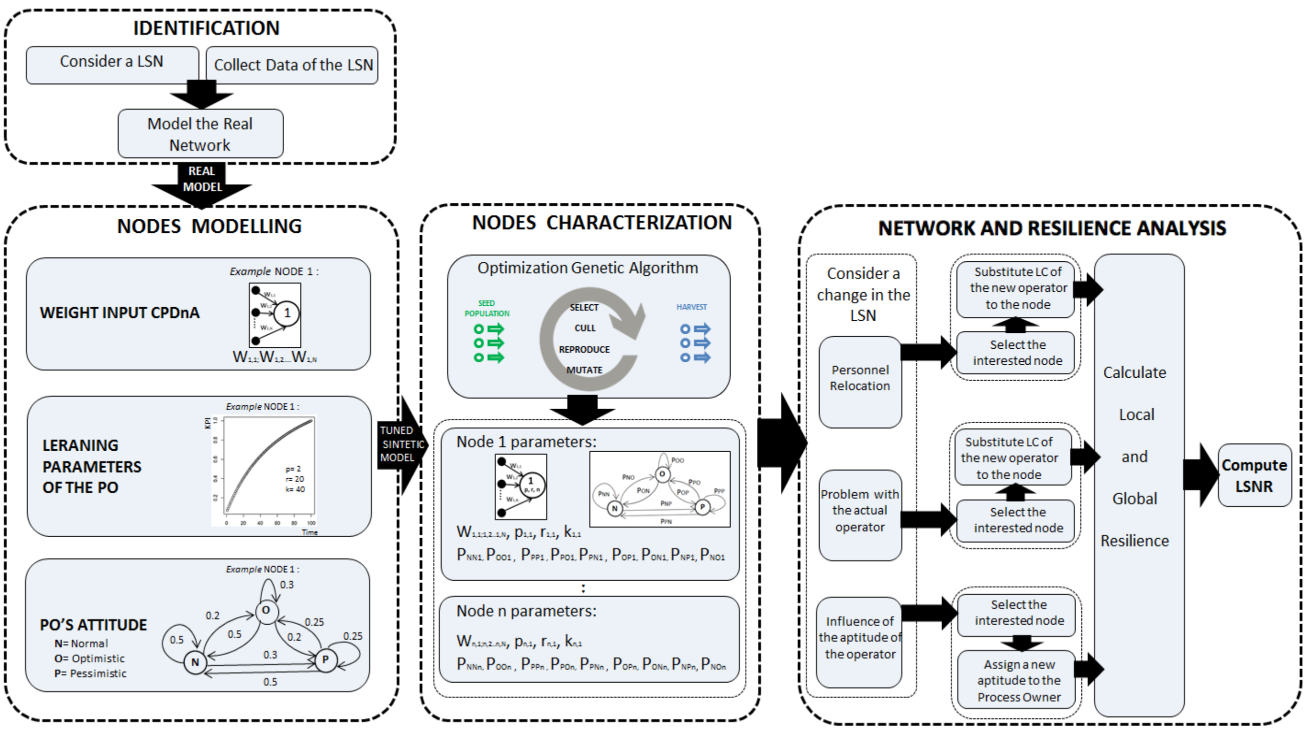

Figure 6. Detailed methodology of Lean structural Network Resilience study.

3.3.1 Identification

As presented in section 2.1 literature shows great attention to organizations' characterization as networks. Any kind of company and network definition could be considered for the proposed methodology. But, as the aim of this study is focusing the attention on Lean companies, where the inter-process information exchange between POs occurs in a standardized way, for this particular research we considered the firm as a LSN.

Hence, data from the LSN considered will be collected. In particular, POs connections and the KPIs trends during time associated to the various $(CPD)_n$As are gathered. The LSN is modelled as an organizational structural directed graph composed by a set of nodes formed by the processes, represented by their related POs of the organization and a set of edges formed by $(CPD)_n$As that are reporting selected process KPIs from several POs to others.

Main outcomes from this step are the relevant network topology as well as the KPIs values throughout time.

3.3.2 Modelling of Nodes behaviour

Thus, in order to model nodes' behaviour, we generated a node behaviour simulator and some assumptions were made:

- The network considered has a fixed topology as time passes, including process owner positions. Topological changes will be managed as new configurations;
- The KPI values associated to each $(CPD)_n$A will be standardized (values between 0 and 1);

- A value (OPT) equal to +1 will be associated to each KPI if the optimal status is growing and -1 if the optimal status is decreasing;
- As $(CPD)_nA$ in entrance to a node could have different frequencies in time (hourly; shift; daily; weekly, etc..), the frequency of the $(CPD)_nA$ in output will be the minimum frequency values in entrance for the specific node.

Thus, each node will have a transfer function depending on the weight of the $(CPD)_nA$ in input to the node, on the learning curve of the process owner representing the node and on his aptitude.

The $(CPD)_nA$ in input to the node moderate the transfer function through the function expressed by formula 9.

$$\mathrm{IN}\ (\mathrm{j},\mathrm{t}) = \sum_{\mathrm{i}=1}^{\mathrm{N_j}} \mathrm{f}\big(\mathrm{KPI}(\mathrm{i},\mathrm{t})\big)\mathrm{w}(\mathrm{i},\mathrm{t}) \qquad \forall\, t \in (1,\dots,T) \wedge \forall\, j \in (1,\dots,N) \qquad (9)$$

Formula 9 reports the moderation function of node j, where N_j are the total links entering into the node (i.e. the total process owners (N_j) reporting to the current process owner (j)), while $\mathrm{f}(\mathrm{KPI}(\mathrm{i},\mathrm{t}))$ represents how to proceed (average, lastest, max, dist(range), etc.) with $(CPD)_nA$ with different frequency. Lastly, $\mathrm{w}(\mathrm{i},\mathrm{t})$ represents the way of weighting each $(CPD)_nA$ in entrance when a node has several KPIs as its input.

Hence, up to this point, based on the state of the operator at time t the transfer function of each node is expressed by formula 10. Where, $IN(j,t)$ represents the moderation function due to the CPDnA in input (formula 9) and y the 3-parameter hyperbolic learning curve of the operator expressed in formula 1 and considered by Anzanello and Fogliatto (Anzanello and Fogliatto, 2007) as the most robust in terms of efficiency, stability, parsimony and ability. Finally g functions enables a non linear transformation because of the particularities of the process itself.

$$T(j,t) = g\,(k * IN(j,t), y) \qquad \forall\, t \in (1, \dots, T) \wedge \forall\, j \in (1, \dots, N) \qquad (10)$$

But, as detailed in literature review section, the aptitude of the process owner is an important aspect to take into account. Three different process owners' states have been defined: normal, optimistic and pessimistic.

In order to represent the probability distribution of transition from a state to another, the process owners evolution have been modelled through a Markov process with unobserved (hidden) states: Hidden Markov Model (HMM) (Ghahramani, 2001). Indeed, the transition properties of process owner' s aptitude from one state to another could be held in the property of the Hidden Markov Model (HMM). The HMM first assumes that the observation at time t is caused by some process whose state S_t is hidden from observer. Second, it assumes that the state of this hidden process satisfies the first order Markov property that given the value of S_{t-1}, the current state S_t is independent of all the states prior to t-1 (Ghahramani, 2001). For sure this is a simplification of reality that can be argued as being aligned with the short term memory of the process owner.

Hence, once obtained the aptitude state of the process owners for all the instants of time, another moderation function should be defined. Formula 11 reports the logistic function chosen to describe the variation in performance during time due to the operator aptitude. The parameter A varies based on the aptitude ($A_{pessimistic} = 1.6$; $A_{optimistic} = 0.6$; $A_{normal} = 1$) of the operator at time t. Formula 11 represents the final node transition function, including all the previous formulas enunciated and thus, considering the $(CPD)_n$A tend and weight in input to the node, the learning curve of the POs an the POs' aptitude.

$$a(j,t) = A\frac{1-e^{-T(j,t)}}{1+e^{-T(j,t)}} \qquad \forall\, t \in (1, \dots, T) \wedge \forall\, j \in (1, \dots, N) \qquad (11)$$

After this step, a clear operational model explaining the Process Owner behaviour and based on Process Owner attitude and learning behaviour has being established and it enables its implementation to estimate the hidden effects and to predict evolution of Process Owner's behaviours. This means that, according to the model, the foreseen evolution of KPI will be driven by formula (12):

$$KPI(j, t+1) = KPI(j, t) + OPT * a(j, t) \;\; \forall\, t \in (1, \ldots, T) \wedge \forall\, j \in (1, \ldots, N) \tag{12}$$

3.3.3 Characterization of nodes

But even if the data gathered from the LSN describe the network topology and the KPI trend associated to each $(CPD)_nA$, so far we are not able to know node's characteristic. Indeed, as mentioned above each process owner is characterized by a learning curve and an aptitude that influence his performances. Collect all values of an operator could be difficult and time consuming.

Thus, in order to demonstrate the validity of the simulated model and derive the set of values that describe each node (the weight w of each $(CPD)_nA$ in input to the node, the parameters p r k of hyperbolic learning curve and the probability distribution of transition from a state to another), it is possible to use an optimization process, which aim to minimize the difference between the data generated by the simulation and previously acquired data from the real system (Troitzsch, 2004).

A Genetic algorithm (GA) has been used for the optimization process (Scrucca, 2013). GAs are inspired by the mechanics of natural evolution, including survival of the fittest, reproduction, and mutation(Goldberg, 1989; Mitchell, 1998). They transform a population (set) of individual objects, each with an associated fitness value, into a new generation of the population using the Darwinian principle of reproduction and survival of the fittest and analogs of naturally occurring genetic operations such as crossover (sexual recombination) and mutation. Each individual in the population represents a possible solution to a given problem. The genetic algorithm attempts to find the best solution to the problem by genetically breeding the population of individuals over a series of generations.

An initial set of candidate solutions for the control variables are created and their corresponding fitness values are calculated. This set of solutions is referred to as a population and each solution as an individual.

The individuals with the best fitness values are combined randomly to produce offspring which make up the next population. To do so, individual are selected and undergo cross-over (mimicking genetic reproduction) and also are subject to random mutations. This process is repeated again and again and many generations are produced that should create better and better solutions.

The fitness function is defined as the Symmetric mean absolute percentage error (SMAPE) and it reported in Equation 13.

$$SMAPE = \frac{1}{N}\sum_{1}^{T}\frac{|(KPI_S(t)-KPI_R(t))|}{\frac{|(KPI_S(t)|+|KPI_R(t))|}{2}} \qquad 13$$

Where $KPI_S(t)$ is the output from the simulation and $KPI_R(t)$ is the real data. T represents the instants of time where real and predicted are data are available and N the number of data available. The GA will provide for each node the best values of the control variables (w, p, r, k,) that minimize the value of SMAPE.

This step will bring specific parameters able to explain, under the adopted hypotheses, the behaviour of the POs, which can enable to better understand the latent attitude of the process owner as well as the status of the exhibited learning capabilities.

3.3.4 Network analysis and Resilience calculation

Once the virtual model has been carried out the resilience calculation begins, by defining type of events considered that could lead to a change of performances: operators' relocation, problem in the process due to equipment failures and/or human errors, and change in the aptitude of the process owner's.

In the first and the third cases, this study supports human resources' decisions in personnel relocations. Indeed, after selecting the node representing the process owner that they would like to relocate, it is possible to substitute the learning curve parameters of the current process owner with the parameters belonging to different process owners. This will allow human resource managers to consider and quantitatively evaluate the effect of a process owner's relocation in terms of KPI variability at any place. Moreover as detailed in section 2.3.2 the aptitude of employees could influence their performance. Thus, changing the probability distribution of the Markov chain managers will be able to evaluate the impact of a possible change in operators' aptitude due modification such as a new boss, new tasks, new responsibilities etc.

In the second case, considering a reduction of a node's performances due to machines and/or human errors will allow human resource and production managers to evaluate the local and global effect of node's failure or reduction of service level.

The second step will be calculating the Resilience of the LSN at the network level. In order to define a metric of resilience this thesis considers the McManus (S. McManus et al., 2007) theoretical proposal as the basic idea. But, as we applied resilience to a dynamic system such as a LSN we enlarged their definition, inserting operators' learning curve, aptitude and the possibility of having different outcome for the value stream map (VSM).

Figure 7 represents local and global effect of a LSN, represented at the centre of the image, where the affected node is object of personnel relocation (upper part of figure 7) and of a reduction of performances (lower part of figure 7).

When a node in the LSN is hit by whatever disruption event the immediate effect is on the local KPIs associated to the outgoing edges ($(CPD)_nA$). But, considering the Resilience of a LSN just based on the reduction of the nodes' KPI could be limitative. Indeed when the propagation of effects starts to happen, impacts on different nodes are then seen at their KPIs throughout their $(CPD)_nA$ until the KPI outcomes for the VSM are reached. Thus, in order to make the measure of the LSNR (Lean Structural Network Resilience) complete and independent from the KPI dimension, the effect of the disruption event at the network level will be divided by the effect at the node level (formula 14).

$$LSNR(f,j,e) = \frac{\int_{t1}^{t2}[KPI_f(t) - KPI(t)]dt}{max_i\left(\left(\int_{t1,i}^{t2,i}[KPI_e - KPI(t)]dt\right)_{(CPD)_nA_i}\right)} \quad \forall i \in 1,\ldots,N_j \quad (14)$$

Considering the affected process owner the disruption event will be propagated in different way for the n edges leaving the node (3 in the example of figure 7). We took into account as local node resilience only the $(CPD)_nA$ mostly affected by the variation of the KPI until the KPI returns to the last value it had before the event occurs (KPI_e). Thus, the resilience (every shaded area on the NODE side of figure 7) is calculated as the area included between the KPI trend during the time of the disruption event and the straight line parallel to the time axes, passing through KPI_e. Those effects can be seen as the seed for the perturbation of the LSN network. Moreover, it can be seen that in the personnel relocation case the duration of the disruption event depends on the learning curve of the new operator and it affects even the future KPI trend, while in the second case the event's duration has a fixed time before returning to the previous trend.

Indeed, a relocation of a node with many paths to the output is supposed to have a different propagation compared to a less connected node. Indeed, the different paths from the node in question to the ending node produce, in different instances of time, several impacts in the KPI outcome for the network (shaded areas left side of figure 7). In addition, depending on the paths' length, the expected time when impacts happen will be different as well (shaded areas on the NETWORK side of figure 7). Moreover, the trend forecasting of the network LSN KPI is represented by a straight line named $KPI_f(t)$.

The LSN Resilience at the network level for the output f of the VSM because of the event e at node j (LSNR (f,j,e) will be calculated as the sum of the areas included between the variations of network LSN KPI trend against the straight line $KPI_f(t)$ through time over the j node's resilience due to the e event. The time occurrence for the effects of event e happens between $t_{1,i}$ and $t_{2,i}$ per $(CPD)_n A_i$, $i \in 1, \dots, N_j$. Therefore, t1 = min (t1,i) and t2 = max (t2,i) $\forall\, i \in 1, \dots, N_j$.

The next step, when needed, is to iterate over the relevant set of nodes C potentially affected by an event class to determine the global LSN Resilience by considering all the VSM outcomes (VSMo), as established by formula (15), where global effect because of total effect of a node as well as aggregated effect at network level have been derived.

$$\begin{cases} \mathrm{LSNR}(j,e) = \sum_{f=1}^{VSM_o} \left(\mathrm{LSNR}(f,j,e) \right) \\ \mathrm{LSNR}(e) = \sum_{f=1}^{VSM_o} \left(\max_j \left(\mathrm{LSNR}(f,j,e) \right) \right) \end{cases} \forall\, j \in C \land \forall\, f \in VSM_o$$

(15)

In this way the proposed methodology enables to determine a topology independent, yet fully generic metric of resilience and, even better, it will not only answer the resilience of the current configuration of the organization but also to simulate different events like attitude degradation of specific POs or replacement of POs, when the attitude and learning parameters can be derived.

The defined metrics enable to study both, the resilience because of events at $(CPD)_nA$ or node levels but the global resilience at network level, which accounts for the topological properties of the network itself. This last dimension allows to analyse efficiency versus resilience when the $(CPD)_nA$ based LSN evolves because of its natural trend towards increase relevant connections. Therefore, not only long term changes in the topology due to the evolutionary behaviour of the $(CPD)_nA$ type of network can be assessed, mainly related to strategy aspects but also local effects more related to the human resource management needs.

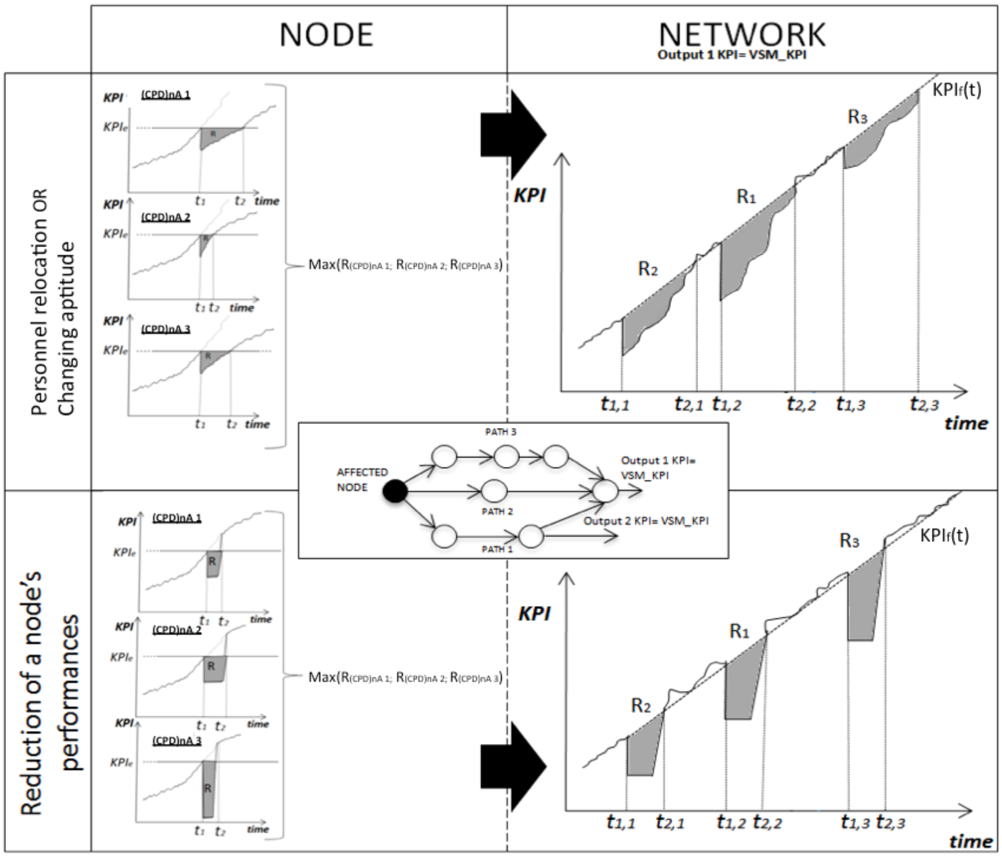

Figure 7 Node and network Resilience calculation

Chapter 4.

