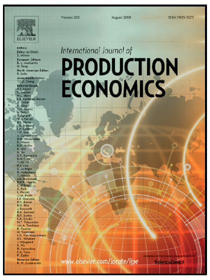

The lean and resilient management of the supply chain and its impact on performance

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The lean and resilient management of the supply chain and its impact on performance

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The lean and resilient management of the supply chain and its impact on performance

Abstract

The relationship between lean management and resilience in the supply chain, whether negative or positive, is still not clear from the existing literature. This paper aims to investigate the relationship and links between lean and resilient supply chain (SC) practices and their impact on SC performance. To achieve this objective, the aerospace manufacturing sector (AMS) is chosen as the study sector because of the importance of both paradigms. Interpretive Structural Modeling (ISM) approach is used in order to identify linkages among various lean and resilience practices and SC performance metrics through a single systemic framework. ISM is an interactive learning process based on graph theory where experts' knowledge is extracted and converted into a powerful well-structured model. For that purpose, a heterogeneous panel of experts in the AMS was formed, providing a complete view of all SC levels in the sector. The final ISM model revealed that lean SC practices act as drivers for resilient SC practices, since implementing the former in isolation could lead to a more vulnerable SC. The findings also show that lean SC practices lead to a higher performance improvement than resilient SC practices. This is due to the fact that resilient SC practices do not exert influence over all SC performance metrics as it occurs with lean SC practices. In addition, several managerial implications regarding the most convenient practices in terms of the company's objectives are drawn from this study.

1. Introduction

Supply chain management (SCM) leads on to increased organizational effectiveness, enhanced competitiveness, better customer care and increased profitability. SCM also promotes the integration between firms and their suppliers through the development of supplier partnerships and strategic alliances. Therefore, the set of practices selected to manage those relationships with suppliers is a critical issue since it will affect companies and overall supply chain (SC) performance (Gunasekaran et al., 2004).

Lean is a work philosophy that defines the means for improvement and optimization of the production system focusing on identifying and eliminating all types of waste, reducing or minimizing the variability from demand to supply (Shah and Ward, 2007). Lean philosophy applied to manufacturing has been widely studied. Its application to SCM has started to interest companies as well. Firms must adopt lean, both internally and externally, spreading lean principles and practices through the whole SC in order to achieve all the potential benefits of this philosophy (Shah and Ward, 2007). Lean principles are, therefore, applicable to the whole SC, from the provider to the final distributor and the final customer delivery, leading to what is known as Lean SCM.

In the last years, numerous interruptions and unexpected events derived from the nature's action (earthquakes, tsunamis, floods,…) or the man's action (cyber-attacks, terrorism, accidents,..) (Fahimnia et al., 2014; Tukamuhabwa et al., 2015), have perturbed the regular flow of products, components and materials along the SC (Svensson, 2000; Kleindorfer and Saad, 2010). As a result, operational and financial performances as well as the market have been harmed by such events (Hendricks and Singhal, 2003). This negative effect has spread through all the firms pertaining to the SC as well (Ambulkar et al., 2015).

For this reason, SC risk management has been one of the more analyzed topics in the literature in the production/operations area. This interest was motivated by new business tendencies and the advance in information technologies and systems (Blackhurst et al., 2005; Giannakis and Papadopoulos, 2016; Hendricks et al., 2007). In addition, such advances have driven more complex global SC (Trkman and McCormack, 2009) managed under a greater uncertainty. In fact, companies face challenges such as high variability of demand, increase in competition, reduction of products life cycle and higher customer demands, which increase the complexity of their SC, making them more instable and unpredictable (Roberta Pereira et al., 2014). With the intention of minimizing the effects of such unexpected events, both academicians and professionals have showed an increasing interest in resilient SC (Fahimnia et al., 2014; Roberta Pereira et al., 2014; Tukamuhabwa et al., 2015).

With the aim of improving SC performance in mind, previous studies consider different paradigms (lean, agility, green, resilience) and their influence on the SC (Carvalho et al., 2011; Carvalho and Cruz-Machado, 2011; Govindan et al., 2015). Other studies also reveal that these practices may affect SC sustainability (Govindan et al., 2014). However, the joint influence of lean and resilient practices in SC performance at economical and operational levels has not yet been examined in depth. In order to bridge the gap, we developed the present study that does not attempt to empirically test any hypothesis but to develop new theoretical frameworks on the interrelationships between lean and resilience paradigms.

With this in mind, we try to answer the following questions: What are the economical and operational benefits for companies that implement lean and resilient practices in their SC? Is there any relationship between lean and resilient SC practices that may help in the implementation of such practices?

To address the aforementioned questions, this paper is organized as follows. First, we carry out and extensive literature review on lean and resilient SC practices as well as on SC performance measures to identify the most important practices and measures. Next, the case study is explained and the methodology and research design is developed. Finally, we discuss the results obtained enumerating the managerial implications of such findings and conclude remarking the contribution of this work as well as the limitations and future extensions.

2. Literature Review

Lean Supply Chain Management

Lean production is defined as a set of tools and methodologies focused on continuously improving processes, with the objective of eliminating all non-value adding activities and reducing waste within an organization (Womack et al., 1991). Waste is an activity, which does not create any value to the customer or product. In SCM, wastes are created by improper information, material and funds flows in the system (Jasti and Kodali, 2015). Therefore, lean can be considered as an integrated activity into SCM designed to achieve high-volume flexible production using minimal inventories of raw materials (Agus and Hajinoor, 2012).

Lean SC represents a strategy based on cost reduction and flexibility and it embraces all the processes starting with the product design to the product sale (Carvalho et al., 2010). The principles of lean can be applied throughout the SC from the process of placing orders to suppliers to product distribution and customer delivery (Martínez-Jurado and Moyano-Fuentes, 2014; Moyano-Fuentes and Sacristán-Díaz, 2012). Similarly, the concept of lean can be extended to the downstream or distribution level. Lean is applicable to many SCs, particularly those seeking to improve performance by reducing waste (Arif-Uz-Zaman and Ahsan, 2014).

Lean implementation helps SCM by achieving significant improvements in resource productivity, reducing the amount of energy, water, raw materials, and non-product output associated with production processes; minimizing the ecological impact of industrial activity (Larson and Greenwood, 2004). Moreover, leanness in a SC maximizes profits through cost reductions (Singh and Pandey, 2015). Extending lean principles from manufacturing to SCM can leverage the SC's competitiveness further with increased responsiveness to demand changes and reduced operating costs (Oliver et al., 1993).

Lean may be viewed as a configuration of practices/tools because the relationships among the elements of lean are neither explicit nor precise in terms of linearity or causality (Shah and Ward, 2007). Practices of lean production vary from a company or country to another, however, most if not all focus on minimization and eventual elimination of non-value adding activities (Agus and Hajinoor, 2012). Some practices are related to suppliers (i.e., procurement consolidation, supplier certification; supplier evaluation and rating) (Wiengarten et al., 2013); some related to customers' relationship (i.e., supplier involvement in product development) (Kou and Lee, 2015); and some practices are related to operations, for example, electronic-enabled supply chains (So and Sun, 2010), JIT delivery practices (Agus and Hajinoor, 2012), pull production systems (Marodin et al., 2016), inter-organizational value stream mapping (Hines and Rich, 1997) and training in lean initiatives (Lopes de Sousa Jabbour et al., 2014). In this regard, we have identified a total of eight lean SC practices that will be used in our study (Table 1).

Table 1. Lean practices in the SCM

ID Lean	Lean SC practice	Description	References
L1	Supplier selection, evaluating and monitoring	Cooperative relationships based on trust and mutual commitment, longer-term relationship	(Azevedo et al., 2012; Campos and Vazquez-Brust, 2016; Kou and Lee, 2015; Qrunfleh and Tarafdar, 2013; Simpson and Power, 2005; So and Sun, 2010; So, 2010; Wiengarten et al., 2013)
L2	Suppliers and company involvement in NPD (New Product Development)	Cooperation and activity integration between manufacturers and suppliers encourages the suppliers to be involved early in the product design process	(Campos and Vazquez-Brust, 2016; Kou and Lee, 2015; Qrunfleh and Tarafdar, 2013; Simpson and Power, 2005; So and Sun, 2010; So, 2010; Wiengarten et al., 2013)
L3	Communication and information exchange between suppliers and company	Effective information sharing across the coordination and collaboration of information in the supply chain	(Campos and Vazquez-Brust, 2016; Qrunfleh and Tarafdar, 2013; Simpson and Power, 2005; So and Sun, 2010; So, 2010; Wiengarten et al., 2013)
L4	Electronic-enabled supply chains	The aspect of using e-business system and information sharing allows better integration of production planning and scheduling to improve operational efficiency and increase materials flows and information flows accuracy	(Azevedo et al., 2012; Campos and Vazquez-Brust, 2016; So and Sun, 2010; So, 2010)

L5	JIT delivery practices	This practice involves frequent deliveries of small quantities from the tier suppliers to the production line	(Agus and Hajinoor, 2012; Azevedo et al., 2012; Campos and Vazquez-Brust, 2016; Govindan et al., 2015, 2014; Shah and Ward, 2003; Wiengarten et al., 2013)
L6	Pull production systems	A method of controlling the flow of resources by replacing only what the customer has consumed, thus eliminating not only waste but also the sources of waste	(Agus and Hajinoor, 2012; Campos and Vazquez-Brust, 2016; Marodin et al., 2016; Perez et al., 2010; Shah and Ward, 2003)
L7	Value stream mapping (VSM)	VSM includes a representation of the flow of materials and information from supplier to customer	(Campos and Vazquez-Brust, 2016; Hines and Rich, 1997)
L8	Lean training	Training lean initiatives are mechanisms to enable an exchange of experiences and for proposing goals for the extending of lean manufacturing practices	(Campos and Vazquez-Brust, 2016; Lopes de Sousa Jabbour et al., 2014; Stewart et al., 2010)

Resilient Supply Chain Management

Implementing lean principles can provide reduced cost, greater manufacturing efficiency and flexibility, and thus an increased profitability (Vonderembse et al., 2006). However, this also has made modern SC more vulnerable, since firms have seen their buffers availability reduced not being able to face disasters or unexpected event impacts.

In this context, disruptions are described as unforeseen events that disrupt the normal activity and flow of goods, components and materials among the SC players (Craighead et al., 2007; Svensson, 2000). These are characterized by a high uncertainty, which may arise from many sources as physical events (i.e., a fire, power cuts), personnel events (i.e., malicious actions), information crisis (i.e., cyber-attacks), environmental disasters (i.e., earthquakes, floods), terrorism actions (i.e., bomb attack in Brussels-National airport) and even political instability. In order to minimize the consequences of such events, managers have become more concerned about building more resilient SC.

A resilient SC is capable of anticipating and minimizing negative effects of disruptions, as well as meaningfully reducing the recovery time needed to return to the normal activity (Blackhurst et al., 2011; Pettit et al., 2010; Rice and Caniato, 2003). Moreover, a more resilient firm may improve its competitive position and the response capability of its SC (Sheffi and Rice Jr., 2005).

Achieving resiliency along the SC demands coordinated efforts from all upstream and downstream corporate entities. With this in mind, previous studies described robust strategies to improve firms 'capabilities (Juttner et al., 2003; Tang, 2006). Stecke and Kumar (2009) linked disruption types with the most appropriate mitigating strategies. In the same line, Chowdhury and Quaddus (2015) developed a multi-objective approach to determine the most efficient portfolio of resilient strategies in order to mitigate the negative effects of disruptions. Rajesh et al. (2015) applied a diagraph based method and grey theory for ranking resilient strategies according to its effectiveness. Carvalho et al. (2012) went one step further with simulating different alternative SCs in order to study how mitigation strategies impact on each SC player performance.

We have identified a total of twelve resilient SC practices that will be used in the current study and that are represented in Table 2.

Table 2. Resilient practices in the SCM

Code	Resilient SC practice	Description	References
R1	Use of control information system	Use of control information system to detect, monitor and/or respond to unexpected events	(Chowdhury and Quaddus, 2015; Elzarka, 2013; Guojun and Caihong, 2008; Pettit et al., 2013, 2010; Rice and Caniato, 2003; Romano et al., 2013; Stecke and Kumar, 2009; Tukamuhabwa et al., 2015)
R2	Communication and information sharing with suppliers	Information sharing between SC entities to detect, monitor and/or respond to unexpected events	(Chowdhury and Quaddus, 2015; Elzarka, 2013; Guojun and Caihong, 2008; Rajesh et al., 2015; Soni et al., 2014; Stecke and Kumar, 2009)
R3	Flexible supply base	Create a preferred supplier group to maintain material procurement when an unexpected event will happen	(Govindan et al., 2014; Guojun and Caihong, 2008; Iakovou et al., 2007; Rajesh et al., 2015; Spiegler et al., 2012; Stecke and Kumar, 2009; Tang, 2006)
R4	Real options	Core firm pays a proportion of costs derived from their supplier/s get/s redundancy	(Guojun and Caihong, 2008)
R5	Establishment of agreements between SC partners.	Resulting in more mutually beneficial agreements with clearly stated incentives and obligations	(Juttner et al., 2003; Pettit et al., 2013, 2010; Rajesh et al., 2015; Rice and Caniato, 2003; Romano et al., 2013; Tang,

		across time. Both parties undertake to improve its response capacity against unexpected events	2006; Tukamuhabwa et al., 2015)
R6	Improve visibility, collaboration, coordination and understanding with suppliers	Core firm and suppliers state procedures/mechanics/systems to anticipate, monitor and respond against unexpected events in a coordinated way	(Chowdhury and Quaddus, 2015; Elzarka, 2013; Govindan et al., 2015, 2014; Iakovou et al., 2007; Mascaritolo and Holcomb, 2008; Pettit et al., 2013, 2010; Ponomarov and Holcomb, 2009; Rajesh et al., 2015; Scholten et al., 2014; Soni et al., 2014; Spiegler et al., 2012; Stecke and Kumar, 2009; Tang, 2006; Tukamuhabwa et al., 2015; Zailani et al., 2015)
R7	Maintaining excess capacity in productions, storage, handling and/or transport.	SC partners maintain excess capacity in productions, storage, handling and/or transport to cope with the new requirements arising from the occurrence of unexpected event	(Chowdhury and Quaddus, 2015; Elzarka, 2013; Govindan et al., 2015; Iakovou et al., 2007; Juttner et al., 2003; Pettit et al., 2013, 2010; Rajesh et al., 2015; Rice and Caniato, 2003; Romano et al., 2013; Soni et al., 2014; Spiegler et al., 2012; Stecke and Kumar, 2009; Tang, 2006; Tukamuhabwa et al., 2015; Zailani et al., 2015)
R8	Enforce security	SC partners enforce security against delivered attacks	(Stecke and Kumar, 2009; Tukamuhabwa et al., 2015)
R9	Contingency planning	Set of measures aimed at identifying and treating s risky event before it affects normal activity of company	(Hohenstein et al., 2015; Pettit et al., 2013, 2010; Tukamuhabwa et al., 2015)
R10	Disaster Recovery Plan	Set of measures aimed at recovering the normal activity of the company after an unexpected event had happened	(Pettit et al., 2013, 2010; Romano et al., 2013)
R11	Alternative transportation routing	Core firm plan alternative transportation routing to make deliveries on time after an unexpected event had happened	(Chowdhury and Quaddus, 2015; Govindan et al., 2015, 2014; Mascaritolo and Holcomb, 2008; Pettit et al., 2013, 2010; Rajesh et al., 2015; Rice and Caniato, 2003; Romano et al., 2013; Spiegler et al., 2012; Stecke and Kumar, 2009; Tang, 2006)
R12	Visible transportation	Core firm implements advanced tracking system that enables to know where transported elements in real time are	(Romano et al., 2013; Stecke and Kumar, 2009)

Conflicts and synergies of lean and resilience paradigms

Lean philosophy focuses on producing exactly what is needed and when is needed, and therefore, on reducing all kind of wastes on manufacturing systems (i.e. raw materials, work in process and final products inventory). As a consequence, this reduction in inventory makes it more difficult for the system to immediately recover against unexpected disruptions that lead to an interruption in the materials flow throughout the SC. Lean SC that focus on minimizing inventory may be more vulnerable to major information system failures unless specific steps to build resilience along the SC are taken (Dynes et al., 2007). In fact, there are companies that even though applying lean philosophy in their manufacturing system, still maintain high inventory levels in order to face uncertainty in their SC (Sezen et al., 2012).