Results

4.1 Lean practices, operational responsiveness and firms' growth performances results

The sample considered for this part of the study is composed by 254 companies and it represents 10.5% of Italian manufacturing companies considered for the study and, although limited, it could be considered significant for the study (Burgess-Limerick et al., 1998). Results show a Cronbach's alpha coefficient of 0.881, which is above the recommended value of 0.7 (Babbie, 1992).

A list of the survey items used to measure Product mix variety, Product Innovation, time effectiveness, company growth performance and Lean best practices is reported in Table 6. This table highlights that the main characteristic of the operational responsiveness on which Italian manufacturing companies focus their attention is Time effectiveness. Moreover, Lean best Practices present a low level of application in all the impact areas. Indeed, their mean value range between 3 and 4, which means that Italian manufacturing firms are mainly in the Start-up phase or they have just started applying lean manufacturing. Observing the high standard deviation values of Lean best practices we can highlight different levels of lean practices implementation in the companies. In particular, the highest standard deviation values are for supplier and workforce lean practices implementation.

Latent Variables	Observed Variables	Item	Mean	Standard Deviation
PRODUCT MIX VARIETY	Different Finished Product managed by the company.	PM_1	2.49	0.85
	New finished products produce each year.	PM_2	2.92	1.27
	Batch size variation	PM_3	3.96	1.26
PRODUCT INNOVATION	Percentage annually invested in R&D.	INN_1	2.65	1.19
	Percentage of customizable products.	INN_2	3.22	1.17
TIME EFFECTIVENESS	Mean time of stock in the warehouse	TE_1	4.47	1.23
	Inventory turnover	TE_2	4.21	1.05
	Speedy response time to Warranty claim	TE_3	3.74	1.10
JUST IN TIME	Pull production / Kanban implementation	JIT_1	3.98	1.69
	Quick changeover techniques (SMED)	JIT_2	3.70	1.74
	Production smoothing/ Heijunka/Mixed model	JIT_3	3.65	1.83
TOTAL QUALITY MANAGEMENT	Statistical process control	TQM_1	3.91	1.17
	Customer involvement in product offerings	TQM_2	4.05	1.39
	Process feedback	TQM_3	3.99	1.10
SUPPLIER MANAGEMENT	Supplier partnership	SM_1	4.02	2.08
	Involvement of supplier in the lean journey	SM_2	2.44	.942
	Supplier quality involvement	SM_3	1.98	1.92
HUMAN RESOURCE MANAGEMENT	Multi-skilled Workforce/ Job Rotation	WF_1	4.11	2.14
	Employees' involvement (Suggestion schemes)	WF_2	4.08	2.32
	Lean Management training	WF_3	4.66	2.14
GROWTH PERFORMANCES	Employee growth variation in the last 2 years	GP_1	2.76	.980
	Sales growth variation in the last 2 years	GP_2	2.45	.741
	Customer Retention	GP_3	1.98	.706

Table 6 Descriptive statistics of variables.

4.1.1 Measurement validation

Data were collected and analysed by SPSS and SPSS Amos and a Confirmatory Factor Analysis (CFA) procedure was performed for all latent constructs using a pooled CFA. Indeed, lean best practices implementation has been evaluated as a second order variable (called "LEAN_BEST PRACTICES"), so firstly a CFA for the first order latent sub variables (JIT, TQM, SM and HRM) should be conducted. Indeed, the second order variable loads onto its respective sub-variables should be confirmed (Byrne, 2013). Confirmatory Factor Analysis (CFA) was conducted to assess the measurement properties of the lean practices implementation variable. After the CFA for first order latent sub-variables has been conducted, the research is continued by running the second order CFA for the main variable that is Lean best. Finally a pooled CFA of the whole model has been conducted. The initial model (Figure 8) was found to be discredited, considering the overall fit analysis (χ^2 (203)= 1210.686. p=0.000 RMSEA =.151. CFI=.519. IFI=.525 TLI =.452). Modifications were made to the model according to the iterative procedure described by Bortolotti et al. (2015a) and Li et al. (2005). The modification procedure starts with a review of the factor loading of each item and removal of the items that do not exceed 0.5. It continues with a review of the standardized residual where the items with a value higher than 2.58 are dropped and it ends with a review of the modification index to improve the model. During the modifications procedure three items were dropped (PM_3; TE_1; GP_3).

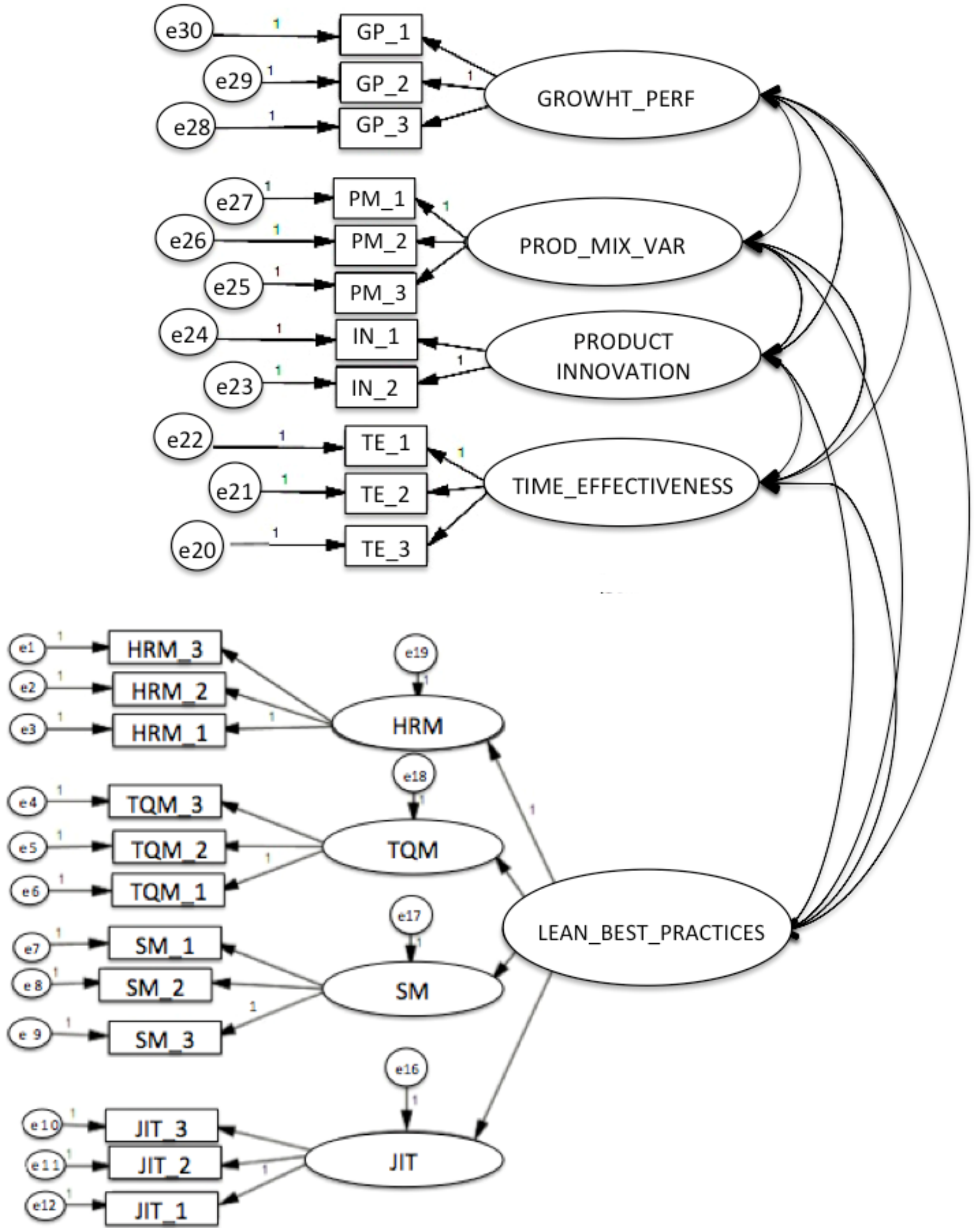

Figure 8 Initial model CFA

Table 7 presents the Parameter estimates, Standard errors and Critical ratios for the Final Measurement model, test of reliability and validity.

Internal consistency reliability to test unidimensionality was assessed by Cronbach's alpha. The resulting alpha values ranged from 0.599 to 0.747 and are considered between acceptable and high (Babbie, 1992; Chen et al., 2009). The measure of the Composite Reliability (CR) exceeds 0.6, the Average variance extracted exceeds 0.5 and the discriminant validity was also assessed.

To summarize, the overall results of the goodness-of-fit of the model and the assessment of the measurement model substantially confirm the proposed model.

Latent Variable	**Item**	**Standardized Factor loading**	**Standard [a] Error**	**Critical[b] Ratio**	**Cronbach's alpha**	**Average Variance Exceeded**	**Composite Reliability**
LEAN_IMPLEMENTATION	SM	. 911	.111	8.911	.747	0.691	0.851
	HRM	. 796	- [c]	-			
	TQM	. 837	.111	5.731			
	JIT	.640	.113	7.361			
TIME_EFFECTIVENESS	TE_2	.531	- [c]	-	.652	0.561	0.701
	TE_3	.890	.127	5.921			
PRODUCT INNOVATION	INN_1	.692	- [c]	-	.602	0.640	0.701
	INN_2	.722	.186	2.76			
PRUCT_MIX_VARIETY	PM_1	.690	- [c]	-	.599	0.601	0.640
	PM_2	.772	.250	8.803			
GROWTH_PERF	GP_1	.727	.220	5.785	.692	0.660	0.739
	GP_2	.689	- [c]	-			

Table 7 Parameter estimates. Standard errors. Critical ratios.

Fit indices: (χ^2(175)=282.78; CMIN/ df= 1.61; RMSEA =.049; CFI=.941; IFI=.942; TLI =.930

[a] SE is an estimate of the standard error of the covariance

[b] C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. A value exceeding 1.96 represents a level of significance of 0.05.

[c] Indicates a parameter fixed at 1.0 in the original solution.

4.1.2 Hypothesis Testing

Once the latent constructs had passed the CFA stage, Structural Equation Modelling was developed which allowed researchers to explore the pattern of inter-relationships between variables (Bollen, 1989; Pedhazur and Schmelkin, 1991; Kellowway, 1998).

The model's overall fit with the data was evaluated using common model goodness-of-fit measures estimated by AMOS 20. Using common model goodness-of-fit measures, the final structural model, presented in Figure 9, provided an adequate model fit of companies and indicate that the data adequately support the estimated model (χ^2(174)=303.226; CMIN/ df= 1.74; RMSEA =.054; CFI=.930; IFI=.931; TLI =.915). Table 7 shows the estimate of the covariance standard error (S.E.), the critical ratio obtained by dividing the covariance estimate by its standard error (C.R.) and the significant probability (P) for each hypothesis.

As a rule of thumb, the C.R. needs to be greater than 1.96 or smaller than -1.96. As a value exceeding 1.96 represents a level of significance of 0.05 (Hair et al., 1998; Koufteros, 1999; Byrne, 2001).

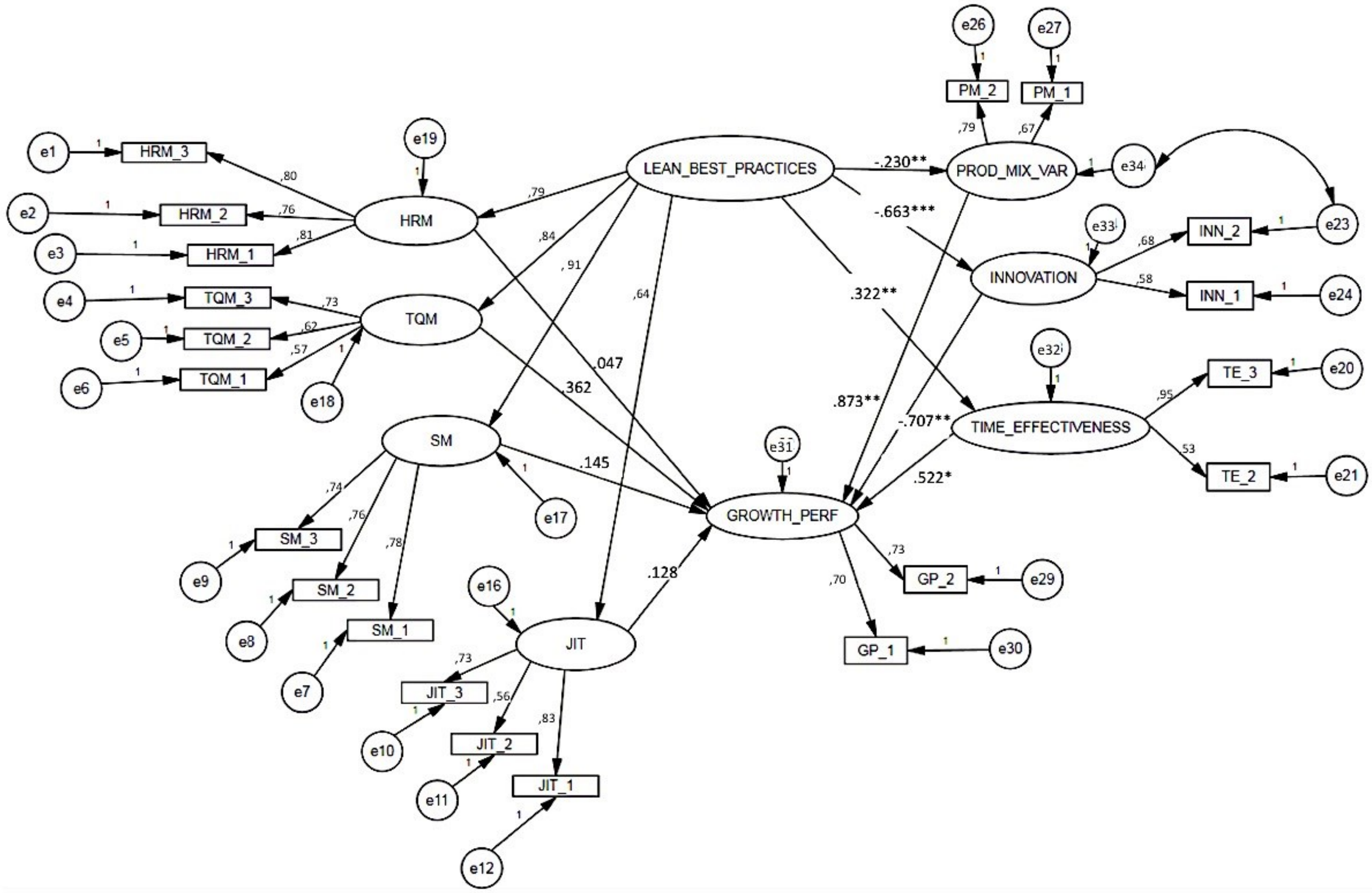

Figure 9 Final structural model

The results in Table 7 show that all the hypothesis relationships are significant except for the paths from LEAN_PRACTICES (HRM, TQM, SM and JIT) to GROWTH_PERF. Hence, hypothesis H2a-H2b-H2c-H2d, which assumes that the firm growth performances are positively influenced by the application of different lean best practices, and in particular, by lean practices related with workforce, quality, supplier or production efficiency, are not supported (H2a: CR=.308 and p=.758; H2b:CR=1.62 and p=.105; H2c: CR=.582 and p=.561; H2d:CR=1.128 and p=.259)

Lean Best Practices are found to have a significant relationship with *Product mix variation*, *Product Innovation* and *time effectiveness* (H1a: estimate=-.230 and C.R.=-2.397; H1b: estimate=-.663 and C.R.= -3.95; H1c: estimate=.332 and C.R.= 2.012). Moreover, Product mix variation and innovation are found to have a strong significant relationship with Firm Growth Performance Improvement (H3a: estimate= .873; C.R.= 4.301; H3b: estimate=-.707; C.R.= -2.33). Even time effectiveness has a positive significant relationship with Firm Growth Performance Improvement (H3c: estimate=.522; C.R.= 2.108).

Finally, the firm growth is not directly influenced by Lean Practices of different areas.

Paths	**Estimate**	**S.E.** ^{a}	**C.R.** ^{b}	**P** ^{c}	
H1a: LEAN_BEST_PRACTICES ->PROD_MIX_VAR	-.230	.036	-2.397	**	Accepted
H1b: LEAN_BEST_PRACTICES ->PRODUCT INNOVATION	-.663	.097	-3.95	***	Rejected
H1c: LEAN_BEST_PRACTICES -> TIME_EFFECTIVENESS	.322	.047	2.012	**	Accepted
H2a: LEAN_PRACTICES (HRM) -> GROWTH_PERF	.047	.059	.308	.758	Rejected
H2b: LEAN_PRACTICES (TQM) -> GROWTH_PERF	.362	.141	1.622	.105	Rejected

Paths	Estimate	S.E. [a]	C.R. [b]	P [c]	
H2c: LEAN_PRACTICES (SM) -> GROWTH_PERF	.145	.110	.582	.561	Rejected
H2d: LEAN_PRACTICES (JIT) -> GROWTH_PERF	.128	.042	1.128	.259	Rejected
H3a: PROD_MIX_VAR -> GROWTH_PERF	.873	.114	4.301	**	Accepted
H3b: PRODUCT_INNOVATION -> GROWTH_PERF	-.707	.447	-2.33	**	Rejected
H3c: TIME_EFFECTIVENESS -> GROWTH_PERF	.522	.083	2.108	*	Accepted

Table 8 Results of Structural equation modelling

Fit indices: $\chi^2(174)$=303.226; CMIN/ df= 1.74; RMSEA =.054; CFI=.930; IFI=.931; TLI =.915

[a]SE is an estimate of the standard error of the covariance

[b]C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. A value exceeding 1.96 represents a level of significance of 0.05.

[c]P is the significant probability. The symbol (***) represents a significant probability level less than 0.001. The symbol (**) represents a significant probability level less than 0.05.

4.1.3 Endogeneity bias

Lastly we should consider one key estimation problem that most leadership and management research ignore: Endogeneity bias. Such endogeneity bias frequently is rooted in the omission of variables that are embedded in the errors, thus simultaneously affecting both predictor and dependent variables (Antonakis et al. 2014). To reduce the risk of endogeneity bias, we compare the findings of our model with an extended model that includes four additional constructs that, from a conceptual standpoint, appear likely to cause potential endogeneity: Company size (OS), Sector (S) market share at European (MSE) and national level (MSN).

We included these four variables as exogenous in the model, with paths on operational responsiveness and firm performances. Running the model, the model fit of the extended model was similar to the original one, with CMIN/df= 1.3; RMSEA =.022; CFI=.971; IFI=.972; TLI =.964. Indeed, we found that significance of the paths from the original model did not change. No paths that had been significant turned insignificant and no insignificant paths turned significant.

We also found that CS item has positive significant relationship with the three variables of operational responsiveness and the growth performances. Sector has a positive significant relationship just with time effectiveness. But both MSE and MSN variables show no significant relationships with the operational responsiveness and firm performances constructs.

Concluding, omission of variables CS, MSE and MSN does not seem to lead to endogeneity, indeed our findings do not change by including these variables. But results indicate that company size influence the operational responsiveness and firm growth while the sector seems to impact only on time effectiveness aspect.

Table 9 reports the effect of control variables CS, S, MSE and MSN on operational responsiveness and firm growth performances. The path estimation of the other variables have been omitted as the results are in accordance with previous ones.

Paths	**Estimate**	**S.E.** [a]	**C.R.** [b]	**P** [c]
Control Variable: OS-> PROD_MIX_VAR	.339	.234	2.501	**
Control Variable: OS-> PRODUCT INNOVATION	.288	.586	2.050	**
Control Variable: OS-> TIME_EFFECTIVENESS	.257	.207	2.351	**
Control Variable: OS-> GROWTH_PERF	.734	.457	2.558	**
Control Variable: S-> PROD_MIX_VAR	.051	.005	.681	.496
Control Variable: S-> PRODUCT INNOVATION	.147	.013	1.870	**
Control Variable: S-> TIME_EFFECTIVENESS	.469	.006	6.348	***
Control Variable: S-> GROWTH_PERF	-.252	.018	-.880	.379
Control Variable: MSE-> PROD_MIX_VAR	.081	.086	.786	.432
Control Variable: MSE -> PRODUCT INNOVATION	-.126	.218	-1.15	.249
Control Variable: MSE -> TIME_EFFECTIVENESS	.052	.076	.625	.532
Control Variable: MSE -> GROWTH_PERF	.330	.418	.603	.547
Control Variable: MSN-> PROD_MIX_VAR	.019	.145	.200	.842
Control Variable: MSN -> PRODUCT INNOVATION	.063	.370	.643	.520
Control Variable: MSN -> TIME_EFFECTIVENESS	-.015	.128	-.207	.836

Paths	Estimate	S.E. ^{a}	C.R. ^{b}	P ^{c}
Control Variable: MSN -> GROWTH_PERF	-.130	.293	-.638	.524

Table 9 Effect of control variables

Fit indices: CMIN/ df= 1.3; RMSEA =.022; CFI=.971; IFI=.972; TLI =.964.

^{a}SE is an estimate of the standard error of the covariance

^{b}C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. A value exceeding 1.96 represents a level of significance of 0.05.

^{c}P is the significant probability. The symbol (***) represents a significant probability level less than 0.001. The symbol (**) represents a significant probability level less than 0.05.

4.1.4 Qualitative interviews

In order to find reasons of missed connection between lean practices and growth performance, 39 managers with more than 10 years of experience in Lean, belonging to different sectors and companies, have been interviewed.

A semi-structured qualitative interview has been developed for this aim. This means that the interview is not highly structured, as is the case of an interview that consists of all closed-ended questions, nor is it unstructured, such that the interviewee is simply given a license to talk freely about whatever comes up. Semi-structured interviews offer topics and questions to the interviewee, but are carefully designed to elicit the interviewee's ideas and opinions on the topic of interest, as opposed to leading the interviewee toward preconceived choices (Qu and Dumay, 2011).

Thus, it helps to understand the ways in which managers make sense of, and create meanings about, their jobs and their environment.

The two main questions of the interviews were:

-Do they consider the implementation of lean practices, in any area, as a direct method to increase the growth performance of the firm?

-What are the main barriers they faced during the development of lean projects?

Moreover, trying to maintain equilibrium between SME and large firms, a mix of companies that show high performance in the majority of the practices and companies that are characterized by very limited implementation of lean practices has been considered.

What emerged from the interview was that many company managers do not see the implementation of lean practices, in any area, as a direct method to increase the growth performance of the firm. Indeed companies that generally seem to respond better to the Lean application are characterized by a sustainable approach along mouths.

Moreover, because of the complexity and effort for the implementation of certain lean practices connected to supplier, workforce, quality and production efficiency, these practices are suitable only for firms with enough resources.

4.2 Results lean difficulties

4.2.1 Sample Characteristics

The final database used for our analyses, after discarding some incomplete answers, consisted of 150 questionnaires and included plants located in 27 different countries (Austria, Brazil, Canada, Colombia, Croatia, Czech Republic, Denmark, France, Germany, Holland, Hungary, India, Italy, Lithuania, Mexico, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Switzerland, United Kingdom and United States). Considering the Globe study and country clusters, the majority of plants belong to Latin Europe (57.9%). Anglo companies are 10.5%, Latin America 8.6%, Eastern Europe 8.6%, Germanic Europe 6.6% and other clusters are represented by the minority.

Country	**Sector**							**Total plants per country**
	Food & beverages products	**Textile, leather & clothes products**	**Chemical products**	**Pharmaceutical products**	**Transport products**	**Electrical and mechanical**	**Others**	
Group 1	1.3%	0.0%	0.0%	0.0%	2.0%	6.7%	2.7%	19
Group 2	5.3%	1.3%	1.3%	2.0%	5.3%	32.0%	16.7%	96
Group 3	2.7%	5.3%	0.7%	0.7%	1.3%	4.7%	8.0%	35

Table 10 Sample distribution

In addition the sample has been split into three groups according to the internati onal Monetary Fund World Economic classification (International Monetary Fu nd, 2015), which classified the wealth of countries through their Gross Domesti c Product (GDP) per capita, based on the Purchasing Power Parity (PPP) metho dology: Group 1, wealthy countries (GDP (PPP) per capita between 143,427 U SD and 45,888 USD), Group 2 (GDP (PPP) between 45,888 USD and 29,925 U SD) and Group 3 up to 29,925. Table reports the sample distribution in differen t country groups and sectors. Wealthy countries belong to Group 1 and represen t 12.5% of the sample, Group 2 64.5%and Group 3 23% respectively.

Moreover, considering the European Commission definition, SMEs are enterprises with a head count less than 250 or a turnover ≤€ 50 million and consequently large enterprises have more than 250 employees or a turnover of more than € 50 million (European Commission, 2016).

SMEs represent 30.3% of the sample, large enterprises the 67.8% of the sample. Figure 10 shows the respondents, which the survey has been administered to.

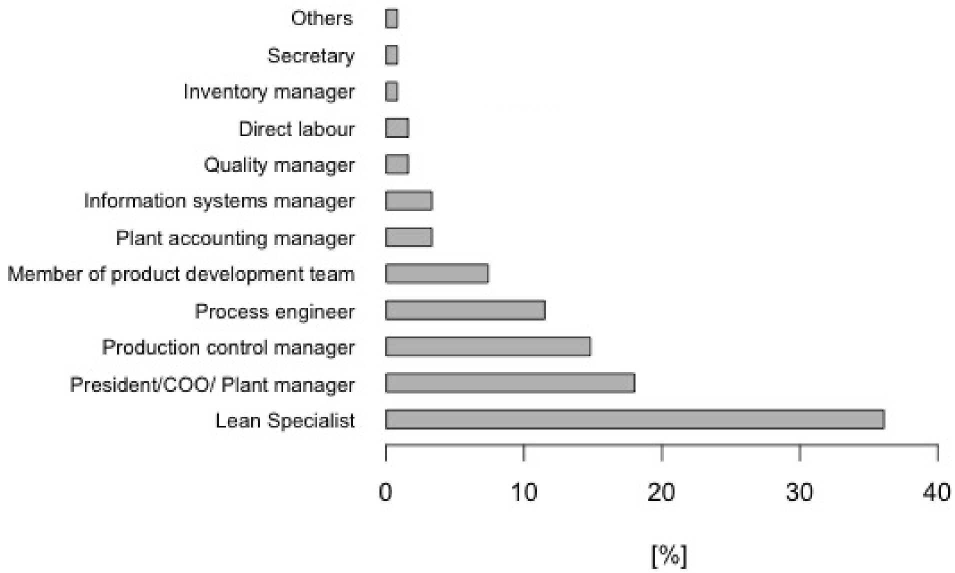

Figure 10 Respondents to Lean Barriers survey.

Table 11 reports the complete list and descriptive statistic of HLP and SLP. Table 12 and Table 13 show for each category the item code and the name of each barrier. The questions results were aggregated into 6 main categories using simple averages.

Category	Item Code	Item Description	Mean	SD
Hard Lean Practices (HLP)	B1.A1	Setup time reduction/Single Minute Exchange of Die (SMED).	3.49	1.85
	B1.A2	Kanban Implementation.	3.50	1.83
	B1.A3	Equipment layout for continuous flow.	3.69	1.83
	B1.A4	Statistical Process Control.	3.64	1.86
	B1.A5	Total Productive Maintenance.	3.27	1.82
	B1.A6	Just in time delivery by supplier.	3.21	1.89
Soft Lean Practices (SLP)	B1.A7	Employee involvement (e.g. Suggestion Scheme).	3.87	1.70
	B1.A8	Total Quality Management.	3.38	1.95
	B1.A9	Continuous improvement techniques.	4.47	1.41
	B1.A10	Training Employees.	4.51	1.39
	B1.A11	Supplier partnership.	3.45	1.89
	B1.A12	Customer involvement.	3.23	1.97

Table 11 HLP, SLP and descriptive statistics.

Category	Item Code	Item Description	Mean	SD
STRATEGIC DIFFICULTIES	C1.A1	Top managements disregard lean projects.	2.08	1.16
	C1.A2	Lean project goal is not clear.	2.56	1.17
	C1.A3	Unclear future vision.	2.96	1.13
	C1.A4-5=Max {C1.A4; C1.A5}	Unclear Starting Point.	2.81	1.04
	C1.A6	Project are not in line with organization bonus, rewards or incentives systems.	3.30	1.33
ECONOMIC DIFFICULTIES	C1.B1-2=Max {C1.B1; C1.B2}	Lack of economic availability for the initial Employees' training course.	3.86	1.70
	C1.B3-4=Max {C1.B3; C1.B4}	Lack of economic availability for the initial Top managers' training course.	3.38	1.95
	C1.B5-6=Max {C1.B5; C1.B6}	Lack of economic availability for invests in Lean program.	4.47	1.39
	C1.B7	Lack of economic availability for initial Outside experts support.	4.51	1.41
	C1.B8	Lack of Human resources to invest initially in lean program.	3.44	1.89
	C1.B9	Lack of Technical resources to invest initially in lean program.	3.22	1.97
SUPPLY CHAIN INTEGRATION	C1.C1	Difficulties in involving customer in lean projects start-up.	3.74	1.10
	C1.C2-3-4-5= Max {C1.C2; C1.C3;	Difficulties in involving supplier in lean	3.98	0.96

DIFFICULTIES	C1.C4; C1.C5}	projects start-up.		
	C1.C6	Difficulties in involving Carriers and logistic providers in lean projects start-up.	3.81	1.08
HUMAN DIFFICULTIES	C1.D1	Top management disapproval of lean projects start-up.	3.01	1.16
	C1.D2	Personnel support disapproval of lean projects start-up.	2.34	1.23
	C1.D3-4= Max {C1.D3; C1.D4}	Employees do not actively participate to lean projects start-up.	2.74	1.11
	C1.D5	Leadership refusal to participate in lean start-up projects.	2.64	1.20
CULTURAL DIFFICULTIES	C1.E1	Lack of cross-functional group.	2.64	1.29
	C1.E2	Personnel unresponsiveness.	2.7	1.11
	C1.E3	Top manager's unresponsiveness.	2.73	1.12
	C1.E4	External experts are not well accepted.	2.90	1.36
	C1.E5	Any training roadmap to the personnel has been decided.	2.91	1.40
	C1.E6	Low education of employment.	3.22	1.25

Table 12 Lean start-up difficulties (LSUD) and descriptive statistics.

Category	Item Code	Item Description	Mean	SD
STRATEGIC DIFFICULTIES	C2.A1	Ineffective Road Map of future activities.	2.98	1.37
	C2.A2	No Performance measurement systems.	2.44	1.16
	C2.A3	Absence of incentives systems.	3.46	1.28
ECONOMIC DIFFICULTIES	C2.B1	No Human resource Availability for sustaining the project.	3.14	1.15
	C2.B2	No economic availability for sustaining lean program.	3.09	1.20
	C2.B3	No economic availability for external experts support.	3.16	1.12
	C2.B4-5= Max {C2.B4; C2.B5}	No economic availability for Employees' training courses.	2.96	1.36
	C2.B6-7= Max {C2.B6; C2.B7}	No economic availability for Top managers' training courses.	2.58	1.08
	C2.B8-9= Max {C2.B8; C2.B9}	Managers' decision-making.	3.1	1.15
SUPPLY CHAIN INTEGRATION DIFFICULTIES	C2.C1	Unclear communication with customers.	3.7	1.10
	C2.C2	Suppliers are not using lean system.	4.1	0.91
	C2.C3	Supplier management department has no interaction with the other organizational structures.	3.82	1.13
	C2C4	Carriers and logistic providers are excluded	3.75	1.00

		from lean projects.		
	C2.C5-6-7= Max {C2.C5; C2.C6; C2.C7}	Hindrance of suppliers.	3.13	1.12
	C2.C8	Suppliers are far from the company.	3.54	1.02
HUMAN DIFFICULTIES	C2.D1-2-3= Max {C2.D1;C2D2,C2D3}	Managers do not support lean journey.	3.04	1.19
	C2.D4	Difficulties in changing the mind-set of workers.	3.46	1.10
	C2.D5	Teams are not autonomous.	2.98	0.95
	C2.D6	Workplace administrated by mangers.	3.14	1.09
	C2.D7	Lack of cooperation and mutual trust between managers and workforce.	2.85	1.05
	C2.D8-9= Max {C2.D8;C2.D9}	Lack of communication.	2.5	1.06
	C1.D10	Lack of different functional area awareness.	3.06	1.22
CULTURAL DIFFICULTIES	C2.E1	Lean culture is not supported.	2.83	1.25
	C2.E2	Group oriented activities are not supported.	2.68	1.17
	C2.E3	Lack of personnel responsiveness.	2.84	1.11
	C2.E4	Lack of top managers' responsiveness.	2.73	1.09
	C2.E5	Outside experts not well accepted.	2.86	1.23
	C2.E6	Absence of cross-functional group.	2.77	1.06

C2.E7	Lean terminology is not used.	2.85	1.03
C2.E8	Low education of employment.	3.23	1.20

Table 13 Lean maintaining difficulties (LMAD) and descriptive statistics.

4.2.2 Measurement scale asses- Lean barriers

In order to verify whether there is a relationship between the observed variables and their underlying latent constructs, we ran a pooled Confirmatory Factor Analysis (CFA) using R ("R: The R Project for Statistical Computing").

Three constructs have been analysed: Lean management implementation (LMI), Lean start-up difficulties (LSUD) and Lean maintaining difficulties (LMAD). The first model, concerned LMI, examined HLP and SLP. The second and third models concerned LSUD and LMAD respectively and include 6 latent variables each.

Tables 14-15-16 report CFA results for measurement models. The final measurement models have excellent fit to the observed data. In fact, the Normed Chi-square is between 2 and 5, the comparative fit index (CFI) are greater than 0.9 and the Root mean square error of approximation (RMSEA) are values between .08 and 0.1 that indicate a reasonable error of approximation (Hair et al., 2006). In each CFA, all standardized factor exceed 0.5, and all the corresponding z-values are statistically significant (z-values statistically significant at $p<0.001$).

Internal consistency reliability to test unidimensionality was assessed by Cronbach's alpha (Cronbach, 1951). Resulting factors are all characterized by sufficient reliability, which is always in the range of high (0.70- 0.89) and very high (0.90- 1.00) values, indicating that the resulting items contribute to the factors identified. The measure of Composite Reliability (CR) exceeds 0.6, the average variance extracted (AVE) exceeds 0.5 and thus the discriminant validity was also assessed.

Construct	Item	Standardized factor loading	z-value	CR	AVE	Cronbach's alpha
HARD LEAN PRACTICES (HLP)	B1.A2	0.686	$-^{a}$	0.775	0.54	0.817
	B1.A3	0.620	6.220			
	B1.A4	0.664	6.620			
	B1.A5	0.773	7.552			
		0.567	5.757			
SOFT LEAN PRACTICES (SLP)	B1.A6	0.760	$-^{a}$	0.818	0.50	0.85
	B1.A7	0.684	7.650			
	B1.A8	0.821	9.162			
	B1.A9	0.833	11.932			
	B1.A10	0.556	6.118			
	B1.A11	0.590	5.952			
	B1.A12	0.760	6.220			

Table 14 LMI model: $\chi^2(36) = 54.32$; RMSEA =.0.064 [0.023- 0.097]; CFI=.976.

$-^{a}$ Indicates a parameter fixed at 1.0 in the original solution.

Construct	Item	Standardized factor loading	z-value	CR	AVE	Cronbach's alpha
STRATEGIC DIFFICULTIES (S_SU)	C1.A1	0.665	$-^{a}$	0.863	0.520	0.858
	C1.A2	0.828	9.956			
	C1.A3	0.832	8.026			
	C1.A4	0.816	7.901			
	C1.A5	0.623	6.249			
	C1.A6	0.581	5.898			
ECONOMIC DIFFICULTIES (E_SU)	C1.B1	0.839	$-^{a}$	0.935	0.711	0.958
	C1.B2	0.913	15.662			
	C1.B3	0.702	8.945			
	C1.B4	0.891	13.652			
	C1.B5	0.907	12.473			
	C1.B6	0.840	18.158			
	C1.B7	0.891	11.898			

	C1.B8	0.831	11.183			
	C1.B9	0.824	11.054			
SUPPLY CHAIN INTEGRATION DIFFICULTIES (SCI_SU)	C1.C2	0.981	$-^{a}$	0.907	0.787	0.948
	C1.C3	0.833	15.477			
	C1.C4	0.828	15.059			
	C1.C5	0.928	21.671			
HUMAN DIFFICULTIES (H_SU)	C1.D1	0.826	$-^{a}$	0.85	0.648	0.919
	C1.D2	0.777	10.097			
	C1.D2	0.798	10.549			
	C1.D4	0.767	9.958			
	C1.D5	0.851	13.820			
CULTURAL DIFFICULTIES (C_SU)	C1.E1	0.733	$-^{a}$	0.899	0.600	0.896
	C1.E2	0.839	9.639			
	C1.E3	0.790	9.037			
	C1.E4	0.751	8.536			
	C1.E5	0.828	9.533			

Table 15 LSUD model: $\chi^2(361)$ = 795.26; RMSEA =.09 [0.089-0.108]; CFI=.903.

$-^{a}$ Indicates a parameter fixed at 1.0 in the original solution.