Therefore, there seems to be a “conflict” between lean and resilience paradigms (identified in the literature) since both pursue objectives that, at times, may require opposite actions. Under these circumstances, some attention has been paid to procedures to overcome this conflict. Costantino et al. (2014) propose a new inventory replenishment policy that relies on information sharing in order to increase SC resilience when lean practices are implemented in the system. Mohammaddust et al. (2014) propose a mixed lean and responsive technique, which determines optimal SC design according to the organizations’ uncertainties and their performance goals. It identifies, thus, convergence and divergence points between lean and resilience paradigms.

Despite this “conflict” between lean and resilience paradigms described in the literature, there are also recent works that support the synergistic relationship between both paradigms. In fact, Birkie (2016) show that certain lean manufacturing practices can be of help in increasing resilience to unexpected events. Purvis et al. (2016) illustrate the importance of lean paradigms, as well as other paradigms, in order to increase the company’s ability to deal with disturbances in the SC. Lotfi and Saghiri (2018) show that a higher level of leanness may lead to a better recovery time and therefore, to a higher resilience in the system. Therefore, the trade-offs between lean and resilient practices in the SC should be examined in detail, since it highly depends on the group and combination of practices implemented. This paper aims to shed light on the relationship between lean and resilience paradigms and their impact on the SC.

Supply chain performance measurement

Choosing appropriate SC performance measures is a difficult task due mainly to the complexity of such systems (Beamon, 1999). Several efforts have been made in the literature to create a general framework to evaluate SC performance (Beamon, 1999; Gunasekaran et al., 2004, 2001). Having just a single performance measure is generally inadequate since it probably ignores critical factors and important interactions of the SC. However, having too many performance measures is not useful in practice. Measuring SC performance becomes even harder when different practices are implemented and the impact of those practices needs to be evaluated.

We will focus on operational and economic performance measures in order to evaluate SC performance using some of the performance measures established in the literature and in previous studies (Chan and Qi, 2003; Chavez et al., 2013; Gunasekaran et al., 2004, 2001; Prajogo et al., 2016). A total of five economic performance measures (Table 3) and eight operational performance measures (Table 4) are considered in this study in order to evaluate SC performance.

Table 3. Economic performance measures to evaluate SC performance.

Code	**Economic performance**	**Reference**
ECP1	Decrease in cost for materials purchasing	(Green et al., 2012; Prajogo et al., 2016; Zhu et al., 2008)
ECP2	Decrease in cost for energy consumption	(Green et al., 2012; Zhu et al., 2008)
ECP3	Decrease in fee for waste treatment	
ECP4	Decrease in transportation cost	(Chan and Qi, 2003; Gunasekaran et al., 2004, 2001)
ECP5	Decrease in production cost	(Chan and Qi, 2003; Chavez et al., 2013; Gunasekaran et al., 2004, 2001; Prajogo et al., 2016)

Table 4. Operational performance measures to evaluate SC performance.

Code	**Operational performance**	**Reference**
OPP1	Increase in goods delivered on time	(Chan and Qi, 2003; Prajogo et al., 2016)
OPP2	Decrease in inventory levels	(Chavez et al., 2013; Gunasekaran et al., 2004, 2001; Prajogo et al., 2016)
OPP3	Decrease in scrap rate	(Gunasekaran et al., 2004, 2001)
OPP4	Increase in product quality	(Chan and Qi, 2003; Gunasekaran et al., 2004, 2001)
OPP5	Improved capacity utilization	(Chan and Qi, 2003; Gunasekaran et al., 2004, 2001; Prajogo et al., 2016)
OPP6	Reduction in delivery time	
OPP7	Increase in customer satisfaction	(Govindan et al., 2015; Gunasekaran et al., 2004, 2001)
OPP8	Increase in productivity	(Bonavia and Marin, 2006; Chan and Qi, 2003; Chavez

		et al., 2013)

3. Description of the study

The aim of this research is to study the interdependence between lean and resilient SC practices and its impact on SC performance. For that purpose we chose a sector, the aerospace sector, in which both strategies, lean and resilient, are of great importance. On one hand, lean is important not only on production processes but also on the supply function within the aerospace sector (Bortolotti et al., 2016; Michaels, 1999). SC in the aerospace sector contain a large number of small businesses making inexpensive parts, as well as other larger companies producing more expensive parts or assemblies (Bales et al., 2004; Ehret and Cooke, 2010; Hickie, 2006). On the other hand, supplier risk is high in these types of SCs and in this sector, which makes necessary ways of mitigating supplier risks in the SC (Sinha et al., 2004).

The aerospace manufacturing industry is one of the EU's key high-tech sectors on the global market since it provides more than 500,000 jobs and generated a turnover of close to 140 billion € (in 2013). The industry is highly concentrated, both geographically (in particular EU countries) and in terms of the few large enterprises involved. Employment in the aerospace sector is particularly significant in the United Kingdom, France, Germany, Italy, Spain, Poland and Sweden.

4. Methodology and Research Design

In this section we describe the methodology used in this research. Figure 1 presents the step-by-step process followed in the research through a basic flow chart.

We first start carrying out an extensive literature review on lean and resiliency practices applied to the SCM as well as on SC performance measures. In order to identify them, we consulted the following bibliographic databases: Science Direct, Willey Online Library, Emerald Management Xtra, Taylor & Francis Online and SpringerLink. The period of time was not limited. Among the detected publications, we only selected those that clearly identify either the practices or measures above-mentioned. Tables 1 and 2 presents the lean (L) and resilient (R) SC practices, respectively, collected through the literature review, whereas Tables 3 and 4 show the SC performance measures, divided into economic (ECP) and operative (OPP) measures, respectively.

Once we collected all the practices found in the literature, we performed a preliminary survey with various experts of the aerospace manufacturing sector in order to identify the practices suitable for the sector in terms of importance and degree of implementation in the sector. These experts were chosen to have extensive knowledge on the aerospace manufacturing industry. For that purpose, we contacted *Fundación Hélice (http://helicecluster.com/)*, a member of the European Aviation Clusters Partnership, funded by the European Commission with the aim to promote the development of Industrial Clusters in the Aerospace industry, and chose the senior members to carry out the first phase of the study.