Construct	**Item**	**Standardized factor loading**	**z-value**	**CR**	**AVE**	**Cronbach's alpha**
STRATEGIC DIFFICULTIES (SD_MA)	C2.A1	0.689	$-^{a}$	0.757	0.512	0.758
	C2.A2	0.698	7.030			
	C2.A3	0.761	7.529			
ECONOMIC DIFFICULTIES (E_MA)	C2.B1	0.907	$-^{a}$	0.928	0.697	0.955
	C2.B2	0.930	17.608			
	C2.B3	0.836	13.673			
	C2.B4	0.855	14.145			
	C2.B5	0.861	19.652			
	C2.B6	0.863	13.548			
	C2.B7	0.796	12.158			

	C2.B8	0.694	9.523			
	C2.B9	0.694	9.519			
SUPPLY CHAIN INTEGRATION DIFFICULTIES (SCI_MA)	C2.C1	0.745	$-^{a}$	0.850	0.541	0.840
	C2.C2	0.810	8.935			
	C2.C3	0.852	9.406			
	C2.C4	0.740	8.384			
	C2.C5	0.502	5.376			
HUMAN DIFFICULTIES (H_MA)	C2.D1	0.613	$-^{a}$	0.854	0.567	0.918
	C2.D2	0.582	17.144			
	C2.D4	0.605	5.885			
	C2.D6	0.807	7.257			
	C2.D7	0.773	10.268			
	C2.D8	0.862	7.587			
	C2.D9	0.869	7.620			
	C2.D10	0.833	7.399			
CULTURAL DIFFICULTIES (C_MA)	C2.E1	0.854	$-^{a}$	0.937	0.653	0.935
	C2.E2	0.916	14.505			
	C2.E3	0.774	10.700			
	C2.E4	0.853	12.684			
	C2.E5	0.737	9.101			
	C2.E6	0.845	12.405			
	C2.E7	0.767	10.668			

Table 16 LMAD model: χ^2 (460)= 922.91; RMSEA =.09 [0.082-0.099]; CFI=.902.

$-^{a}$ Indicates a parameter fixed at 1.0 in the original solution.

4.2.3 Network characteristics and visualization

The highly interconnected nature of company dynamics indicates that it is limitative to consider company characteristics, national culture, lean practices and lean difficulties in different phases as being independent of one another or interconnected partially. Indeed, without deciphering these links, our understanding of LM barriers will remain incomplete. Thus, comprehending all relationships between company characteristics, national culture, lean practices and success, strategic, human, cultural, supply chain and economic barriers in start up and sustaining phase is essential for a deeper unravelling of LM. Hence, considering the results of the association rules reported in appendix 3, 3 networks have been realized: LMI, LSUD and LMAD (Figure 11; Figure 12; Figure 13).

The attractiveness of single nodes, estimated through the degree centrality (formula 8), is proportional to their diameter in figures and their normalized values (degree of centrality divided by the maximum value per network) reported in Table 17.

Variables	**Degree centrality**		
	LMI	**LSUD**	**LMAD**
Country=2	32.0%	27.2%	24.0%
Country=3	/	34.6%	/
Sector=ELECTRICAL AND MECHANICAL MACHINERY AND EQUIPMENT	30.5%	/	/
Country Culture= Latin Europe	/	/	16.8%
A=2	46.2%	66.8%	98.7%
FO=2	/	51.1%	23.6%

FO=3	/	/	59.1%
GC=2	91.6%	51.1%	23.9%
GE=3	40.9%	47.6%	63.6%
HO=2	57.8%	86.6%	58.6%
IC=3	/	/	48.3%
PO=3	91.6%	66.8%	87.0%
PD=1	/	/	30.3%
UA=2	57.4%	56.7%	33.4%
UA=3	/	60.0%	/
Dimension=SME	/	/	33.4%
Dimension=LARGE ENTERPRISES	58.9%	61.2%	77.6%
Complexity_of_production=2	27.5%	35.3%	/
Demand_variability=1	/	49.1%	/
Demand_variability=2	96.1%	79.0%	54.0%
SLP=3	77.8%	33.8%	16.8%
SLP=5	92.7%	100.0%	76.1%
HLP=2	53.0%	25.6%	17.1%
HLP=5	94.7%	51.3%	/
HLP=3	/	/	17.1%
Lean_Success=2	61.1%	60.4%	0.0%
Lean_Success=3	32.6%	61.9%	16.8%
Lean_Success=4	50.1%	37.1%	/
E_SU=1	36.5%	36.1%	100.0%
C_SU=1	73.3%	49.9%	70.0%
H_SU=1	/	/	88.9%
H_SU=2	70.9%	37.1%	31.2%
S_SU=1	54.8%	54.2%	67.7%
S_SU=3	56.6%	36.3%	33.6%
E_SU=3	/	/	25.5%
E_SU=4	/	/	52.0%
C_SU=3	38.7%	43.7%	86.3%
H_SU=1	32.6%	58.4%	87.0%
H_SU=2	70.9%	37.1%	/
C_SU=4	/	/	88.7%
SCI_SU=3	/	40.2%	/

SCI_SU=5	53.0%	79.0%	/
C_MA=1	53.4%	/	71.8%
H_MA=1	36.3%	/	/
E_MA=1	37.5%	/	51.6%
S_MA=1	80.9%	/	56.2%
C_MA=3	38.7%	/	63.3%
E_MA=3	/	/	18.0%
H_MA=3	46.2%	45.6%	23.8%
SCI_MA=3	38.7%	38.3%	/
SCI_MA=4	43.2%	42.7%	/
C_MA=4	62.5%	61.7%	84.3%
E_MA=4	/	/	41.1%
S_MA=4	100.0%	98.8%	/

Table 17 Node centrality for LMI, LSUD, LMA network.

The arrows' thickness is proportional to the lift of the association rules (formula 7). If an arrow represents more than association rules, the lift values have been summed. Above each arrow, the name of the association rule represented is reported. Moreover, in order to analyse the structure of the network, the Modularity algorithm (Blondel et al., 2008) has been implemented in Gephi. It helps us to look for groups of nodes more densely interconnected internally than with the rest of the network. Different colours have been associated to different groups.

Figure 11 shows the Moderating effects of variables on different level of Lean success and distinct degrees of Soft and Hard lean practices (LMI network).

Many authors sustain that in order to remain competitive in developing or developed economies, companies need to reduce their production costs, improve quality and conformance to customers' specifications as well as to deliver goods faster and on time. If firms achieve these goals they will be able to survive in the present turmoil and to invest to improve their processes, systems and technologies. But, they do not mention that an effective Lean implementation (Lean_Success=4) is moderated mainly by human and cultural aspects. Indeed, few human obstacles in the start-up phase (H_SU=2), associated with medium level HO and GC, high degree of GE (rule r32) and PO (rule r31) bolster an high Lean_Success (Lean_Success=4). On the other end, focusing on the blue cluster, a cultural (r14) or strategic support (r20) in the maintaining phase with a medium value of UA (r14) or GC (r20) could lead to an unsuccessful lean management (Lean_Success=2). It is evident that an effective application of SLP (SLP=5) needs to be supported economically, strategically, humanly and culturally in the start-up and maintaining phase (rules: r1-2-4-6-7-8-9-10). On the other hand, HLP seems to necessitate mainly strategic and cultural support in the initial and further steps (r3-5-11-13).

Results from the network analysis (Table 17) indicated that S_MA=1; HLP=5; SLP=5; PO=3; GC=2; Demand variability=2 are the most central nodes in the LMI network.

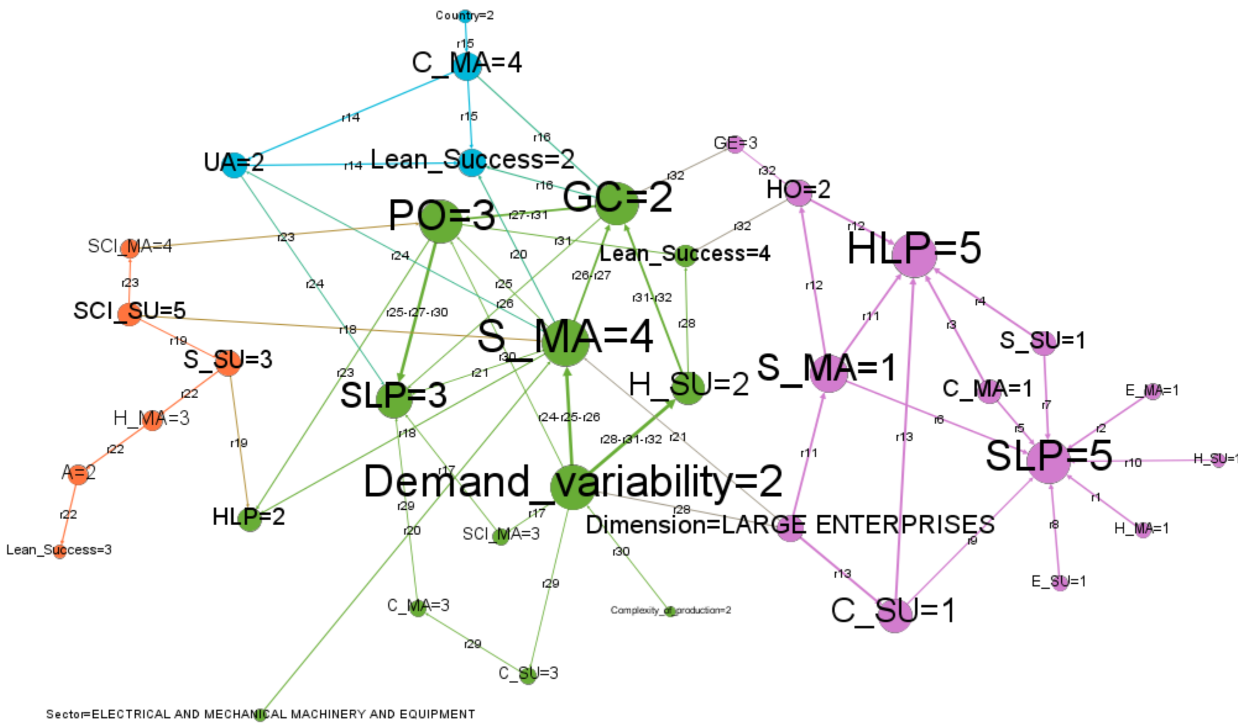

Figure 11 LMI Network

Figure 12 represents the interdependencies between variables influencing the economic, cultural, human and supply chain integration barriers in the start-up phase (LSUD network). An effective implementation of HLP is combined with low cultural and strategic barriers (r2-r1). The Green module highlights interrelationships between high implementation of SLP, Large enterprises, high GE, low demand variability, medium HO and really low human and economic barriers. With these same circumstances the SCI seems to be a medium obstacle (SCI_SU=3). Moreover, the high Centrality of HO=2 and SLP=5 highlights how they are the hub of the green and blue module. The pink cluster contains as RHS item-sets the SCI barriers (SCI_SU=5) and a little and moderate effect of human and strategic barrier (H_SU=2; S_SU=3). In this cluster it's possible to notice how lower level of soft lean practices, high degree of PO and UA and, medium GC, FO and A are related to high supply chain barriers in the initial phases. High PO and medium A in courtiers classified as group 3 are even linked to high supply chain barriers.

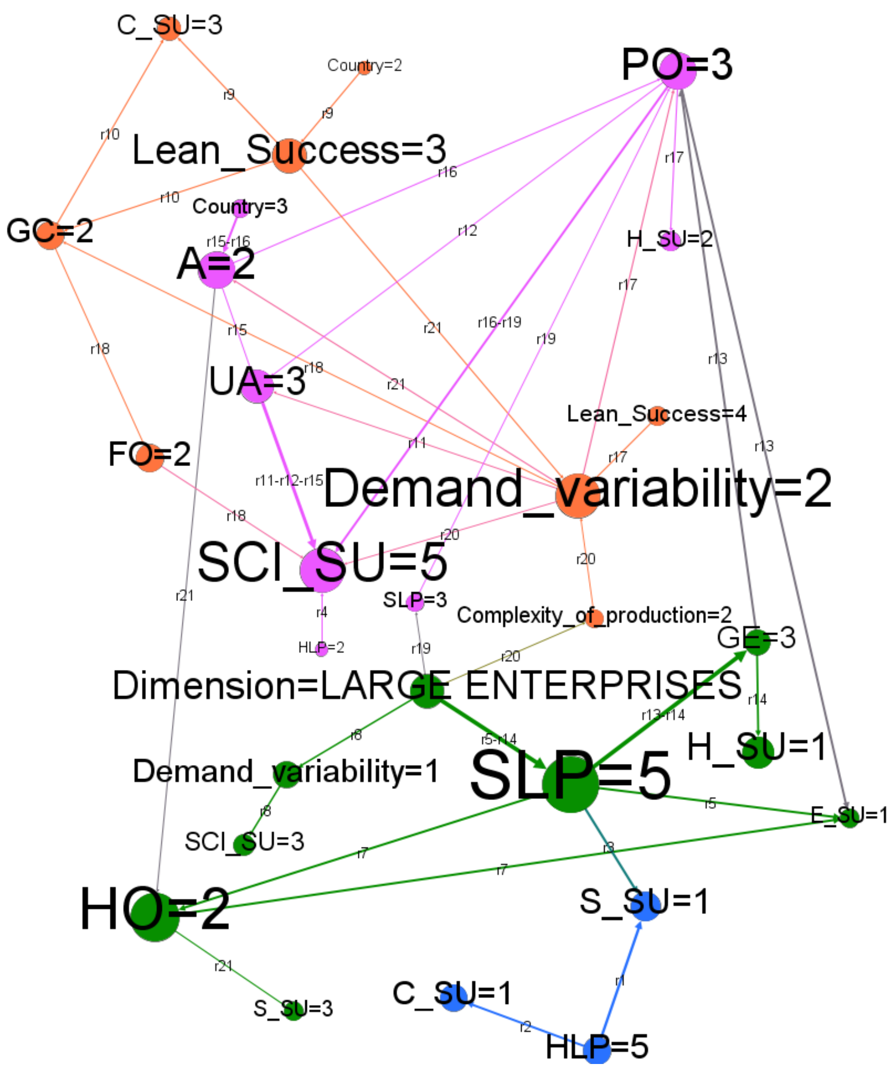

Figure 12 LSUD Network

Figure 13 represents the factors influencing the LMAD. Results shows how a cultural support in the maintaining phase could be achieved by a high degree of soft lean practices, high PO, and cultural, human, strategic and economic support in the first phase of the lean projects (r4/9). It's interesting to note how Large and SME respectively belong to 2 different modules part of the network. The module to which Large enterprises belong is characterized by a high level of SLP and low level of lean barriers in the start-up and maintaining phase. In particular, in large companies, low strategic barriers in the maintain phase (S_MA=1) are enabled mainly by high attention to soft lean practices (SLP=5), economic and human support in the start-up phase (H_SU=1; E_SU=1) and GE=3.

Rules 26-27-28 and 29 show these relationships. Moreover from the arrow 21, 22, 23 and 24 it's evident that in large companies, even the low economic and cultural barriers in the sustaining phase are enabled by the previous factors. But, on the left part of the network, on the edge of the 2 clusters, we found a group of rules (r39-r48/r56) linking large enterprises with a moderate cultural lean barrier (C_MA=3). Hence, focusing on this part of the network, it can be inferred that cultural barriers in the start-up phase drag on the further phases. Moreover, high level of FO, PO and IC with medium levels of GC, HO and A seem to affect the cultural issue. These problems seem to affect more than others, countries classified in Group 2 and Latin Europe (r48-49). Moving on the pink cluster, which the SMEs belong to, high levels of cultural barriers represent the main problem. Little attentions to the economic and cultural aspects combined with a low PD seem to negatively influence cultural barriers in SMEs during the maintaining phase (r11-12-13). Finally, results from the network analysis (Table 17) indicated that in the green cluster SLP=5; E_SU=1; C_SU=1 and Large Enterprises are the most central nodes, whereas in the pink cluster A=2; GE=3; PO=3 and C_SU are the most central.

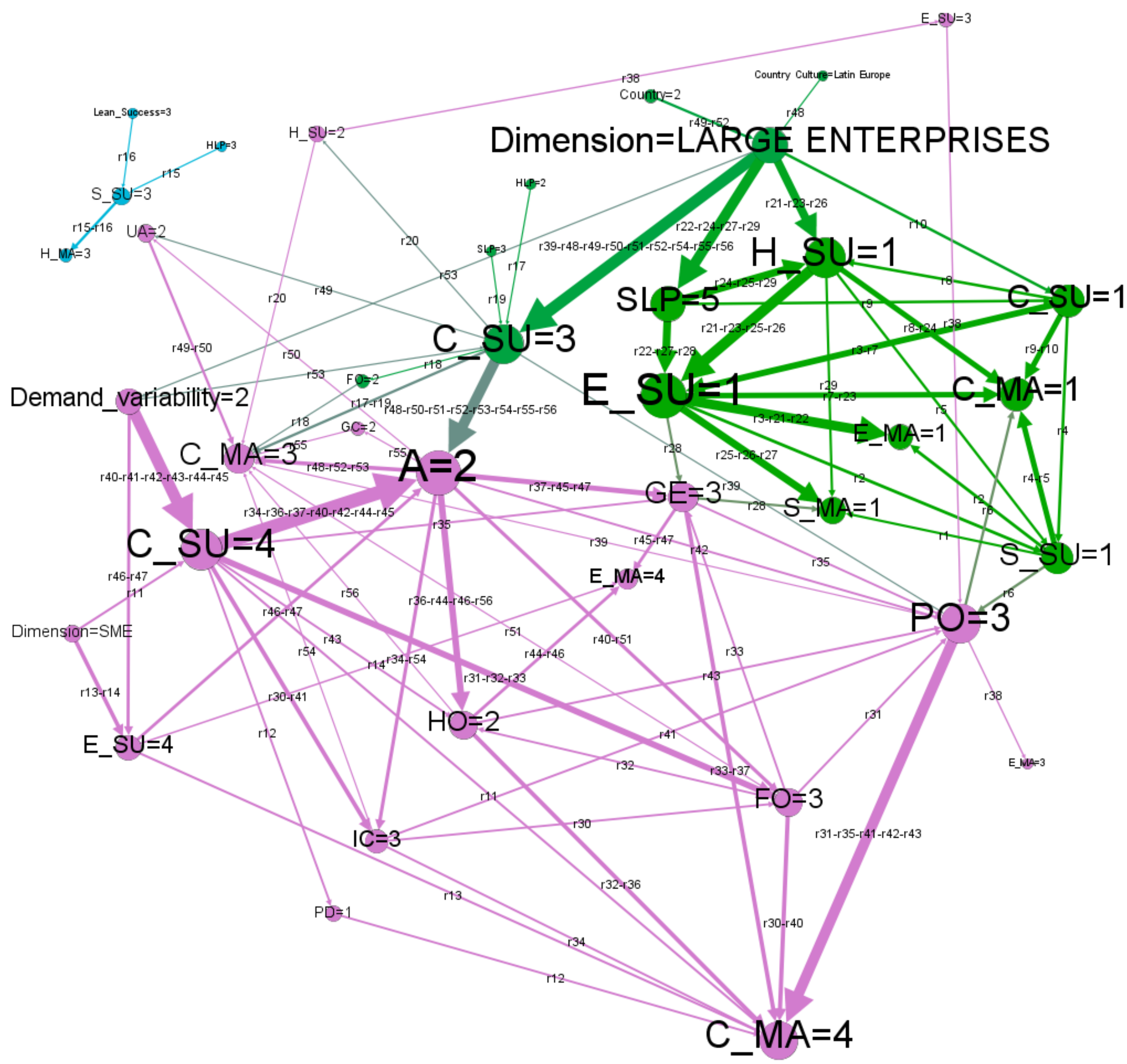

Figure 13 LMAD Network

4.3 Lean Structural Network Resilience results

For developing the third part of this thesis, the company selected is a German-based manufacturing facility. The facility presented a workforce of 500 people and 34 managers distributed within three management levels E1–E2–E3 being E1 the highest in hierarchy. The inter-process standard $(CPD)_nA$ was implemented within the 34 managers and the evolving dynamics followed a hierarchical and value-stream oriented preferential attachment.

Eleven managers part of such network have been involved for this specific study and figure 14 is a graphical representation of their hierarchies.

The LSN considered for testing the simulator of a node modelling behaviour is reported in figure 15. Each arrow is a reporting line between two managers and represents a $(CPD)_nA$. Five months daily data related to each $(CPD)_nA$ have been collected.

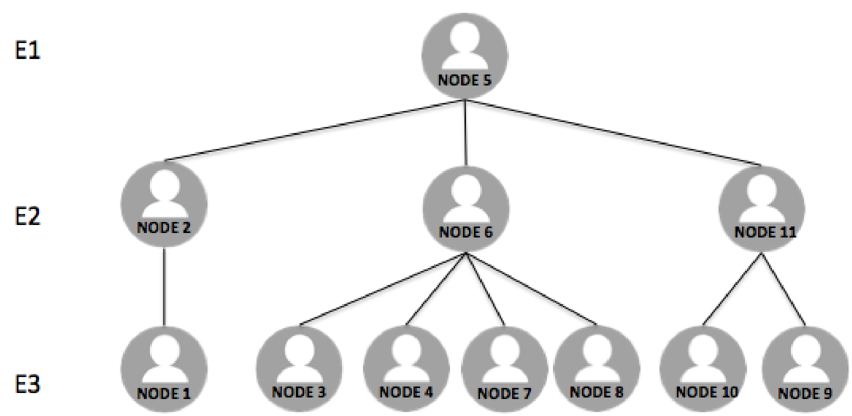

Figure 14 Organigram of the eleven managers considered as case study.

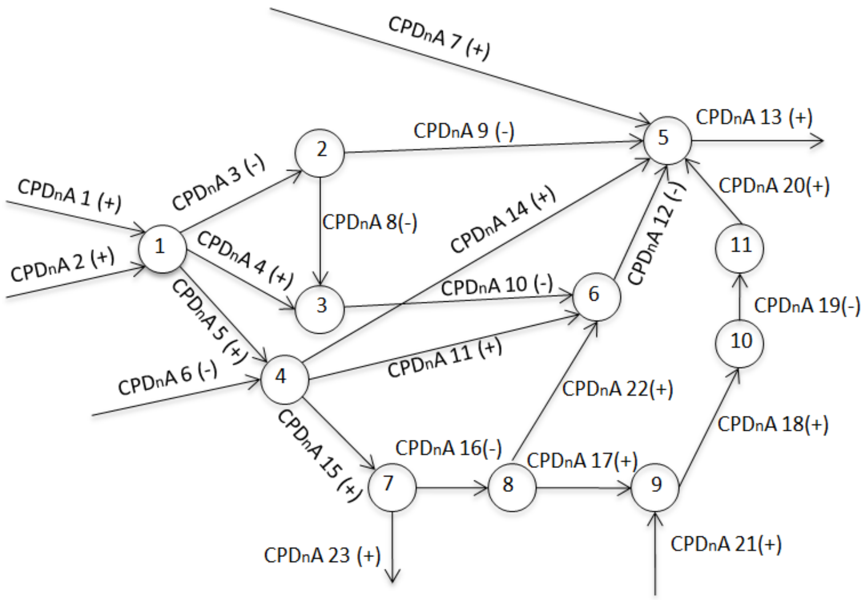

Figure 15 Lean structural network case study.

4.3.1 Nodes' modelling and characterization results

For this section two sample nodes (node 3 and 6) with two and three CPDnA in entrance respectively have been taken into account. The behaviour of node 3 and 6 has been modelled as described in section 3.2.

After, through the GA, the parameters w, p, r, k, and the probability distribution of the Markov chain (OPTIMISTIC-OPTIMISTIC: P_{OO} ; OPTIMISTIC-PESSIMISTIC: P_{OP}; OPTIMISTIC-NORMAL: P_{ON}; PESSIMISTIC-OPTIMISTIC: P_{PO} ; PESSIMISTIC-PESSIMISTIC: P_{PP}; PESSIMISTIC-NORMAL: P_{PN} ; NORMAL-OPTIMISTIC: P_{NO} ; NORMAL-PESSIMISTIC: P_{NP}; NORMAL-NORMAL: P_{NN}) which minimize the difference between the data generated by the simulation and previously acquired data from the real system, have been calculated.

Hence, our optimization procedure starts with the definition of the genetic algorithm used. The type "real-valued" of genetic algorithm has been run because of the nature of decision variables (floating-point representations of real numbers). The population size for each generation has been imposed equal to 2000. Small perturbations were applied to 5% (mutation percentage) of the parameters of each child in order to explore nearby solutions. Moreover the maximum number of iterations to run before the GA search is halted has been imposed equal to 5000 and, the number of consecutive generations without any improvement in the best fitness value before the GA is stopped equal to 200.

Figure 16 shows the 2 sample nodes' parameters results and the value of the fitness function (SMAPE) for each node that measures how closely the model prediction matches the expected data.

The trend produced by the node simulators for one-month data is close to the trend observed by the real data. Indeed the SMAPE is equal to 0.086 for node 3 and 0.099 for node 6.

The last column of Figure 16, reports the parameters that characterize the learning curve of the process owner (k, p, r), the weight of each $(CPD)_nA$ in entrance in the node (w) and the probability distribution of the Markov chain. In node 3 the $(CPD)_nA$ in entrance has a total weight approximately of 70%. It means that, for the remaining 30%, the nodes' behaviour are not influenced by the $(CPD)_nA$ in input, but there are other factors such as the process owner behaviour (active, passive, aggressive).

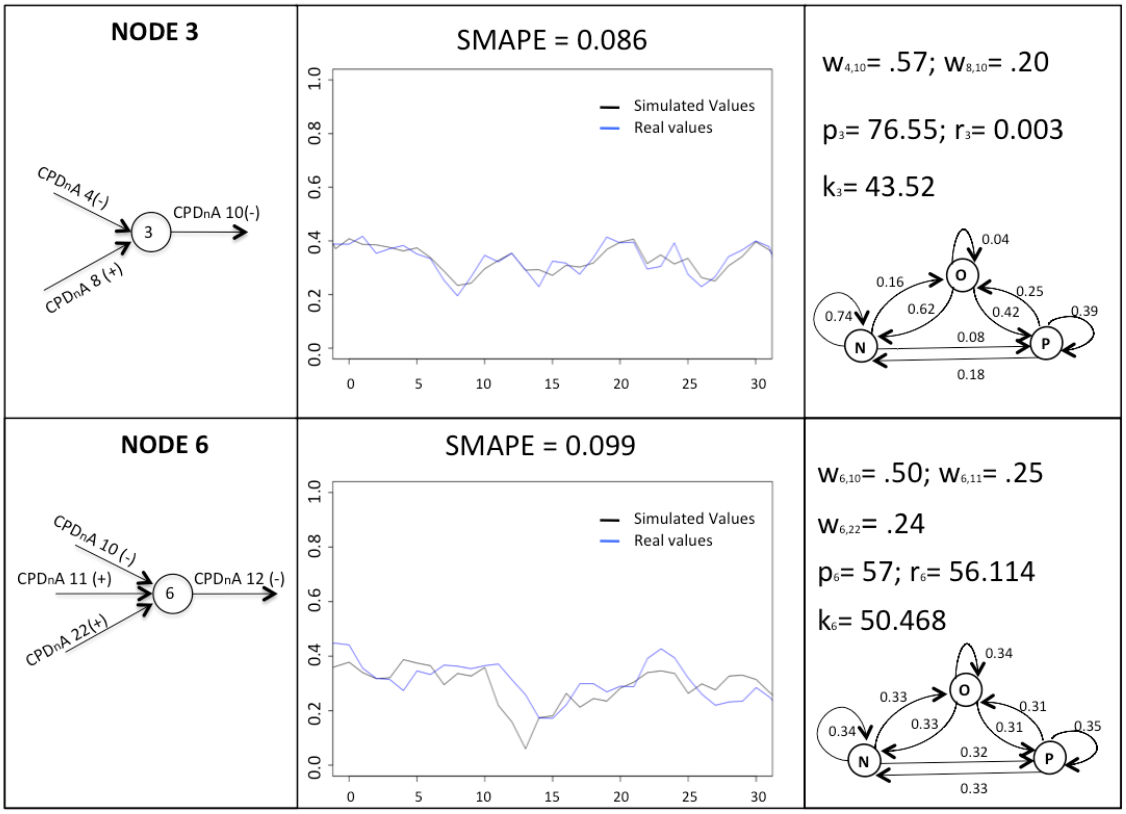

Figure 16 Node 3 and Node 6 example of characterization

Those examples exhibited in Figure 16 enable us to estimate individual behaviour for our process owner virtual model that could explain the evolution of KPIs according to their inputs. It is necessary to highlight that it is not enforced that the real process owner will behave like its virtual counterpart but, at least, it could be reasonable behaviour. Therefore, based on the effect at KPI level, it can be kept as the best estimation for its behaviour and it can be compared to those from other process owners.

4.3.2 Lean Structural network resilience calculation

After having demonstrated that our mathematical model is able to reproduce a reliable node behaviour, and have characterized each node, we expose the LSN to different changing events.

The first event generated is a peak in the KPI trend. This peak could be caused by a broke down of the machine associated to a random node or a decrease of operator's performances. For this specific case we suppose that the node 4 is affected by a technical problem. The parameters that describe the behaviour of node 4 are reported in Table 18.

NODE 4	
k	50
p	5
r	20
P_{OO}	0.30
P_{OP}	0.20
P_{ON}	0.50
P_{PP}	0.25
P_{PN}	0.50
P_{PO}	0.25
P_{NO}	0.20
P_{NP}	0.30
P_{NN}	0.50
$w_{5,11}$	0.80
$w_{5,14}$	0.50
$w_{5,15}$	0.70
$w_{6,11}$	-0.20
$w_{6,14}$	-0.50
$w_{6,15}$	-0.30

Table 18 Node 4 characterization

The technical problem on Node 4 caused a decreasing on the performances of the KPIs associated to the $(CPD)_nA$ in output to the node ($(CPD)_nA$ 11; $(CPD)_nA$ 14; $(CPD)_nA$ 15). The top part of Figure 17 shows the 3 different peaks on the $(CPD)_nA$ 11, $(CPD)_nA$ 14 and $(CPD)_nA$ 15 generated by a problem on node 4. As explained in section 3.5, the local resilience is calculated as the maximum value of the areas included between the KPI trend, associated to the edges in output from the node affected, since the time of the disruption event and the straight line parallel to the time axes, passing through KPI_e. Thus, the Local resilience for this specific case is equal to 2.96 and it is the maximum value of the 3 areas calculated for each peak and reported on the top of each $(CPD)_nA$ trend.

As we are interested not only in the local effect but even in the global effect, we analyse and compute the propagation of the 3 peaks on the ending edge of the network ($(CPD)_nA$ 13 and $(CPD)_nA$ 23). The global resilience is equal to 3,74 and, as detailed in section 3.5, it has been calculated as the sum of the areas included between the variations of network KPI trend against time. Hence the LSNR for this specific event is equal to 1.25.

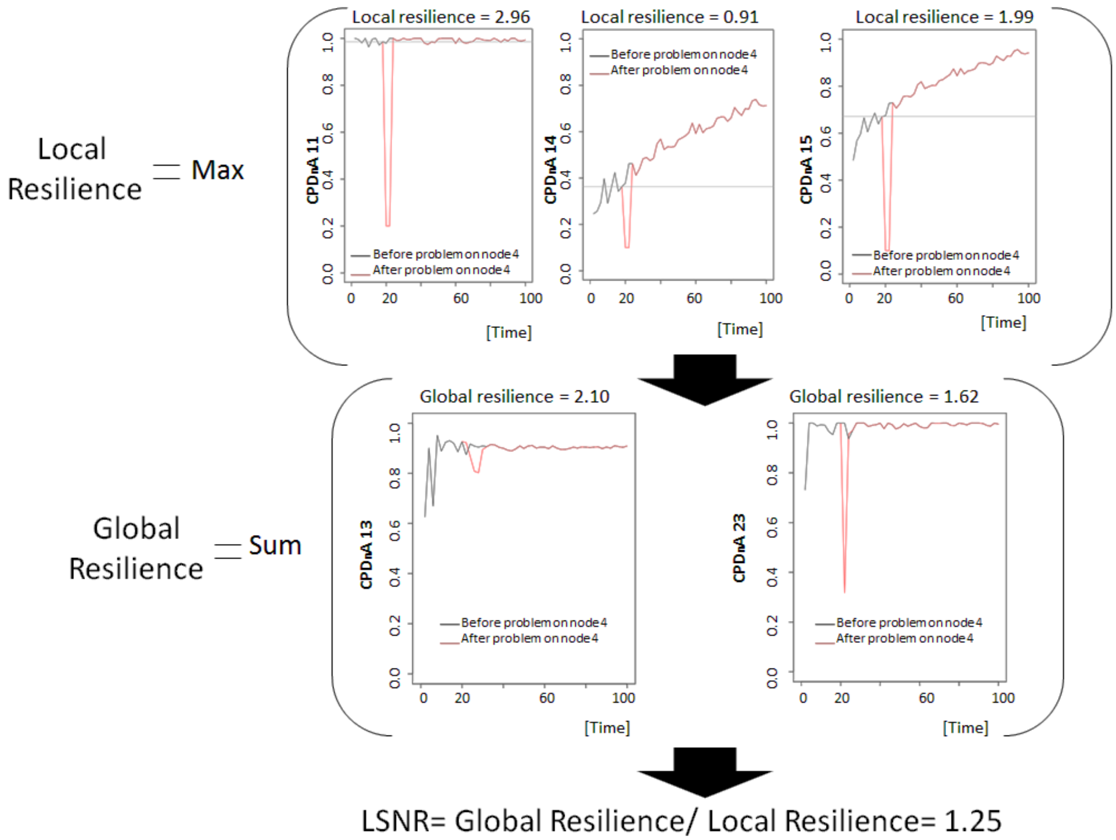

Figure 17 Example of LSNR calculation when the machine associated to node 4 is affected by a problem.

The second event responsible for the peak is a different learning curve associated to the process owner. Indeed in this example we suppose that the process owner represented by node 4 is replaced by a process owner with a different learning curve.

In particular, the Leaning process of operator 4, described by k, p, r equal to 50, 5 and 20 respectively, has been substituted with a process owner that we supposed to have a faster learning process but without experience on this task (k=10; p=0; r=30). Results of this simulation are shown in figure 18.

The 3 areas, calculated as defined in section 3.2 measure respectively 0.44, 0.01, 0.06 for $(CPD)_n$A 11 -14 and 15. Hence, as described by the denominator of formula 13 the local resilience is equal to the maximum of the three values equal to 0.44. Global resilience is represented by the sum of the two values on the bottom of the figure 18. It is possible to note as the global resilience of $(CPD)_n$A 13 has a negative value. It means that the substitution of process owner 4 with a less experienced worker does not impact the KPI associated to $(CPD)_n$A 13. On the contrary it improves slightly the performances of the KPI linked to $(CPD)_n$A 13. LSNR for this specific case is equal to 1.32.

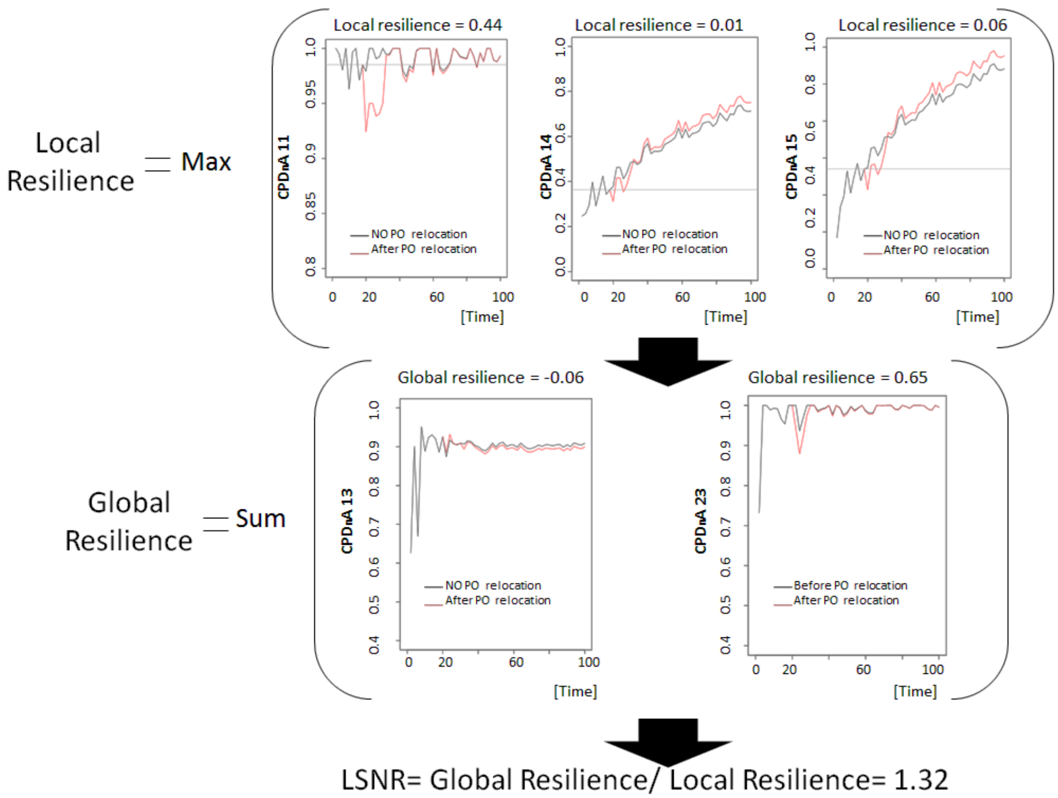

Figure 18 Example of LSNR calculation when the process owner associated to node 4 is substituted by a process owner with a different learning curve (k=50; p=5; r=20).

Results shown on this section are just 2 possible simulations that could be done on the LSN considered. Other possible simulation, to which researchers and practitioners could be interested are changes in the aptitude of the process owner. Indeed, in this case, the probability distribution that characterize node 4, describes the aptitude of the process owner associated to this node as constantly normal.