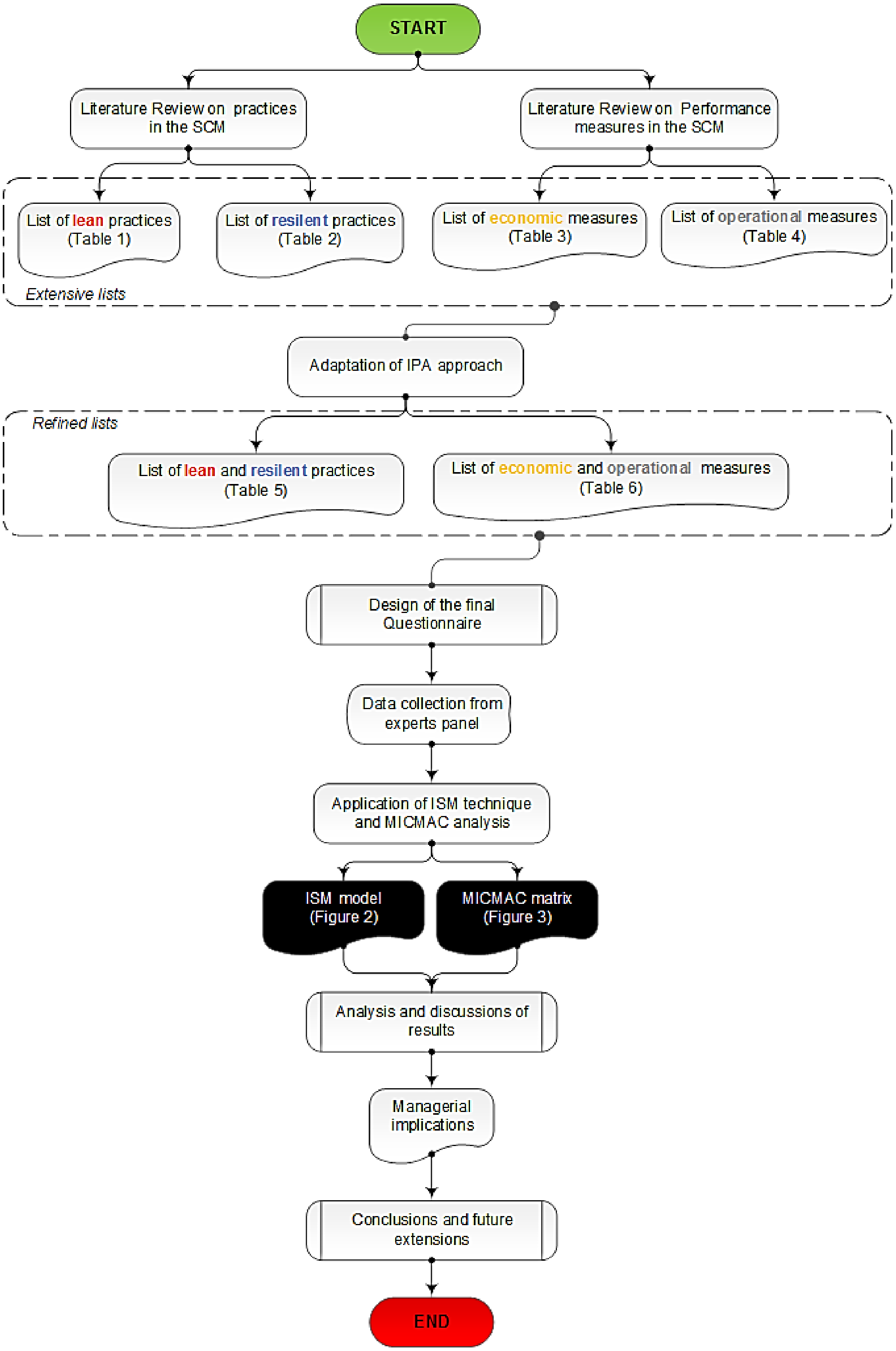

Figure 1. Research procedure

Subsequently, we adapted the importance-performance analysis (IPA) technique defined by Martilla and James (1977) with the aim of understanding customer satisfaction in the automobile industry. Our adaption of IPA screens lean and resilient practices on the basis of two dimensions: importance and grade of implementation in the aerospace manufacturing industry. The first dimension was only considered to screen SC performance measures. The questionnaire was designed using a 5-point Likert scale, where 1 means "not important" or "not implemented" and 5 means "very important" or "completely implemented". From the data collected in face-to-face interviews with experts, we calculated the means of both importance and grade of implementation dimensions so that global mean to identify the limit between low and high scores. Results allowed us to sort lean and resilient practices in four quadrants (Appendix A). Those practices put together in Quadrant B (high importance and high grade of implementation) were finally selected. These are showed in Table 5. The same procedure was applied with SC performance measures, although these elements were only sorted in two quadrants (Appendix B). Table 6 presents SC performance measures used in the aerospace manufacturing sector.

Table 5. Refined list of lean and resilient practices

Code	**Lean SC practice**	**Code**	**Resilient SC practice**
L1	Supplier selection, evaluating and monitoring.	R1	Use of control information system
L2	Suppliers and company involvement in NPD (New Product Development)	R3	Flexible supply base
L3	Communication and information exchange between suppliers and company	R9	Contingency planning
L4	Electronic-enabled supply chains.	R10	Disaster recovery plan
L5	JIT delivery practices.	R11	Alternative transportation routing
L6	Pull production systems.		
L8	Lean training.		

Table 6. Refined list of economic and operational performance measures

Code	**Economic performance measure**	**Code**	**Operational performance**
ECP1	Decrease in cost for materials purchasing	OPP1	Increase in on time deliveries
ECP3	Decrease in fee for waste treatment	OPP4	Increase in product quality
ECP5	Decrease in production cost	OPP5	Improved capacity utilization

4.1. Data collection

Since ISM models are built upon experts' knowledge (Govindan et al., 2012; Toktaş-Palut et al., 2014), the recruitment of participants is critical to obtain a model that can be generalizable and representative of the entire aerospace manufacturing SC. With this in mind, the recruitment was developed in two stages:

The first stage consisted in identifying companies in the aerospace manufacturing sector, using again the database of *Fundación Hélice*. Firms with manufacturing plants in Spain, one of the countries in which the aerospace industry is significant as stated in the previous section, were selected.

The second stage focused on recruiting experts from the selected companies who were willing to participate in the study. In order to guarantee the robustness of the model and generality of its findings in all SC levels, the panel of experts should pertain to a wide variety of positions and backgrounds (Lummus et al., 2005; Qazi et al., 2018). Therefore, the sample was selected to form a heterogeneous group of experts. The main selection criteria considered were a profound knowledge on lean or resilient management, current position, level of its firm in the SC and absence of conflicts of interest.

Data collection can be performed using a great variety of tools like brainstorming, questionnaires or nominal techniques (Govindan et al., 2015), amongst others. With this in mind, a specific questionnaire was designed to collect the necessary data. The first part included questions about experts' profile. The second part contained Structural Self-Interaction Matrix (SSIM) information. Personal interviews with the chosen experts were performed during the months of June to November of 2016.

A total of 15 experts pertaining to a total of 14 aerospace manufacturing plants agreed to participate in the study. Table 7 summarizes experts' profile. They belong to different professional scales and backgrounds as well as proven experience in lean and resilient management. These experts formed a heterogeneous panel where the entire SC insight was represented. Indeed, three of the experts belong to the OEM, whilst five, four and three of the experts belong to firms that operate in the first, second and third level of the aerospace manufacturing SC, respectively. Because of the high heterogeneity of the panel of experts, 15 participants is considered a good size in accordance to previous research (Clayton, 1997; Okoli and Pawlowski, 2004).

Table 7. Experts'profile

Position		**Academic background**		**Experience in lean, resilience**	
Plant Quality manager	6	Bachelor's Degree	1	1-5 years	7, 6
Operations manager	3	University Degree	3	6-10 years	3, 4
Lean manager	2	Diploma of Higher Education	2	>10 years	5, 5
Performance monitoring	1	Engineer's Degree	5		
Supply Chain manager	1	Not mentioned	4		
Facility manager	1				
Deputy Director of Plant	1				

4.2. ISM technique

After data collection, we used Interpretive Structural Modeling (ISM) to identify the practices that lead to or drive other practices and the ones that have any impact on the economical and operational performance measures and we analyze the results obtained. ISM is a known technique to solve complex decision making problems and to identify relationships among specific items which define a problem or issue (Sage, 1977; Warfield, 1973). ISM helps transform unclear and poorly articulated mental models into visible and well-defined structural models showing the interrelationships between the variables (Attri et al., 2013; Diabat et al., 2014; Dubey et al., 2015). Thus, this research does not attempt to empirically test any hypothesis but to develop new theoretical frameworks.