Figure 19 shows the local effect on $(CPD)_nA$ 14 of what would happen if the aptitude of a process owner switch from normal to pessimistic from the instant t=40.

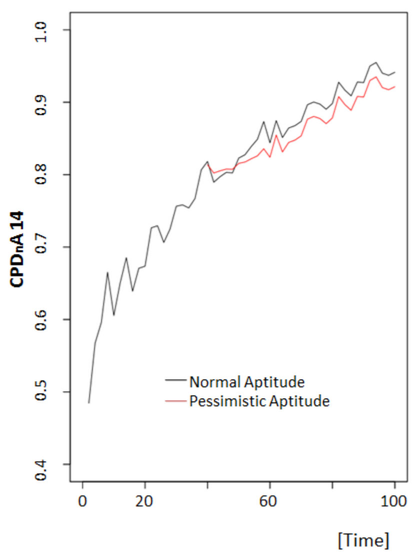

Figure 19 Trend of KPI associated to $(CPD)_nA$ 14. Local effect of change of aptitude from normal to pessimistic from t= 40.

Chapter 5.

Discussion

A number of theoretical and practical contributions can be highlighted by results obtained in this thesis. In the following sections a discussion of these results has been provided according to research model proposed in section 3.

5.1 Discussion of results linking Lean practices, operational responsiveness and firms' growth performances

5.1.1 Relationships between lean practices and operational responsiveness

The study of Qrunfleh and Tarafdar (2013) demonstrated that the supply chain responsiveness is not increased by the presence of Lean strategy. Taking into consideration this result, the first part of this thesis aims at examining the reason of this difficulty from an operational point of view. With this aim, operational responsiveness has been split into 3 main factors: *Product mix variety, Product innovation* and *Time effectiveness*.

In particular, our work confirmed Hypothesis 1a, which sustains that the lean practices implementation is negatively related to the *Product mix variety*. The negative loading of the regression weight could be explained by three reasons: Variance in products, variance in routings and variance in cycle time. The number of products causes a non-repetitive process with different process routings, or order of stations it has to visit and different capacity requirements of a specific machine, which limits the predictability of the process and the capacity of obtaining a pulled production. Indeed, the “Pull production/Kanban implementation” (JIT_1) is the observed variable that most negatively affects the *Product mix variety* and in particular the batch size variation (PM_3), (Pearson Correlation= -.170; p=0.007).

Hypothesis H1b, which sustains that the *Product Innovation* is positively connected to lean best practices for manufacturing firms is not accepted. The regression weight between Lean best practices and product innovation is negative for H1b, in discordance with previous studies (Ellis, 2016; George Byrne et al., 2007; Reinertsen and Shaeffer, 2005; Yang et al., 2011a). Implementing Lean in innovation successfully require a rethink of the company culture, which identifies needs for improvement and is prepared for constant change (Johnstone et al., 2011). Indeed it is more than only the usage of the right methods and tools, participants have to be involved and get used to a continuing improvement process.

Thus maintaining a competitive advantage in research and development requires not only increases in effectiveness, but also in efficiency of R&D (Johnstone et al., 2011). Systematic methods for lean in innovation, such as the Value System developed by Schuh (2008), cannot be set up one-time but strategies should be applied on a long term basis.

Another reason for these negative regressions could be found in the study made in 2007 about Italian lean production implementation (Staudacher and Tantardini, 2008). They sustain that the Lean approach opens the way to address managerial levers to improve competitiveness, whilst non lean implementers rely much more on technology and innovation. In order to demonstrate this, they grouped actions according to whether they were related to Management, Technology innovation/automation, or Product Innovation. The results show that the 70% of corrective actions selected by lean implementers are in the management area, while only 45% for non-lean implementers. On the contrary, 45% of non-lean implementers' selections are in the technology and product innovation area and only 20% of lean implementers.

According to this result we can conclude that the cause of the negative regression could be found in the poor perseverance of companies in sustaining Lean in innovation probably because the interest of lean implementers is more on product and process improvement, rather than technology and product innovation.

In order to further investigate the reason of the negative regression and see what variable mainly affects it, the relationship between the observed variables describing Lean best practices and product innovation has been studied. The results shows that "Lean Management training" (WF_3), "Process feedback" (TQM_3) are negatively correlated with the percentage annually invested in R&D (INN_1), (INN_1-WF_3: Pearson Correlation=-.232; p=0.027; INN_1-TQM_3: Pearson Correlation=-.201; p=0.002).

In our work *Time effectiveness* latent variable is the one of the primary performance outcomes associated with leanness. This result confirms the studies carried out by several authors (Christopher and Towill, 2000; Narasimhan et al., 2006; Rachel Mason- Jones et al., 2000; Shah and Ward, 2003) where the Time effectiveness variables (assuring short "Mean time of stock" in the warehouse, a high "Inventory turnover" and a "Speedy response time to Warranty claim") are positively related to the lean practices implementation (H1c). In accordance with Matt and Rauch (2013) this result demonstrates that, even if in the majority of the cases, enterprises fear that implementing lean manufacturing is costly and time consuming, they are not only applicable in small enterprises but also bring about improvements and advantages in terms of Time effectiveness.

Moreover, some interesting and unexpected results emerged analysing further the link between *Time effectiveness* and the variables belonging to Lean practices. In particular, "Supplier partnership" (SM_1) and "Involvement of supplier in the lean journey" (SM_2) can positively affect the "Speedy response time to Warranty claim" (TE_3), (TE_3-SM_1: Pearson Correlation=.313; p=0.002; TE_3-SM_2: Pearson Correlation=.455; p=0.005). Moreover, Quality lean practices impact positively on the Inventory turnover (TE_2- TQM_1: Pearson Correlation=.333; p=0.005; TE_2- TQM_2: Pearson Correlation=.201; p=0.002; TE_2- TQM_3: Pearson Correlation=.301; p=0.006).

5.1.2 Relationships between lean practices and growth performance

From this study, it emerged even that there is not a direct relationship between lean best practices implementation and company growth performance (H2a-d).

Our result disagrees with the study of Salles et al. (2011), where it emerged that in the Spanish and Portuguese auto parts industries, those players that do not apply the lean approach, or those that do not apply it consistently, have great difficulty obtaining above average results compared with their competitors. Indeed, as practitioners have seen improvements through the use of the technical lean manufacturing tools derived from the Toyota Production System, it is natural to postulate that the use of the same tools could lead to firms' improvements. But, although in literature a number of authors have argued that many companies have successfully deployed Lean initiatives, a significant number of companies have failed to gain any benefits from their deployment and other companies have failed to achieve the expected results (Maneesh Kumar et al., 2008; Martínez-Jurado and Moyano-Fuentes, 2014; Netland, 2016). In order to find reasons of missed connection between lean practices and growth performance, 39 managers, belonging to different sectors and companies, have been interviewed. What emerged from the interview was that many company managers do not see the implementation of lean practices, in any area, as a direct method to increase the growth performance of the firm. But many times the lack of systematic and sustainable approach along mouths, such as Value Stream Mapping, could lead to a misapplication of lean manufacturing tools. It could be the cause of additional waste of time and money and it may decrease the confidence employees and managers have in implementing lean manufacturing (Pavnaskar et al., 2003).

In addition, lack of training, education of operators and limited resources are serious limitations faced during the development of lean projects. Moreover the difficult economic circumstances made it even harder for the SMEs to obtain financing from banks, capital markets or other credit suppliers. However, the poor collaboration and education of operators is not the main barrier to face. Indeed, top management commitment and involvement and the lack of communication are the main reasons for lean failure. Most large enterprises are aware of this, regardless of their choice of cultural models or success in using them, but many SMEs by default, reflect in their culture the personality of the owner/manager and are limited by this in terms of the changes they may be able to undertake.

Moreover contingency factors could influence the effect of lean practices on firms' performances (Büyüközkan et al., 2015). Indeed prior to implementing lean, it is important for organizations to understand the environmental context in which they are operating. Lean tools are nothing without the system thinking behind it. The same approaches could lead to different results maybe due to the effect of contextual factors and environmental conditions (Büyüközkan et al., 2015). Hence, a contingency theory approach to the deployment of Lean principles is necessary (Patrizia Garengo and Umit Bititci, 2007; Peter Hines et al., 2004).

Finally another explication of the absence of connection between firm growth performances and Lean practices could be the absence of any policy deployment (Hoshin Kanri) in the Lean practices. Indeed even if Hoshin Kanri is not as popular as some of the other lean tools, it is a method that increases the effectiveness of organizations, striving to get every employee pulling in the same direction at the same time (Diez et al., 2015b; Jackson, 2006). It achieves this by aligning the strategy of the company with the plans of middle management (Tactics) and the operations and thus, aiming at eliminating the waste that comes from inconsistent direction and poor communication.

According to this result it is evident that an increase of the firm's performance cannot be achieved by the application of lean concept in isolation at a company level.

5.1.3 Relationships between operational responsiveness and growth performance

Lastly, this study analysed the relationships between operational responsiveness characteristics of the company and the growth performance (stated in terms of employee growth variation, sales growth variation and customer retention). In particular, our work verified the relationship between *Product mix variety* and growth performance (H3a). The result implies that companies able to have a wide range of finished products and reconfigure the production system can positively influence their performance. The result is also consistent with the recent theoretical development that has endeavoured to demonstrate an early tautological problem in explaining the link between dynamic capability and company performance (Cepeda and Vera, 2007; Inman et al., 2011; Lewellyn and Bao, 2015).

Hypothesis H3c confirmed that also the *Time effectiveness* latent variable is an important characteristic for companies in the current market and it is directly linked to growth performance.

Hence, *Product mix variety* and *Time effectiveness* are the main characteristics of the operational responsiveness that positively influence company growth performance. In particular, *Time effectiveness* could be considered as an intermediate variable, called the "mediator", between lean best practices and company growth. The "mediator" helps to explain how or why an independent variable influences an outcome. Hence, a higher level of lean implementation could help companies to increase their *Time effectiveness* and it impacts positively on the growth performance of the firm.

Even the *Product mix variety* represents one of the key factors in order to reach better performance, but it cannot be used as a "mediator" because Lean best practices are not positively linked to the product variation.

5.2 Lean barriers, discussion of results

Many researchers have argued that the success of lean could depend on different factors such as company dimension, environmental complexity, incorrect focus on lean practices or human, cultural, economic, strategic or supply chain integration barriers. Lack of a complete overview leads us to investigate the main reasons for a lean success and failure. Indeed, in addition to previous studies we considered fundamental analysing not only the enabling factors for a lean success and failure, but even the union of factors that could lead to the necessity to face obstacles in the first and further phases of a lean project. Thus, this research contributes to the existing theoretical literature on lean barriers, providing a first empirical evidence of factors influencing lean barriers in different contexts and courtiers.

Based on a structured literature review, we developed different variables, including national culture, LM success, soft and hard lean practices and barriers in the start-up and maintaining phase. Compared to studies that analysed LM, the present work is based on an innovative method (associations rules combined with network analysis) that is appropriate for studying the complicated interrelationships between variables. Indeed, three different networks have been used to break down and plot the interdependencies and interrelationships of factors, influencing lean success and lean barriers in the start-up and sustain phase.

5.2.1 Lean Management implementation and success

Results from the first network (LMI) highlight positive effects of human support and national culture on Lean Success. In accordance with Kull et al. (2014) hypothesis, and in discordance with their results, we found that the PO culture contributes to the success of lean. Indeed, PO culture encourages and rewards employees' training and development (House et al., 2004) and it helps employees to acquire lean skills and knowledge. High PO reflects even on personal ambition and individual responsibility for success (House et al., 2004) that would motivate employees on new challenges and continuous improvement. An high PO culture values timely feedback, which facilitates an effective lean implementation (Kull et al., 2014). Moreover, in discordance with Kull et al. (2014), minimizing gender inequality affects positively the success of LM. Indeed, there is growing recognition that addressing gender equality in the labour force enables firms to attract and retain the best employees, increase productivity, improve morale, reduce absenteeism, increase return on investment in staff training and career development, enhance the corporate image and reputation, and increase innovation (Oxfam International, 2012). In addition to the cultural aspects, and in accordance with previous studies (Azadegan et al., 2013; Bruce et al., 2004; James- Moore and Gibbons, 1997), the environment context and in particular the demand variability, still remains an obstacle for LM success. Moreover, a positive correlation between Lean success, SLP and HLP confirms previous study results (Bortolotti et al., 2015a; Kull et al., 2014; Shah and Ward, 2007a). Bortolotti et al. (2015a) affirmed that SLP are fundamental for becoming a successful lean plant, but they do not offer evidence of how culture, lean practices, lean success and barriers interact. Results from the first network (LMI) explain how an effective application of SLP requires a joint effort (economical, strategic, cultural and human) if it is to succeed. On the other hand, a correct HLP seems to be easily achieved by strategic and cultural supports. Moreover, from r11-12-13, large enterprises result to be those best suited to an effective HLP implementation.

Many studies demonstrated that company size is a factor that influences the effectiveness of LM implementation (Achanga et al., 2006; Yang et al., 2011b), but few studies offered a description of interconnections between lean barriers and companies dimension. Focusing on the financial barrier, it's interesting to notice how for large organizations the cost of implementing lean did not pose a great barrier. Moreover, lack of economic barriers in the start-up phases of a lean project in large company dimension is linked with high soft lean practices, medium value of HO and high values of IC.

In addition, involving the entire supply chain in a lean project seems to be one of the main obstacles faced by firms in the initial phase. The central tenet of the lean enterprise is to reduce waste and simultaneously increase value to the customer (Shah and Ward, 2007a). Since productions of a high percentage of the value-added components in many manufacturing firms are outsourced, being an efficient firm is not enough. Building an efficient network is required.

5.2.2 Lean Management Barriers in the start-up phase

Network LSUD shows that companies with low levels of SLP and HLP have difficulties in involving their upstream and downstream stakeholders in the lean project. If the firm is not the first to trust in the lean project, it cannot expect the supplier to support them.

A recent study limited to three Andalusian aeronautics network shows that if the supply chain integration faces an unfavourable initial situation, lean practices should initially aim at modifying the mismatching supply chain network characteristics (Bortolotti et al., 2016). Indeed suppliers could be reluctant in applying lean because they see little incentive in adopting the JIT approach, when the primary benefits of the program go to the buyer (Jadhav et al., 2014). Hence, systems integration and an effective channel for communications can contribute to integrate the entire supply chain in the lean projects. Instead of focusing on a "price down" strategy, organizations need to employ a "cost out" strategy. This requires a holistic view of the supply chain whereby an organization works with its supply base to achieve the removal of waste through joint initiatives aimed at value creation (Simons and Economou, 2002).

But, after a preliminary reconfiguration of the network, if the distance between the lean knowledge owner and the recipient is large, managers face a very unfavourable situation that limits the number of initiatives that can be successfully activated (Bortolotti et al., 2016).

In addition, even cultural and economic aspects seem to influence upstream and downstream stakeholders' integration. Countries belonging to group 3 are linked to supply chain integration problem. For example, Mexico (belonging to group 3) has been losing competitiveness because of high transportation costs, electricity and other infrastructure costs, as well as the relatively low level of education of its labour force (Dahlman, 2007). Mexico has spawned some large competitive companies in the food, auto or technology sector (América Móvil; FEMSA and GRUMA, Modelo and Nemak), but most of them are expanding more abroad than in Mexico because of the difficult economic conditions. Another example of countries belonging to group 3 is India, where poor infrastructure, in terms of power supply, roads, ports and airports, and an excessively bureaucratic and regulated environment increases the cost of doing business. All these factors limit the ability of the Indian economy to react to changing opportunities and influence the existing firms to have a conservatory behavior with a lower UA and FO.

5.2.3 Lean Management Barriers in the maintaining phase

Once passed the first phase of a lean project, the sustaining phase of improvement programs is even more difficult to achieve. As resulting from LMAD network and from Table 13, sustaining lean initiatives through intellectual support and physical engagement represents the main problem. Results show that building a weak lean culture in the first phases of the journey leads to face cultural barriers even in the further steps. Achanga et al. (2006) classified management, finance and organizational culture as the most critical issues for the successful adoption of lean within SMEs environment. Indeed, cost is the uppermost consideration for smaller organizations because they need to secure the additional funding to a level whereby the savings from lean start to materialize (Bhasin, 2012a). The centrality of cultural barriers in LMAD pink cluster confirms Achanga et al. (2006) results and shows that sustaining a lean culture is even more critical than starting it. Employee attitudes to change whilst rated marginally higher for large organizations, is relatively important for SMEs (Bhasin, 2012a). In addition, a poor initial lean culture, cost and time required during the first phases are the main factors influencing the cultural barriers in the sustaining phase. But facility culture is also strongly influenced by the national culture. Indeed, when a cultures values individual responsibility for success (high PO), it seems to positively affect lean success and cultural barriers (LMAD pink cluster). Furthermore, cultural barriers in the start-up phase associated with low PD values lead to high cultural barriers in the maintaining phase. Some authors affirmed that the more a culture values PD, the less effective lean will be (Kull et al., 2014; Yauch and Steudel, 2002). Through our study we can add that high PD values negatively influence lean culture support. Indeed employees are reluctant to expose problems and share opinions and prefer to wait for managerial decisions, increasing the cultural barrier. Moreover, in large companies, high values of institutional collectivism and future orientation are helpful to reduce cultural lean barriers. Kull et al (2014) affirmed that IC and FO increase the effectiveness of LM. Indeed, FO encourages employees to solve problems in the long term and welcome investments in redesign even if benefits are not immediately apparent. IC focuses on teamwork and high interdependences among people. These two characteristics positively help to abolish the cultural resistance in large enterprises.

5.3 Lean Structural Network Resilience discussion

The LSNR model illustrated in the third part of the thesis is applicable to any organization belonging to whichever sector under the Lean principles, therefore capable of implementing $(CPD)_nA$ as their Lean Structural Network configuration.

Some previous researchers reported different network organizational structures and demonstrated that collaborative inter-organizational relationships offer greater agility and adaptability helping to transfer and exchange uniquely complementary sets of knowledge resources and relationships (Leiblein, 2011; Pal et al., 2014; Sheffi, 2005b). Through our research we are able to evaluate and quantify the capability of a specific enterprise, modelled as a LSN, to adapt easily and respond to immediate and unexpected changes. Moreover we demonstrated that the $(CPD)_nA$ is a precious tool not only to improve the interchange of information and the manufacturing performances (Villalba-Diez & Ordieres-Meré, 2015) but also to allow researchers and practitioners to get close to the ever more requested capability of being resilient.

Figure 17 shows an example of LSNR calculation in the case of a Process owner relocation. This study could be a valuable tool for human resource managers who have to deal with workforce relocation and/or mobility. Previous research papers studied work assignments based on the learning curve of the operators (M. J. Anzanello & Fogliatto, 2007; Michel J. Anzanello & Fogliatto, 2011). Anzanello and Fogliatto (2007) developed a study, clustering models of products in homogeneous families based on quantitative and qualitative variables. After, based on the workers' learning curve and product complexity, they assigned different assembly operations to different teams of workers. Subsequently, Anzanello and Fogliatto (2011) proposed a method to select the best clustering variables aimed at grouping product models into families. Two groups of clustering variables were considered: those generated by an expert assessment on product features that may impact on productivity, and those representing learning rate of workers, obtained through the LC modelling. Thus, our model, through the concept of resilience, wants to extend these works creating a generic tool, able to be used by all lean firms and able to predict and quantify the local and global effects of a Process owner relocation.