4.2.1. Structural Self-Interaction Matrix (SSIM)

With the contextual relationship described above in mind, the existence of a relation between any two practices and the associated direction of the relation is questioned. The impact of each practice on the economical and operational performance measures considered is also questioned, in this case with only one direction valid, from the practice to the performance measure. Relationships between performance measures are also investigated.

ISM model represents a finite set of n elements in a system represented by $S = (s_1,...,s_i,...,s_n)$. SSIM is built up based on contextual relationships of pair of elements (s_i and s_j). This means that i) one practice enables another one in the same strategy (lean or resilient), or ii) one practice leads to another practice of a different strategy, or iii) one practice impacts on a SC performance measure. In this way, experts were asked to fill out pairwise relationships among elements of the system in a 18*18 SSIM. With this in mind, we provided them the following four symbols:

V: Element i enables/leads to/impacts on element j.

A: Element j enables/leads to/impacts on element i.

X: Elements i and j are mutually interdependent.

O: No relationship between elements i and j.

Finally, we gathered fifteen SSIM from experts. We combined them by a simple averaging process to reach the final SSIM (Table 8).

Table 8. Structural Self-Interaction Matrix (SSIM)

	OPP5	OPP4	OPP1	ECP5	ECP3	ECP1	R11	R10	R9	R3	R1	L8	L6	L5	L4	L3	L2
L1	V	V	V	V	V	V	O	O	V	V	V	O	V	V	X	V	V
L2	V	V	V	V	V	V	O	O	O	O	O	O	O	O	A	X	
L3	V	V	V	V	O	V	V	V	V	V	V	V	X	V	X		
L4	V	O	V	V	O	V	O	O	O	O	V	O	V	V			
L5	V	V	V	V	O	V	V	O	O	V	V	A	X				
L6	V	O	V	V	O	V	V	V	O	V	O	A					
L8	V	V	V	V	V	V	O	V	V	V	O						
R1	V	O	V	V	O	V	V	V	V	O							
R3	V	V	V	V	V	V	O	V	V								
R9	O	O	V	V	O	O	X	V									
R10	O	O	O	O	O	O	X										
R11	O	O	V	O	O	V											
ECP1	O	O	O	V	O												
ECP3	O	O	O	V													
ECP5	A	O	O														
OPP1	A	O															
OPP4	O																

4.2.2. Reachability matrix.

The SSIM is converted into a binary matrix, i.e., the initial reachability matrix by substituting V, A, X, and O by 1 and 0. For better understanding we present the following guideline for translating symbols into binary digits:

- If the (i,j) entry in the SSIM is V, the (i,j) entry in the reachability matrix becomes 1 and the (j.i) entry becomes 0;
- If the (i,j) entry in the SSIM is A, the (i,j) entry in the reachability matrix becomes 0 and the (j.i) entry becomes 1;
- If the (i,j) entry in the SSIM is X, the (i,j) entry in the reachability matrix becomes 1 and the (j.i) entry becomes 1;
- If the (i,j) entry in the SSIM is O, the (i,j) entry in the reachability matrix becomes 0 and the (j.i) entry becomes 0;

Table 9 shows the initial reachability matrix previously obtained. After checking the transitivity property, it is converted into the final reachability matrix. Table 10 depicts the final reachability matrix where driving and dependence power is also represented. Indirect connections are represented with 1*.

Table 9. Initial reachability matrix

	L1	L2	L3	L4	L5	L6	L8	R1	R3	R9	R10	R11	ECP1	ECP3	ECP5	OPP1	OPP4	OPP5
L1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1
L2	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
L3	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
L4	1	1	1	1	1	1	0	1	0	0	0	0	1	0	1	1	0	1
L5	0	0	0	0	1	1	0	1	1	0	0	1	1	0	1	1	1	1
L6	0	0	1	0	1	1	0	0	1	0	1	1	1	0	1	1	0	1
L8	0	0	0	0	1	1	1	0	1	1	1	0	1	1	1	1	1	1
R1	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	1
R3	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1
R9	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0
R10	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
R11	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0
ECP1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
ECP3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
ECP5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
OPP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
OPP4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
OPP5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1

Table 10. Final reachability matrix

	L1	L2	L3	L4	L5	L6	L8	R1	R3	R9	R10	R11	ECP1	ECP3	ECP5	OPP1	OPP4	OPP5	Driver power
L1	1	1	1	1	1	1	1*	1	1	1	1*	1*	1	1	1	1	1	1	18
L2	0	1	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	1	1	1	1	1	17
L3	1*	1	1	1	1	1	1	1	1	1	1	1	1	1*	1	1	1	1	18
L4	1	1	1	1	1	1	1*	1	1*	1*	1*	1*	1	1*	1	1	1*	1	18
L5	0	0	1*	0	1	1	0	1	1	1*	1*	1	1	1*	1	1	1	1	14
L6	0	1*	1	1*	1	1	1*	1*	1	1*	1	1	1	1*	1	1	1*	1	17
L8	0	0	1*	0	1	1	1	1*	1	1	1	1*	1	1	1	1	1	1	15
R1	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1	0	1	8
R3	0	0	0	0	0	0	0	0	1	1	1	1*	1	1	1	1	1	1	10
R9	0	0	0	0	0	0	0	0	0	1	1	1	1*	0	1	1	0	0	6
R10	0	0	0	0	0	0	0	0	0	1*	1	1	1*	0	0	1*	0	0	5
R11	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1*	1	0	0	6
ECP1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
ECP3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
ECP5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
OPP1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
OPP4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
OPP5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	3
Dependence power	3	5	7	5	7	7	6	8	8	12	12	12	13	9	15	14	9	10	

4.1.3. Level partitions

From the final reachability matrix (Table 10), the reachability and antecedent set for each variable is found. Please note that we have two types of variables, the practices and the SC performance measures. The reachability set consists of the variable itself and the other variables that it may drive, whereas the antecedent set consists of the variable itself and the other variables that may help in achieving it. Note that the antecedent set of any practice cannot contain any SC performance measure. SC performance measures could only appear in the reachability set of practices. However, practices could appear on both, the reachability set and the antecedent set of any SC performance measure. Furthermore, the intersection of both sets was deduced for all practices and SC performance measures. The variables for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-element in the hierarchy would not help achieve any other element above its own level, therefore, the SC performance measures should appear in the top levels of the ISM hierarchy. Once an element is assigned to one level it is separated out from the remaining elements. Then, the same process is repeated to find out all the levels and elements assigned to them. This process continues until no element is left without being assigned to a level. The final set of levels and variable assignations is shown in Table 11.