Figure 18 confirms prior studies in literature (Clapp-Smith et al., 2009; Greve, Benassi, & Sti, 2010; Harter et al., 2002; Terry, 2011) and allows managers to understand that companies will perform better when their people are involved and enthusiastic about being actively part of future and current choices. Indeed a correct human resource management enhances a firms' performance by contributing to employee and customer satisfaction, innovation, productivity and development of positive reputation in the firm's community (Bortolotti et al., 2015a; Jadhav et al., 2014). Therefore, through this virtual model, practitioners and researchers are able to quantify earning or losses at different levels or granularity due to a change of the Process owner's attitude.

Chapter 6.

Final remarks

LM is a multi-faceted concept and requires organizations to strive along several dimensions simultaneously.

Hence, the first aim of this thesis is to verify the possibility to apply Lean approach outside high volume manufacturing and stable context. A conceptual model has been proposed for investigating the network of influences among lean practices (supplier management, human resource management, just in time and total quality management practices), operational responsiveness (Product mix variety, Product innovation and Time effectiveness) and company growth performances in Italian companies.

This study highlights that the operational responsiveness is only partially connected to a Lean strategy of a company. Indeed, the lean practices implementations are negatively influenced by Product mix variety and innovation, while positively influenced by Time effectiveness variables. Moreover, product mix variety and time effectiveness are the main characteristics of the operational responsiveness that positively influences company growth performances. So time effectiveness could be considered as a mediator between Lean best practices and firm growth. Moreover no direct relationship has been found between lean bundles and firm's performances.

A structured analysis of the main barriers and the reason for failures of LM implementation in different contexts has been considered as a possible development of this first study.

Thus, the second part of this thesis focus the attention on finding out interesting relationships between national culture, company size, complexity and variability of the environment, as well as hard and soft lean practices implementation, lean success and different barriers during the start-up and the sustainment phase of lean projects. Through a combination of association rules and network analysis, we provided several academic contributions and allows practitioners and researchers to have a strategic overview and to know possible future scenarios in advance.

Our findings confirm that there is mutual influence between LM success, SLP and HLP and, that an effective application of SLPs is not an easy task. Indeed, we found that SLPs are negatively influenced by lack of human and strategic support in the first phases, whereas in the further steps even the cultural, economic and supply chain support is requested.

Our findings are original not only because they describe the interactions between lean effectiveness and lean barriers, but also because they show the interactions of other factors that influence lean success or failure in the first and further phases of a project.

Indeed we found out that cultural competencies such as PO and GE positively affect the success of LM. Moreover, the cultural issues in the first phase of a lean journey don't appear to companies as a barrier to break down. However, in the further steps it is the main barrier that firms have to face. Furthermore,

results show that it is negatively influenced by company dimension, demand variability and PD but, positively influenced by A, HO, IC, FO, GE and PO. Maintaining a lean culture is not easy, indeed it requires even a strong support of human aspects (SLP), economical, strategic, cultural and human joint effort, from the first phases of a lean project.
In addition, companies that are not totally immersed in the lean philosophy have difficulties to involve their upstream and downstream stakeholders. An unexpected contribution shows that the presence of supply chain integration barriers even in large enterprises with low demand variability and low complexity of production. Indeed involving the entire network in a lean project seems to be one of the main obstacles faced by firms in the initial phase. Moreover, countries with poor infrastructure, low UA and FO are strongly linked with supply chain barriers.
Our findings will allow managers to implement LM with a proactive behaviour, to take control and make things happen rather than just adjusting to a situation or waiting for something to happen.
Finally, in the third part of the thesis strategic plans and targets have been included in the lean practices (Villaba Diez et al. 2015).
Indeed taking into account the effect of workforce's mobility on company's resilience, the last part of this thesis proposes an innovative metric for measuring firms' resilience considering the company as a lean structural network. Thus, the proposed methodology to derive virtual models is able to evaluate the local and global effect of technical problems and the personnel

relocation in organizations that are facing a Lean Journey and so that standardized their formal reporting and empowering methods.

Also, the proposed methodology helps managers to estimate local resilience reservoirs, by comparing them with the global one. It enables as well to estimate the resilience because different types of potential events. Even better, it allows to analyse the cost, if any, in terms of resilience for the continuous improvement, because of the network growing.

Such capabilities, even though they are carried out by means of a virtual model of the organization, enable managers to get better understanding of the impact into the organization of performance improvements based on both, improvements in empowering the process owners which behave better and in terms of network rewiring as new process interdependence are identified. By acquiring such additional knowledge about the organizational behaviour, managers can identify leakage of resilience as well as key effects from specific process owners. This information can be useful when process owners reorganization is requested by Human Resource department, as it provides an additional source of information about potential impacts for the organization's performance because of such reorganization.

Chapter 7.

Limitation and future developments

Finally, some limitations of this study suggest caution in interpreting findings of this thesis as well as suggesting the direction for future research.

Indeed, firstly lean practices are limited to the methods most commonly used. Future researches could include policy deployment and systematic and sustainable approach in Lean practices. Indeed, researchers recently argue that not only is support of empowerment management system necessary, but they also be in compliance with strategic plans and targets (Villaba Diez et al. 2015).

Secondly, although the response rate and the overall reliability of the answers collected were useful, the sample of manufacturing companies investigated in this the first part is limited to the Italian case and to 150 manufacturing firms in the second part.

Hence, results of this study would benefit from an enlargement of data, involving more countries.

Thirdly, we surveyed companies operating in different industrial sectors belonging to sector C of the European Economic Classification; repeating the analysis and targeting a specific market field could provide additional useful insights. For instance, other authors analysed the benefits/barriers of lean practices implementation in continuous process manufacturers (Abdulmalek and Rajgopal, 2007; Mahapatra and Mohanty, 2007). According to our finding also in continuous process sector there is a negative correlation between the implementation level of lean practices and product variety. Some typical characteristics of this sector (inflexible machines, long setup times, and the general difficulty in producing in small batches) lead managers to hesitate in adoption of lean manufacturing tools and techniques.

Moreover, some other financial indicators could be used for analysing company performance. We tried to collect other performance information by companies (i.e. profit or cash flow), but collected data are incomplete.

Finally, considering the third part of this thesis in addition to the operators' learning rate, workers' prior experience and attitude, some products' characteristics such as product complexity, number of parts and operations required could influence the learning process (Michel J. Anzanello & Fogliatto, 2011; David A. Nembhard & Osothsilp, 2002). These aspects have been just partially examined. Indeed we can suppose that a more complex workstation is a workstation with more $(CPD)_nA$ in input and output. In any event, this aspect leaves quite a lot of room for improvement of the model.

Other possible future developments would be to consider weight values for process owner parameters when topology of the network which are not constant during time and the way of providing solid interpretation for such contexts.

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Appendices

Appendix 1

Questionnaire Lean implementation and operational responsiveness

Section 1 – Company Information

Section 1a – Organization size

OS_1 Number of employees:
□ <50
□ Between 50 and 249
□ > 249

OS_2 Turnover:
□ ≤ €10m
□ Between €10m and €50m
□ > €50m

MSN What is the percentage of market accounted for by your company at national level?

□ < 5 %

□ Between 5% and 15%

□ Between 15% and 30%

□ Between 30% and 50%

□ > 50%

MSE What is the percentage of market accounted for by your company at European level?

□ < 5 %

□ Between 5% and 15%

□ Between 15% and 30%

□ Between 30% and 50%

□ > 50%

Section 2a – Company's responsiveness

PM_1. How many Different Finished Products are managed by your company?

□ Between 1 and 10
□ Between 11 and 100
□ Between 101 and 1.000
□ Between 1.001 and 10.000
□ > 10.000

PM_2. How many new finished products produce

each year your company?

□ Between 1 and 10
□ Between 11 and 100
□ Between 101 and 1.000
□ Between 1.001 and 10.000
□ > 10.000

PM_3. In your company what is the batch size variation?

□ 0%

□ Between 0% and 5%

□ Between 5% and 10%

□ Between 10% and 20%

□ > 20%

INN_1. What is the percentage annually invested in R&D?

□ 0%

□ Between 0% and 5%

□ Between 5% and 10%

□ Between 10% and 20%

□ > 20%

INN_2. What is the percentage of customizable products?

□ 0%

□ Between 0% and 5%

□ Between 5% and 10%

□ Between 10% and 20%

□ > 20%

TE_1. In your company, what is the Mean time of stock in the warehouse?

□ < 1day

□ Between 1 day and 1 week

□ Between 1 week and two weeks

□ Between two weeks and 1 month

□ >1 month

TE_2. Inventory turnover

□ < 1day

□ Between 1 day and 1 week
□ Between 1 week and two weeks
□ Between two weeks and 1 month
□ >1 month

TE_3. Speedy response time to Warranty claim

□ < 1day

□ Between 1 day and 1 week

□ Between 1 week and two weeks

□ Between two weeks and 1 month

□ >1 month

Section 2b – Company's performance in the last 2 years

GP_1 Variation of sales growth in the last 2 years?
□ < -20%
□ Between -20% and 0%
□ Stable
□ Between 0% and 20%
□ > 20%

GP_2 Variation of employment growth in the last 2 years?
□ < -20%
□ Between -20% and 0%
□ Stable
□ Between 0% and 20%
□ > 20%

GP_3 Variation of customer retention in the last 2 years?
□ < -20%
□ Between -20% and 0%
□ Stable
□ Between 0% and 20%
□ > 20%

Section 3- Implementation of Lean Practices

		NEVER HEARD/NOT IMPLEMENTED	IDEA OF IMPLEMENTATION IN SOME DEPARTMENT	START-UP PHASE JUST STARTED FOR SOME DEPARTMENT	STARTED SUCCESSFULLY FOR SOME DEPARTMENT	IN USE SUCCESFULLY FOR SOME DEPARTMENT LESS THAN 1 YEAR	IN USE SUCCESFULLY FOR SOME DEPARTMENT MORE THAN 1 YEAR	IN USE SUCCESFULLY TO THE WHOLE SYSTEM
JIT	Pull production / Kanban implementation	□	□	□	□	□	□	□
	Quick changeover techniques (SMED) implementation	□	□	□	□	□	□	□
	Production smoothing/ Heijunka/Mixed model	□	□	□	□	□	□	□
TQM	Statistical process control	□	□	□	□	□	□	□
	Customer involvement in product offerings	□	□	□	□	□	□	□
	Process feedback	□	□	□	□	□	□	□
SM	Supplier partnership	□	□	□	□	□	□	□
	Involvement of supplier in the lean journey	□	□	□	□	□	□	□
	Supplier quality involvement	□	□	□	□	□	□	□
HRM	Multiskilled Workforce/ Job Rotation	□	□	□	□	□	□	□
	Employees' involvement (Suggestion schemes)	□	□	□	□	□	□	□
	Lean Management training	□	□	□	□	□	□	□

Appendix 2

Questionnaire Lean barriers

A. General Information

A1. EU COUNTRY

A2. SECTOR

□ FOOD & BEVERAGES PRODUCTS	– Manufacture of food products (C10); – Manufacture of beverages (C11).
□ TEXTILE, LEATHER & CLOTHES PRODUCTS	– Manufacture of textiles (C13); – Manufacture of wearing apparel (C14); – Manufacture of leather and related products (C15).
□ CHEMICAL PRODUCTS	– Manufacture of coke and refined petroleum products (C19); – Manufacture of chemicals and chemical products (C20).
□ PHARMACEUTICAL PRODUCTS	– Manufacture of basic pharmaceutical products and pharmaceutical preparations (C21).
□ TRANSPORT PRODUCTS	– Manufacture of motor vehicles, trailers and semi-trailers (C29); – Manufacture of other transport equipment (C30).
□ ELECTRICAL AND MECHANICAL MACHINERY AND EQUIPMENT	– Manufacture of computer, electronic and optical products (C26); – Manufacture of electrical equipment (C27); – Manufacture of machinery and equipment n.e.c. (C28). – Repair and installation of machinery and equipment (C33)
□ OTHERS	– Manufacture of tobacco products (C12); – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (C16); – Manufacture of paper and paper products (C17); – Printing and reproduction of recorded media (C18); – Manufacture of rubber and plastic products (C22); – Manufacture of other non-metallic mineral products (C23); – Manufacture of basic metals (C24) – Manufacture of fabricated metal products, except machinery and equipment (C25) – Manufacture of furniture (C31); – Other manufacturing (C32);

A3. Respondent positions

□ President/COO/ Plant manager;

□ Plantaccounting manager;

□ Informationsystems manager;

□ Production control manager;

□ Inventory manager;

□ Member of product development team;

□ Processengineer;

□ Quality manager;

□ Supervisor;

□ Plantsuperintendent;

□ Lean Specialist;

□ Human resources manager;

□ Directlabour;

□ Secretary;

□ Others;

A4 COMPANY INFORMATION

A4. DIMENSIONOF THE FIRM

A4.1 Firm employees

□ <10

□ Between 10 and 50

□ Between 50 and 250

□ >250

A4.2 Firm sales

□ ≤ € 2 m

□ Between € 2 m and € 10 m

□ Between € 10 m and € 50 m

□ >€ 50 m

A5. PRODUCT DEMAND CHARACTERISTIC

A5. 1 May the customers' demand* in your company be considered stable?

□ 0%

□ Between 0% and 10%

□ Between 10% and 50%

□ Between 50% and 90%

□ > 90%

*=Formula 1 is reported in the survey

A5. 2 Does your company manage a wide range of different finished products?
□ Between 1 and 10
□ Between 10 and 50
□ Between 50 and 250
□ Between 250 and 1,000
□ > 1,000

A5. 3 Does your company guarantee high customizable finished products*?
□0%
□ Between 0% and 10%
□ Between 10% and 50%
□ Between 50% and 90%
□ > 90%
*=Formula 2 is reported in the survey

A5. 4 Does your company manage a wide batch size variation*?
□0%
□ Between 0% and 10%
□ Between 10%e 50%
□ Between 50% and 90%
□ > 90%
*=Formula 3 is reported in the survey

B1. SUCCESS OF LEAN PRACTICES IMPLEMENTATION
B1 Please indicate the percentage of lean project successfully developed:
□ 0%
□ Between 0% and 20%
□ Between 20%e 50%
□ Between 50% and 90%
□ > 90%

B1. A Please indicate the percentage of success in implementing the following lean practices in your company

			NEVER HEARD/NOT IMPLEMENTED	THE IMPLEMENTATION HAD STARTED AND FAILED	JUST STARTED SUCCESSFULLY FOR SOME DEPARTMENT	IN USE SUCCESFULLY FOR SOME DEPARTMENT LESS THAN 1 YEAR	IN USE SUCCESFULLYFOR SOME DEPARTMENT MORE THAN 1 YEAR	IN USE SUCCESFULLY IN THE WHOLE SYSTEM
HARD LEAN PRACTICES	B1.A1	Setup time reduction/Single Minute Exchange of Die (SMED).	□	□	□	□	□	□
	B1.A2	Kanban Implementation.	□	□	□	□	□	□
	B1.A3	Equipment layout for continuous flow.	□	□	□	□	□	□
	B1.A4	Statistical Process Control.	□	□	□	□	□	□
	B1.A5	Total Productive Maintenance.	□	□	□	□	□	□
	B1.A6	Just in time delivery by supplier.	□	□	□	□	□	□
SOFT LEAN PRACTICES	B1.A7	Employee involvement (e.g. Suggestion Scheme).	□	□	□	□	□	□
	B1.A8	Total Quality Management.	□	□	□	□	□	□
	B1.A9	Continuous improvement techniques.	□	□	□	□	□	□
	B1.A10	Training Employees.	□	□	□	□	□	□

B1.A11	Supplier partnership.	□	□	□	□	□	□
B1.A12	Customer involvement.	□	□	□	□	□	□

C1. Please indicate how much the company complied with these approaches during the start-up phase of the lean project:

			VERY SLIGHTLY/ OT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
STRATEGIC APPROACHES	C1.A1	Top managements are aware of the need for Lean implementation.	□	□	□	□	□
	C1.A2	The Project Goal is clear to all the staff.	□	□	□	□	□
	C1.A3	The staff has a clear vision of the project and a future plan.	□	□	□	□	□
	C1.A4	Top management knows how to get started.	□	□	□	□	□
	C1.A5	Process and division where starting the lean program has been selected with specific criteria.	□	□	□	□	□
	C1.A6	Lean programs are perfectly in line with organization bonus, rewards or incentives systems.	□	□	□	□	□

ECONOMIC APPROACHES	C1.B1	Financial availability for employees' training course.	□	□	□	□	□
	C1.B2	Time availability for the employees' training course.	□	□	□	□	□
	C1.B3	Financial availability for top managers' training course.	□	□	□	□	□
	C1.B4	Time availability for the top managers' training course.	□	□	□	□	□
	C1.B5	Financial availability to invest in lean program.	□	□	□	□	□
	C1.B6	Time availability to invest in lean program.	□	□	□	□	□
	C1.B7	Financial availability to have outside experts for successfully shifting to lean.	□	□	□	□	□
	C1.B8	Availability of human resource to invest in lean program.	□	□	□	□	□
	C1.B9	Availability of technical resource to invest in lean program.	□	□	□	□	□
SUPPLY CHAIN INTEGRATION APPROACHES	C1.C1	Ease in involving customer in lean projects because of consistent and clear communication with them.	□	□	□	□	□
	C1.C2	Ease in involving supplier in lean projects because the majority of them are close to the company.	□	□	□	□	□
	C1.C3	Ease in involving suppliers in lean projects because of long-standing relationship with them.	□	□	□	□	□
	C1.C4	Ease in involving suppliers in lean projects because of consistent and clear communication with them.	□	□	□	□	□
	C1.C5	Ease in involving suppliers in lean projects because they see incentive in adopting the JIT approach.	□	□	□	□	□
	C1.C6	Ease in involving the entire supply chain because of Partnership or closer relations with carriers and logistic providers.	□	□	□	□	□

HUMAN APPROACHES	C1.D1	Top management support in implementing lean projects.	□	□	□	□	□
	C1.D2	Shop floor personnel support in implementing lean projects.	□	□	□	□	□
	C1.D3	Employees are responsive to participate to productivity improvement project and they have no fear of staff reduction.	□	□	□	□	□
	C1.D4	Employees are responsive to participate to productivity improvement project because interested in learning something new.	□	□	□	□	□
	C1.D5	Lean project have committed leadership.	□	□	□	□	□
CULTURAL APPROACHES	C1.E1	Cross Functional group (people from various department and levels within the organization) have been created.	□	□	□	□	□
	C1.E2	Personnel are responsive to participate to training courses in order to receive at least Basic knowledge and skills about lean concepts.	□	□	□	□	□
	C1.E3	Top managers are responsive to participate to training course in order to receive at least Basic knowledge and skills about lean concepts.	□	□	□	□	□
	C1.E4	Outside experts are well accepted by personnel in the start-up phase of the lean project.	□	□	□	□	□
	C1.E5	A training roadmap about lean concepts has been set up.	□	□	□	□	□
	C1.E6	Low education of employment does not represent a barrier in implementing lean.	□	□	□	□	□