Table 11. Level partitions in the ISM model

Level	**Reachable set**	**Antecedent set**	**Intersection**	**Variable**
VIII	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L3, L4	L1, L3, L4	L1
VII	L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L6	L2, L3, L4, L6	L2
V	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L5, L6, L8	L1, L2, L3, L4, L5, L6, L8	L3
VII	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L6	L1, L2, L3, L4, L6	L4

V	L3, L5, L6, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L5, L6, L8	L3, L5, L6	L5
V	L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L5, L6, L8	L2, L3, L4, L5, L6, L8	L6
VI	L3, L5, L6, L8, R1, R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L6, L8	L3, L6, L8	L8
IV	R1, R9, R10, R11, ECP1,ECP5, OPP1, OPP5	L1, L2, L3, L4, L5, L6, L8, R1	R1	R1
IV	R3, R9, R10, R11, ECP1, ECP3, ECP5, OPP1, OPP4, OPP5	L1, L2, L3, L4, L5, L6, L8, R3	R3	R3
III	R9, R10, R11, ECP1, ECP5, OPP1	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11	R9, R10, R11	R9
III	R9, R10, R11, ECP1,OPP1	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11	R9, R10, R11	R10
III	R9, R10, R11, ECP1, ECP5, OPP1	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11	R9, R10, R11	R11
II	ECP1, ECP5	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, ECP1	ECP1	ECP1
II	ECP3, ECP5	L1, L2, L3, L4, L5, L6, L8, R3, ECP3	ECP3	ECP3
I	ECP5	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R11, ECP1, ECP3, ECP5, OPP5	ECP5	ECP5
I	OPP1	L1, L2, L3, L4, L5, L6, L8, R1, R3, R9, R10, R11, OPP1, OPP5	OPP1	OPP1
I	OPP4	L1, L2, L3, L4, L5, L6, L8, R3, OPP4	OPP4	OPP4
II	ECP5, OPP1, OPP5	L1, L2, L3, L4, L5, L6, L8, R1, R3, OPP5	OPP5	OPP5

4.1.4. Formation of ISM-based framework

We represent an initial diagraph according to the level partition of each element and the conical form of the reachability matrix. The conical form of the reachability matrix is achieved by rearranging the elements in the final reachability matrix according to its partitioning level (from highest to lowest). We obtained the initial diagraph by representing each element in its corresponding level, as well as connections between them. Subsequently, we removed transitiveness in the model and replaced each ID node with its corresponding description. Finally, we checked if there was any conceptual inconsistency in the model. Figure 2 shows the final diagraph. Oval circles represent elements and arcs pairwise relationships.

This figure is built upon direct and indirect relationships, so that a practice, which directly does not affect a specific SC performance metric, can finally affect it by the indirect effects between nodes. This is a strength of the ISM method, since Figure 2 shows a complete view of the problem under study. Thus, decision makers can observe beforehand what will happen if one practice is developed.

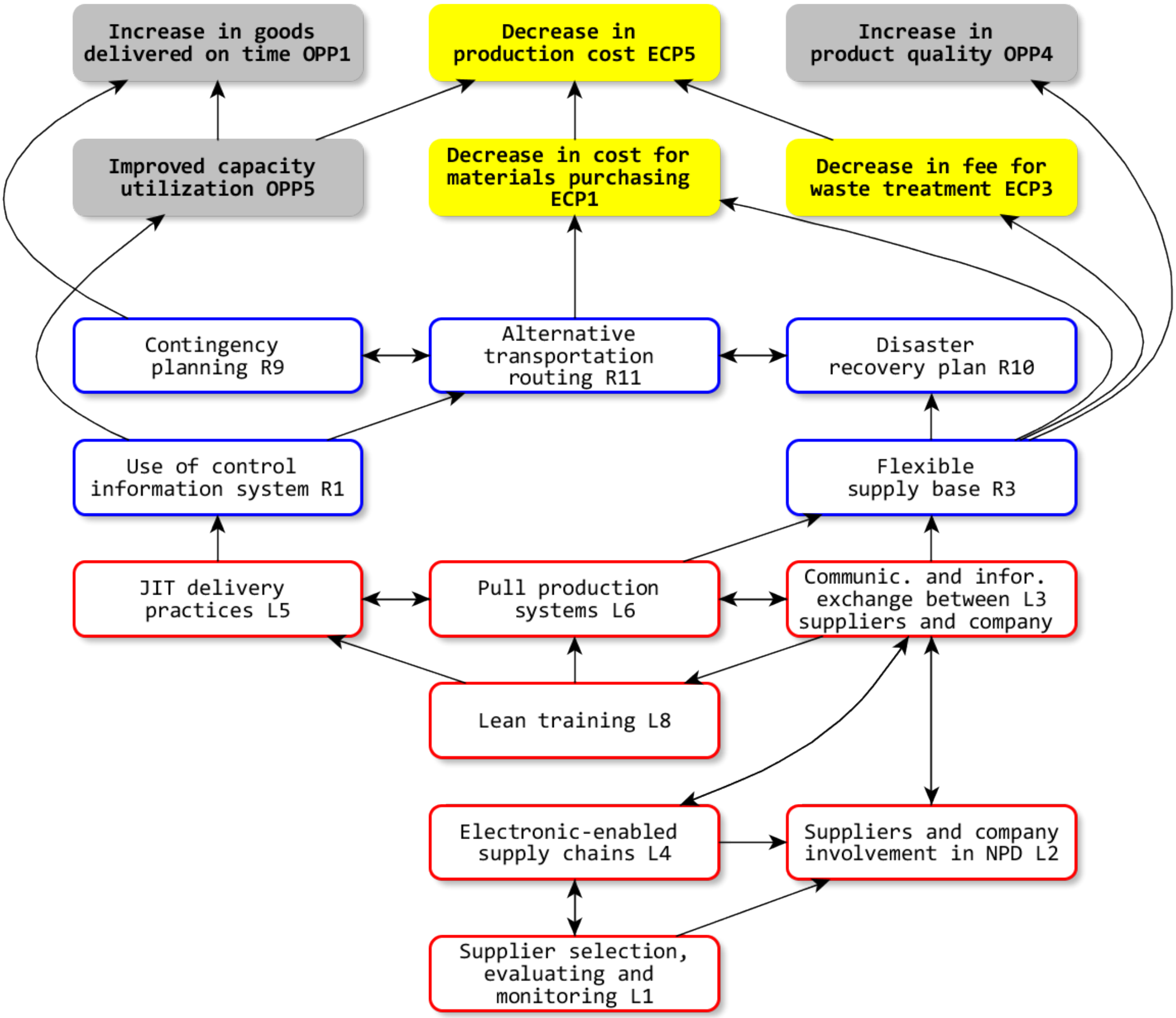

Figure 2. Final ISM diagraph.

4.2. MICMAC analysis

In order to provide a better understanding of interactions among lean and resilient practices, we developed a MICMAC (*Matrice d'Impacts Croisés Multipication Appliquée à un Classement*) analysis (Figure 3). From Figure 3, we divide the group of practices into four clusters according to the driving and dependence power of each practice (Mandal and Deshmukh, 1994; Sharma and Gupta, 1995). Each coloured point on the diagram represents a specific practice. Together with the name of each practice, we add in brackets the economical and operative performance measures, respectively, that are directly impacted by it.

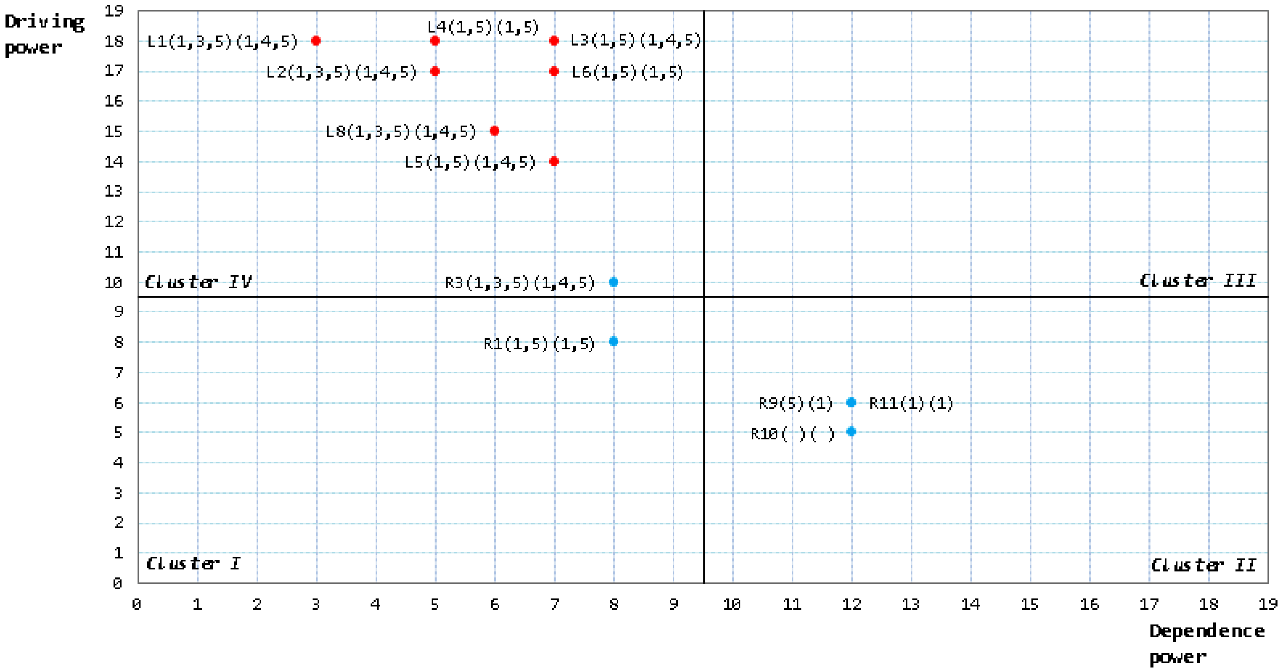

Figure 3. MICMAC matrix

5. Analysis and Discussion of Results

First of all, lean and resilient practices really applicable to the aerospace sector are identified. We observe that lean practices are really important in the sector, as expected, and are the most implemented ones (7 out of 8 are implemented and considered as important). Resilient practices, however, are still not that common on the sector (only 5 out of 12 are implemented and considered as important) although its importance has been highlighted in the first part of this research.

Looking at Figure 3 the following classification of the variables under study can be made:

Quadrant I (Autonomous variables): R1 is the only variable in this quadrant. Elements in this quadrant are weak drivers and weak dependents; and therefore, R1 does not have a high connection degree with the remaining practices. For this reason, R1 should be considered as autonomous variable. However, this does not mean that R1 does not have any influence in SC performance. Indeed, this resilient practice improves economic performance by reducing sourcing and manufacturing costs. Furthermore, R1 also enhances operational performance by increasing on time delivery and by improving capacity utilization. From Figure 2, we can observe that R1 acts as connecting point or driver between lean practices and other resilient practices, and thus, helping also indirectly to achieve a better economical and operational performance in the aeronautical sector. In fact, R1 is placed closely to the limit between Quadrant I and IV.

Quadrant II (Dependent variables): Practices R9, R10 y R11 are represented here. The practices in this quadrant have low driving power and high dependence power. Looking at Figure 2, R9, R10 and R11 are influenced by lean and the rest of resilient practices (R1 and R3). Additionally, these resilient practices provide limited impact on economical and operational performance. More specifically, both R9 and R11 may lead to increase in on time deliveries. By contrast, only R9 can decrease manufacturing cost and R11 can decrease the cost of materials purchasing. R10 does not even provide any improvement neither in the economical nor the operational performance of the company.

Quadrant III (Linkage variables): This quadrant includes unstable variables. That is, any action on these elements will affect the others, and may also have a feedback effect on themselves. In this case no practices appear in this quadrant. This implies that none of the lean or resilient practices act as driver/receiver at the same time. R1 and R3 are close to this quadrant. At the same time, they are located in the intermediate ISM level (Figure 2). In fact, they connect lean practices with other resilient practices. Hence, R1 and R3 would be considered as linkage practices even though they do not appear in this quadrant.

Quadrant IV (Driving variables): All the lean practices and R3 are included here. Lean practices have high driving power and low dependence power. Therefore, we can conclude that lean practices are important enablers for resilient practices, playing R1 and R3 the role of linkage between them. This is also showed in Figure 2. In addition, lean practices are also important to improve economical and operational performance as all of them may positively impact some of the economical or operational measures considered if not all of them. L1, L2 and L8 may lead to improvements in all the economical and operational measures considered, meanwhile L3 and L5 may have a direct influence in five of them. The direct effect of L4 and L6 on performance measures is a bit more limited (only impacting four of them). R3 is very close to the intersection between quadrants and therefore, it is also a very particular variable as R1 is. In fact, we can observe that both, R1 and R3, should be considered as linkage variables between lean practices and the remaining resilient practices as Figure 2 shows. Moreover, R3 may directly lead to improvement in all economical and operational measures under study.

5.1. Contributions to theory

From a theoretical point of view, this research has implications for the implementation of lean and resilient strategies in SCs as well as the impact of both paradigms on SC performance.

By being one of the first works to study the relationship between LSCM practices (Jasti and Kodali, 2015) and RSCM practices (Pettit et al., 2010; Rice and Caniato, 2003) and their joint impact on supply chain performance, this study considers a wide number of practices implemented in each of the strategies and investigate the linkages among such practices and SC performance metrics (operational and economic) through a single systemic framework. We extend, in terms of complexity of the resulting model, the work of Govindan et al. (2015), who studied the influence of lean, green and resilient practices of the company on the SC performance. This study also contributes to the debate on the “synergic/conflicting” relationship between lean and resilient paradigms.

This study shows that lean SC practices promote resilient SC practices when the objective is to improve the operational and economical performance. This finding extends to company's SCs previous studies done at the company's operational level (Birkie, 2016). Birkie (2016) found that for a company showing high performance, if lean implementation is high, then its resilience is almost most probably high. Therefore, in order to improve operational performance when lean practices are implemented, resilience practices also need to be present. This is also true at the SC level.

Additionally, lean practices that facilitate information sharing between parties ("Electronic-enabled SC" and "communication and information exchange") appear jointly with "supplier selection, evaluating and monitoring" as the lean practices with the highest driving power. This finding supports previous studies (Costantino et al., 2014) that have implemented information sharing practices in order to improve SC resilience when lean practices are also implemented in the system.

Finally, resilient SC practices –initially aimed at decreasing recovery time when facing any disturbance– implemented in parallel with lean SC practices, can improve operational and economical performance, in line with Lotfi and Saghiri (2018) which empirically validated a model on the impact of resilience, leanness and agility on different performance outcomes.

5.2. Managerial implications

Taking as reference the results obtained by the combination of the IPA adaptation and the ISM approach, the following managerial implications can be inferred from this study:

1. Lean practices are the most important practices for the aerospace sector as most of them are being implemented (7 out of 8) and they act as drivers for other resilient practices. Therefore, when lean practices are carried out, the implementation of practices in order to make the SC more resilient becomes more necessary.

2. "Supplier selection, evaluating and monitoring" is an enabler for the remaining lean practices under consideration and also helps improve economical and operational performance. Therefore, it appears as a "first step" in order to achieve leanness in the SC, since it facilitates the implementation of other lean practices, and resiliency in the SC, since it drives resilient practices. Hence, if managers seek to improve the operational and economic performance, the above mentioned lean practice should be successfully developed.
3. "Electronic-enabled supply chains" and "Suppliers and company involvement in NPD" also appear as enablers of other lean practices and help improving economical and operational performance.
4. "Training in Lean" is a lean practice that also enables other lean practices and additionally, it helps improving all the economical and performance measures under consideration. Therefore, investing in lean training of providers highly impacts SC performance.
5. "Flexible supply base" is the only resilient practice that helps achieving improvement in all economical and operational performance measures under study. Therefore, if managers seek to improve the operational and economic performance through resilient practices this is the practice recommended for implementation.
6. "Increase in product quality" and "Decrease in fee for waste treatment" are the most difficult performance measures to achieve since they are only achieved by six of the twelve practices considered. If any of those improvements are desired managers should carefully evaluate which practices are the most convenient ones to that end.
7. "Flexible supply base" and "Use of control information systems" can enable the remaining resilient practices and help achieve a better economical and operational performance with respect to other resilient practices. Therefore, if managers seek to improve SC performance through resilient practices these two practices are the most desirable ones.

8. “Disaster recovery plan” does not achieve any economical or operational performance measure. It makes sense since this resilient practice is aimed to recover after a disaster has occurred and therefore nor economical or operational performance can be improved.