C2- Please indicate how much the company complied with these approaches during the SUSTAINING phase of the lean project:

			VERY SLIGHTLY/ NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
STRATEGIC APPROACHES	C2.A1	An effective model or roadmap guides the future steps.	□	□	□	□	□
	C2.A2	Performance measurement systems are used.	□	□	□	□	□
	C2.A3	There is compatibility between lean and organization bonus, rewards or incentives systems.	□	□	□	□	□
ECONOMIC APPROACHES	C2.B1	There is availability of human resources that are dedicated to lean program development.	□	□	□	□	□
	C2.B2	There is financial availability to sustain lean program.	□	□	□	□	□
	C2.B3	There is financial availability to have Outside experts to monitor the correct lean shifting.	□	□	□	□	□
	C2.B4	There is financial availability for the employees' training courses, during the project execution.	□	□	□	□	□
	C2.B5	There is time availability for the employees' training courses, during the project execution.	□	□	□	□	□
	C2.B6	There is financial availability for the top managers' training courses, during the project execution.	□	□	□	□	□
	C2.B7	There is time availability for top managers' training courses, during the project execution.	□	□	□	□	□

	C2.B8	During the project execution managers are free to modify the plant configuration.	□	□	□	□	□
	C2.B9	During the project execution managers are free to invest in new machinery.	□	□	□	□	□
SUPPLY CHAIN INTEGRATION APPROACHES	C2.C1	There is consistent and clear communication with customer during the project execution.	□	□	□	□	□
	C2.C2	During the project execution suppliers operate as the seamless extension of the refined lean system of Toyota.	□	□	□	□	□
	C2.C3	During the project execution supplier management department have significant interaction with the other organizational structure.	□	□	□	□	□
	C2.C4	During the project execution there is a partnership or closer relations with carriers and logistic providers in order to promote an efficient delivers and pick up.	□	□	□	□	□
	C2.C5	Most of suppliers deliver materials at the correct time.	□	□	□	□	□
	C2.C6	Most of suppliers deliver materials at the correct price.	□	□	□	□	□
	C2.C7	Most of suppliers deliver materials at the correct place.	□	□	□	□	□
	C2.C8	During the project execution the majority of suppliers are close to the company.					
HUMAN APPROACHES	C2.D1	Managers persevere in conducting the lean projects.	□	□	□	□	□
	C2.D2	Managers contrast the tendency to revert to original practices when obstacles are faced.	□	□	□	□	□
	C2.D4	During the project execution changing the mindset of workers is easy.	□	□	□	□	□
	C2.D5	During the project execution lean teams are autonomous.	□	□	□	□	□
	C2.D6	During the project execution the administration of workplace is not dominated, commanded and controlled by management.	□	□	□	□	□
	C2.D7	There is cooperation and mutual trust between managers and employees.	□	□	□	□	□

	C2.D3	During the project execution top managers support lean changes.	□	□	□	□	□
	C1.D8	Top managers take into consideration operators' proposal (suggestion box for example).	□	□	□	□	□
	C1.D9	There is wide communication at all level of the organization.	□	□	□	□	□
	C1.D10	People of one functional area are aware of the success of lean project in another functional area and as a consequence support them.	□	□	□	□	□
CULTURAL APPROACHES	C2.E1	Culture of lean improvement is widely sustained.	□	□	□	□	□
	C2.E2	During the project execution group oriented activities are supported.	□	□	□	□	□
	C2.E3	Personnel are responsive to participate to training courses in order to improve their Basic knowledge and skills about lean concepts.	□	□	□	□	□
	C2.E4	Top managers are responsive to participate to training courses in order to improve their Basic knowledge and skills about lean concepts.	□	□	□	□	□
	C2.E5	Outside experts are well accepted during the lean project execution.	□	□	□	□	□
	C2.E6	Cross Functional group (people from various department and levels within the organization) cooperate correctly together.	□	□	□	□	□
	C2.E7	During the project execution personnel are responsive to use and share new lean terminology.	□	□	□	□	□
	C2.E8	Low education of employees does not represent a barrier in maintaining lean.	□	□	□	□	□

Appendix 3

Association Rules obtained imposing as RHS item-set different levels of Lean success and Lean implementation (LMI), different level of lean barriers in the start-up (LSUD) and sustaining phase (LMAD).
The data used for the analysis are limited to a sample of 150 questionnaires.

LMI Rules						
RULE	LHS	=>	RHS	SUPPORT	CONFIDENCE	LIFT
r1	{H_MA=1}	=>	{SLP=5}	0.113	0.850	3.446
r2	{E_MA=1}	=>	{SLP=5}	0.120	0.900	3.649
r3	{C_MA=1}	=>	{HLP=5}	0.100	0.652	4.253
r4	{S_SU=1}	=>	{HLP=5}	0.113	0.654	4.264
r5	{C_MA=1}	=>	{SLP=5}	0.140	0.913	3.702
r6	{S_MA=1}	=>	{SLP=5}	0.147	0.880	3.568
r7	{S_SU=1}	=>	{SLP=5}	0.167	0.962	3.898
r8	{E_SU=1}	=>	{SLP=5}	0.160	0.857	3.475
r9	{C_SU=1}	=>	{SLP=5}	0.133	0.714	2.896
r10	{H_SU=1}	=>	{SLP=5}	0.147	0.688	2.787
r11	{Dimension=LARGE ENTERPRISES; S_MA=1}	=>	{HLP=5}	0.100	0.652	4.253
r12	{S_MA=1; HO=2}	=>	{HLP=5}	0.100	0.652	4.253
r13	{Dimension=LARGE ENTERPRISES; C_SU=1}	=>	{HLP=5}	0.100	0.714	4.658
r14	{C_MA=4; UA=2}	=>	{Lean_Success=2}	0.107	0.800	2.791
r15	{Country=2; C_MA=4}	=>	{Lean_Success=2}	0.107	0.762	2.658
r16	{C_MA=4; GC=2}	=>	{Lean_Success=2}	0.107	0.727	2.537
r17	{Demand_variability=2; SCI_MA=3}	=>	{SLP=3}	0.100	0.652	1.957
r18	{SCI_SU=5; S_MA=4}	=>	{HLP=2}	0.113	0.680	2.429
r19	{SCI_SU=5; S_SU=3}	=>	{HLP=2}	0.100	0.652	2.329
r20	{Sector=ELECTRICAL AND MECHANICAL MACHINERY AND	=>	{Lean_Success=2}	0.107	0.696	2.427

	EQUIPMENT; S_MA=4}					
r21	{Dimension=LARGE ENTERPRISES; S_MA=4}	=>	{SLP=3}	0.113	0.654	1.962
r22	{S_SU=3; H_MA=3; A=2}	=>	{Lean_Success=3}	0.127	0.704	2.778
r23	{SCI_SU=5; SCI_MA=4; PO=3}	=>	{HLP=2}	0.100	0.682	2.435
r24	{Demand_variability=2; S_MA=4; UA=2}	=>	{SLP=3}	0.100	0.714	2.143
r25	{Demand_variability=2; S_MA=4; PO=3}	=>	{SLP=3}	0.140	0.656	1.969
r26	{Demand_variability=2; S_MA=4; GC=2}	=>	{SLP=3}	0.127	0.704	2.111
r27	{S_MA=4; GC=2; PO=3}	=>	{SLP=3}	0.120	0.667	2.000
r28	{Dimension=LARGE ENTERPRISES; Demand_variability=2; H_SU=2}	=>	{Lean_Success=4}	0.127	0.679	2.262
r29	{Demand_variability=2; C_SU=3; C_MA=3}	=>	{SLP=3}	0.100	0.652	1.957
r30	{Complexity_of_production=2; Demand_variability=2; PO=3}	=>	{SLP=3}	0.113	0.654	1.962
r31	{Demand_variability=2; H_SU=2; GC=2; PO=3}	=>	{Lean_Success=4}	0.113	0.654	2.179

LSUD Rules

RULE	LHS	=>	RHS	SUPPORT	CONFIDENCE	LIFT
r1	{HLP=5}	=>	{S_SU=1}	0.113	0.787	4.264
r2	{HLP=5}	=>	{C_SU=1}	0.100	0.700	3.494
r3	{SLP=5}	=>	{S_SU=1}	0.167	0.724	3.898
r4	{HLP=2}	=>	{SCI_SU=5}	0.193	0.738	1.755
r5	{Dimension=LARGE ENTERPRISES; SLP=5}	=>	{E_SU=1}	0.140	0.704	3.516
r6	{SLP=5; IC=3}	=>	{E_SU=1}	0.113	0.756	3.795
r7	{SLP=5; HO=2}	=>	{E_SU=1}	0.147	0.715	3.571
r8	{Dimension=LARGE ENTERPRISES;	=>	{SCI_SU=3}	0.107	0.775	2.597

	Demand_variability=1}					
r9	{Country=2; Lean_Success=3}	=>	{C_SU=3}	0.107	0.744	1.969
r10	{Lean_Success=3; GC=2}	=>	{C_SU=3}	0.113	0.728	1.925
r11	{Demand_variability=2; UA=3}	=>	{SCI_SU=5}	0.120	0.715	1.695
r12	{PO=3; UA=3}	=>	{SCI_SU=5}	0.120	0.715	1.695
r13	{SLP=5; GE=3; PO=3}	=>	{E_SU=1}	0.113	0.702	3.503
r14	{Dimension=LARGE ENTERPRISES; SLP=5; GE=3}	=>	{H_SU=1}	0.120	0.715	3.125
r15	{Country=3; A=2; UA=3}	=>	{SCI_SU=5}	0.100	0.730	1.733
r16	{Country=3; A=2; PO=3}	=>	{SCI_SU=5}	0.100	0.762	1.816
r17	{Lean_Success=4; Demand_variability=2; PO=3}	=>	{H_SU=2}	0.120	0.715	1.961
r18	{Demand_variability=2; GC=2; FO=2}	=>	{SCI_SU=5}	0.100	0.730	1.733
r19	{Dimension=LARGE ENTERPRISES; SLP=3; PO=3}	=>	{SCI_SU=5}	0.100	0.700	1.658
r20	{Dimension=LARGE ENTERPRISES; Complexity_of_production=2; Demand_variability=2}	=>	{SCI_SU=5}	0.100	0.700	1.658
r21	{Lean_Success=3; Demand_variability=2; A=2; HO=2}	=>	{S_SU=3}	0.100	0.700	1.881
r22	{SLP=5; GE=3; PO=3}	=>	{E_SU=1}	0.113	0.702	3.503
r23	{Dimension=LARGE ENTERPRISES; SLP=5; GE=3}	=>	{H_SU=1}	0.120	0.715	3.125
r24	{Country=3; A=2; UA=3}	=>	{SCI_SU=5}	0.100	0.730	1.733
r25	{Country=3; A=2; PO=3}	=>	{SCI_SU=5}	0.100	0.762	1.816
r26	{Lean_Success=4; Demand_variability=2; PO=3}	=>	{H_SU=2}	0.120	0.715	1.961
r27	{Demand_variability=2;	=>	{SCI_SU=5}	0.100	0.730	1.733

	GC=2; FO=2}					
r28	{Dimension=LARGE ENTERPRISES; SLP=3; PO=3}	=>	{SCI_SU=5}	0.100	0.700	1.658
r29	{Dimension=LARGE ENTERPRISES; Complexity_of_production=2; Demand_variability=2}	=>	{SCI_SU=5}	0.100	0.700	1.658
r30	{Lean_Success=3; Demand_variability=2; A=2; HO=2}	=>	{S_SU=3}	0.100	0.700	1.881

LMAD Rules

RULE	LHS	=>	RHS	SUPPORT	CONFIDENCE	LIFT
r1	{S_SU=1}	=>	{S_MA=1}	0.140	0.808	4.846
r2	{E_SU=1; S_SU=1}	=>	{E_MA=1}	0.100	0.833	6.250
r3	{C_SU=1; E_SU=1}	=>	{E_MA=1}	0.107	0.941	7.059
r4	{C_SU=1; S_SU=1}	=>	{C_MA=1}	0.107	0.889	5.797
r5	{H_SU=1; S_SU=1}	=>	{C_MA=1}	0.107	0.800	5.217
r6	{S_SU=1; PO=3}	=>	{C_MA=1}	0.107	0.800	5.217
r7	{C_SU=1; E_SU=1}	=>	{C_MA=1}	0.100	0.882	5.754
r8	{C_SU=1; H_SU=1}	=>	{C_MA=1}	0.100	0.882	5.754
r9	{SLP=5; C_SU=1}	=>	{C_MA=1}	0.113	0.850	5.543
r10	{Dimension=LARGE ENTERPRISES; C_SU=1}	=>	{C_MA=1}	0.120	0.857	5.590
r11	{Dimension=SME; C_SU=4}	=>	{C_MA=4}	0.100	0.882	4.564
r12	{C_SU=4; PD=1}	=>	{C_MA=4}	0.113	0.810	4.187
r13	{Dimension=SME; E_SU=4}	=>	{C_MA=4}	0.100	0.882	4.564
r14	{Dimension=SME; E_SU=4}	=>	{E_MA=4}	0.100	0.882	3.394
r15	{HLP=3; S_SU=3}	=>	{H_MA=3}	0.107	0.889	2.667
r16	{Lean_Success=3; S_SU=3}	=>	{H_MA=3}	0.127	0.864	2.591
r17	{HLP=2; C_SU=3}	=>	{C_MA=3}	0.100	0.833	2.660
r18	{C_SU=3; FO=2}	=>	{C_MA=3}	0.107	0.800	2.553
r19	{SLP=3; C_SU=3}	=>	{C_MA=3}	0.113	0.810	2.584
r20	{C_SU=3; H_SU=2}	=>	{C_MA=3}	0.107	0.800	2.553

r21	{Dimension=LARGE ENTERPRISES; H_SU=1; E_SU=1}	=>	{E_MA=1}	0.100	0.833	6.250
r22	{Dimension=LARGE ENTERPRISES; SLP=5; E_SU=1}	=>	{E_MA=1}	0.113	0.810	6.071
r23	{Dimension=LARGE ENTERPRISES; H_SU=1; E_SU=1}	=>	{C_MA=1}	0.100	0.833	5.435
r24	{Dimension=LARGE ENTERPRISES; SLP=5; H_SU=1}	=>	{C_MA=1}	0.107	0.800	5.217
r25	{SLP=5; H_SU=1; E_SU=1}	=>	{S_MA=1}	0.100	0.833	5.000
r26	{Dimension=LARGE ENTERPRISES; H_SU=1; E_SU=1}	=>	{S_MA=1}	0.100	0.833	5.000
r27	{Dimension=LARGE ENTERPRISES; SLP=5; E_SU=1}	=>	{S_MA=1}	0.113	0.810	4.857
r28	{SLP=5; E_SU=1; GE=3}	=>	{S_MA=1}	0.107	0.800	4.800
r29	{Dimension=LARGE ENTERPRISES; SLP=5; H_SU=1}	=>	{S_MA=1}	0.107	0.800	4.800
r30	{C_SU=4; IC=3; FO=3}	=>	{C_MA=4}	0.107	0.800	4.138
r31	{C_SU=4; FO=3; PO=3}	=>	{C_MA=4}	0.100	0.833	4.310
r32	{C_SU=4; FO=3; HO=2}	=>	{C_MA=4}	0.107	0.800	4.138
r33	{C_SU=4; FO=3; GE=3}	=>	{C_MA=4}	0.107	0.800	4.138
r34	{C_SU=4; A=2; IC=3}	=>	{C_MA=4}	0.100	0.833	4.310
r35	{C_SU=4; GE=3; PO=3}	=>	{C_MA=4}	0.107	0.800	4.138
r36	{C_SU=4; A=2; HO=2}	=>	{C_MA=4}	0.120	0.818	4.232
r37	{C_SU=4; A=2; GE=3}	=>	{C_MA=4}	0.120	0.818	4.232
r38	{H_SU=2; E_SU=3; PO=3}	=>	{E_MA=3}	0.100	0.833	2.976
r39	{Dimension=LARGE ENTERPRISES; C_SU=3; PO=3}	=>	{C_MA=3}	0.153	0.821	2.622
r40	{Demand_variability=2; C_SU=4; A=2; FO=3}	=>	{C_MA=4}	0.100	0.833	4.310

r41	{Demand_variability=2; C_SU=4; IC=3; PO=3}	=>	{C_MA=4}	0.100	0.833	4.310
r42	{Demand_variability=2; C_SU=4; A=2; PO=3}	=>	{C_MA=4}	0.100	0.833	4.310
r43	{Demand_variability=2; C_SU=4; HO=2; PO=3}	=>	{C_MA=4}	0.100	0.833	4.310
r44	{Demand_variability=2; C_SU=4; A=2; HO=2}	=>	{E_MA=4}	0.113	0.810	3.114
r45	{Demand_variability=2; C_SU=4; A=2; GE=3}	=>	{E_MA=4}	0.113	0.810	3.114
r46	{Demand_variability=2; E_SU=4; A=2; HO=2}	=>	{E_MA=4}	0.107	0.800	3.077
r47	{Demand_variability=2; E_SU=4; A=2; GE=3}	=>	{E_MA=4}	0.107	0.800	3.077
r48	{Country Culture=Latin Europe; Dimension=LARGE ENTERPRISES; C_SU=3; A=2}	=>	{C_MA=3}	0.100	0.833	2.660
r49	{Country=2; Dimension=LARGE ENTERPRISES; C_SU=3; UA=2}	=>	{C_MA=3}	0.107	0.800	2.553
r50	{Dimension=LARGE ENTERPRISES; C_SU=3; A=2; UA=2}	=>	{C_MA=3}	0.107	0.800	2.553
r51	{Dimension=LARGE ENTERPRISES; C_SU=3; A=2; FO=3}	=>	{C_MA=3}	0.100	0.833	2.660
r52	{Country=2; Dimension=LARGE ENTERPRISES; C_SU=3; A=2}	=>	{C_MA=3}	0.127	0.826	2.636
r53	{Dimension=LARGE ENTERPRISES; Demand_variability=2; C_SU=3; A=2}	=>	{C_MA=3}	0.100	0.833	2.660
r54	{Dimension=LARGE ENTERPRISES; C_SU=3; A=2; IC=3}	=>	{C_MA=3}	0.100	0.833	2.660
r55	{Dimension=LARGE	=>	{C_MA=3}	0.147	0.815	2.600

	ENTERPRISES; C_SU=3; A=2; GC=2}					
r56	{Dimension=LARGE ENTERPRISES; C_SU=3; A=2; HO=2}	=>	{C_MA=3}	0.120	0.818	2.611