6. Conclusions

This paper presents an investigation of the relationships between lean and resilient SC practices and their impact on economical and operational performance. On one hand, lean SC practices seek to minimize all possible wastes in the SC. On the other hand, resilient SC practices pursue to minimize the impact of any unexpected event and the time that the SC needs to go back to its initial state, before de disturbance took place. In order to carry out the above mentioned investigation we focus on the aerospace sector, as a sector in which both lean and resilient paradigms are of interest.

From the academic point of view, this research provides an explicit research procedure that can be replicated in similar studies, that combines the IPA approach and the ISM technique (Figure 1). Additionally, this research further explores the interrelationship between lean and resilient SC practices and their impact on SC performance, trying to cover the existing gap in the literature on the “conflict/synergy” effect of lean and resilience paradigms. A major contribution of this research lies in the development of linkages among various lean and resilience practices and SC performance metrics (operational and economic) through a single systemic framework. Findings highlight that lean and resilience practices are closely connected, being the first ones leading to the second ones, in line with Govindan et al. (2015). Hence, the lean practices studied might impact SC vulnerability, in line with the results in Dynes et al. (2007). An additional contribution of this study lies in the higher number of practices considered in each paradigm to better capture the existing links between practices, that may have been previously ignored.

From the practitioners' point of view, several managerial implications are deduced from the study that can be used by managers to better choose between different lean and resilient SC practices, depending on the performance objectives of the company.

We find out, first of all, that lean SC practices have a higher rate of implementation than resilient SC practices in the aerospace manufacturing sector. This is consistent with the fact that lean SC practices have been present in the sector longer than resilient SC practices, which is a relatively new trend between academicians and practitioners (Fahimnia et al., 2014; Roberta Pereira et al., 2014; Tukamuhabwa et al., 2015). Nonetheless, the importance of resilience in the sector is recognized by experts promoting even more the importance of the results obtained in this study.

Lean SC practices may clearly lead to resilient SC practices by being drivers of the last ones. This confirms previous studies that state that lean enhancements on operational measures have resulted in SCs more vulnerable to disruptions (Carvalho et al. 2012; Ponomarov and Holcomb 2009; Kamalahmadi and Parast 2016). Therefore, companies that implement lean practices also need the implementation of resilient practices to overcome the increasing vulnerability of their SC and to achieve an adequate SC performance. Clear relationships can be established between Lean SC practices, being "supplier selection, evaluating and monitoring", "electronic-enabled supply chains" and "suppliers and company involvement in NPD" the ones that enable all the remaining lean practices. Lean SC practices as well, drive resilient SC practices as observed in Figure 2, and "use of control information system" and "flexible supply base" are the resilient SC practices that enable the remaining resilient practices.

Regarding their impact on economical and operational performance, lean SC practices are the ones that, in general, offer a greater impact on both performance areas. Resilient SC practices have a limited impact on economic and operational performance, except for "flexible supply base", that achieves improvement in all performance measures under consideration. "Disaster recovery plan" does not impact at all on any SC performance measure, which makes sense, since this resilient practice is aimed to recover the SC once the disturbance has been produced and therefore, operational and economical performance has already been negatively affected.

Taking into account that the relationship and hierarchy among practices and performance measures were identified according to the perceptions of professionals from the Spanish aerospace sector and they will not be so different from the perceptions of a panel of experts from a different country, these finding could be generalized to other countries within the same sector or sectors with the same characteristics as the aerospace sector.

This leads to a limitation of this study which is the sector under consideration. We believe that the results are sector-related as similar studies in different sectors had led to different conclusions. However, some generalization is still possible on the methodology used to identify such relationships between SC practices and performance measures.

Govindan et al. (2015) studied the automotive sector leading to somehow different conclusions to the ones obtained here. This sector follows a mass customization strategy to manufacture high quality and high volume of differentiated products satisfying increasingly personalized customer's desires on time and close to mass production prices. This relies on a high process flexibility (Da Silveira et al., 2001), together with the application of effective scheduling techniques to shorten the lead time. The AMS, on the contrary, follows a project focus strategy to build to order a low volume of unique and high quality aircrafts, being thus necessary to incur longer lead times and higher cost. With these matters in mind, a close collaboration and integration along the entire SC must be achieved (Alfalla-Luque et al., 2013). Hence, some differences between sectors may be found and to generalize the results obtained in this type of study in any sector may lead to some inconsistencies.

On one hand, Govindan et al. (2015) revealed that Just in time (JIT) is the most significant lean practice in the automotive industry, since it enhances production flexibility and drives raw material and work in process inventories down. On the contrary, JIT presents a limited power to enhance all SC performance measures in the AMS. To that end, this practice must be performed along with the resilient practices *use of control information system*s and *flexible supply base*. This is due to the fact that components and pieces supplied by providers are highly complex and customized and therefore are not easily replaced in the short term. Therefore, if an unexpected event happens, lead time might become longer and even lead to delivery delays of the final product. Thus, we can conclude that the greater the level of complexity of components and pieces supplied together with the implementation of JIT, the worse the response to unexpected events. For this reason, JIT drives the establishment of a preferred suppliers' group that guarantees material sourcing at any time.

On the other hand, flexible transportation was viewed in the automotive sector as the most significant resilient practice because of transportation lead time reduction, thereby increasing customer satisfaction (Govindan et al., 2015). Moreover, in the automotive sector, flexible transportation prompts the lean practice total quality management. In the AMS, alternative transportation routes also lead to increase in goods delivered on time, although it does not impact product quality.

Finally, although we do not attempt to generalize the results obtained to different industry sectors, we do believe that more studies in different sectors are needed in order to establish what factors define the relationship between such SC practices and to identify similarities between sectors. As future research, the relationships' map obtained in this study through a panel of experts, can be statistically validated using techniques such as confirmatory factor analysis (CFA).

Looking to the future, further progress is also required to surpass some limitations of the ISM method. Its primary goal is to convert unclear and complex set of items into a well-defined model based on nodes and linkages between them. A critical point in its development lies in the identification of the nodes that should be incorporated into the model, since it extremely conditions its explanatory power and validity. With this in mind, ISM could be coupled with other formal methods that allow researchers to find out which are the most relevant nodes in real-world systems. Focusing now on the linkages between nodes, a greater number of nodes incorporated into the model, a greater number of pairwise comparisons needed. The latter will grow at a $n(n-1)/2$ rate. Thus, it can become a very difficult and time-consuming process, which should lead to the development of a new algorithm for minimizing the required pairwise comparisons. Finally, conventional ISM approach only reflects binary relationship between pairs of nodes. Notwithstanding, in futures studies, fuzzy set theory could be incorporated into the mathematical foundations of ISM to take the strength of connections into consideration and thus getting a more comprehensive model.

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Appendix A. Grade of implementation (G) and Importance (I) ratings of lean and resilient SC practices

	Quadrant A			Quadrant B			Quadrant C			Quadrant D	
Code	G	I	Code	G	I	Code	G	I	Code	G	I
L7	2.2	3	L1	3.5	4	R4	2.6	2.6			
R2	2.4	3.8	L2	3	3.4	R5	2.6	2.6			
R8	2.6	3	L3	3.4	3	R6	2.6	2.4			
			L4	3.4	3	R7	2.4	1.6			
			L5	3	3	R12	2.2	1.6			
			L6	2.8	3						
			L8	3.6	3.6						
			R1	3.2	2.8						
			R3	4.5	2.75						
			R9	3.4	3.8						
			R10	3	3						
			R11	3.4	3.8						

Appendix B. Importance (I) ratings of SC performance measures

	Quadrant A		Quadrant B
Code	I	Code	I
ECP2	3	ECP1	3,75
ECP4	3	ECP3	3,25
ECP6	2,5	ECP5	3,5
OPP2	3,25	OPP1	3,75
OPP3	2,75	OPP4	4
OPP6	3,5	OPP5	3,75
OPP7	3,5		
OPP8	3		

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