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**TESIS DOCTORAL**

# LEAN MANAGEMENT: STATE-OF-THE-ART AND SUCCESS FACTORS IN THE ADOPTION PROCESS. EVIDENCE FROM THE AEROSPACE


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# INTRODUCTION

This doctoral thesis seeks to contribute new explanatory factors of the transition process to Lean Management inferred from an empirical analysis conducted in the aerospace sector.

This introduction sets out the content of the doctoral thesis from a global and integrated perspective. Firstly, the background to the research is described so that the reasons that led us to undertake it can be understood. This includes a description of the origins, the development, the cornerstones and the expansion of Lean Management. The main reasons for conducting this research are then set out, including the objectives being sought and the research questions that we have attempted to answer. Secondly, the methodology used to achieve the proposed objectives and respond to the research questions is described in detail. Finally, the structure of the thesis is outlined and the content of each of the chapters is summarized.

# I. Background

## I.I. Origins, evolution and expansion of Lean Management

Lean Management is a direct descendant of the Toyota Production System (Holweg, 2007). It was first disseminated as a production system in 1990 with the publication of "The Machine that Changed the World" (Womack et al., 1990). This book summarized the findings of a research project entitled "International Motor Vehicle Program" conducted by the Massachusetts Institute of Technology in fifty-two automotive assembly plants in fourteen countries. The researcher in the project, John Krafcik (1988), coined the term "Lean" with the aim of distinguishing a new production approach different from mass production, which enabled small batch sizes of a wide range of products to be manufactured without causing costs to spiral and with zero wastes.

The main findings of the research project showed the key differences between the principles of mass production and Lean, and were also an empirical proof that the latter provided better results and a competitive advantage compared to the mass production system that prevailed in western automotive industries at that time. The findings also showed that the Lean system could be transferred to other organizations and other countries apart from the automotive industry and Japan (Holweg, 2007).

Consequently, the application of Lean Management has had a significant impact both in the academic and the professional worlds from the moment that Womack's pioneering book was published two decades ago.

In 1996 there was a turning-point in research into Lean Management with the publication of "Lean Thinking" (Womack and Jones, 1996). The authors highlighted the large amounts of waste produced in the majority of organizations and showed that a systematic reduction of these types of non-value added activities in an organization and throughout the supply chain can improve business results and the ability to achieve a competitive advantage. They also codified the essence of Lean in five fundamental principles and showed how these can be extended from an organization's production area to other areas and even the supply chain and from automotive production to any company, sector and country. These five fundamental principles are:

1) Specify value from the customer's perspective

2) Identify the value stream

3) Create a continuous value flow

4) Allow the customer to pull value

5) Pursue perfection

Despite researchers adhering to these principles, in recent years the Lean Management system has evolved and expanded significantly.

On the one hand, despite a description of the principles, objectives and general practices of Lean Management being provided by the authors who originally disseminated this management system, a number of researches have been undertaken to develop these further. The literature emphasizes in this respect that Lean Management, as a management theory, has evolved over a long period of time since it was first disseminated and will continue to do so. Specifically, the deployment of its principles and practices outside the manufacturing area has been detected and also across the entire supply chain in order to take advantage of all its potential benefits. Lean Management has therefore evolved to a point where it provides strategic value to the multiple stakeholders of the enterprise (Murman et al., 2002; Hines et al., 2004).

On the other hand, Lean Management has expanded significantly beyond its origins in the automotive sector. Thus, in the past two decades, companies in a wide range of industrial and service sectors have adopted this management system and have moved forward in its implementation, enabling them, in many cases, to improve their results and competitiveness (Hines et al., 2004).

## I.II. Motivation for the doctoral thesis, main objectives and research questions

Empirical evidence shows that although many companies that have made advances in their levels of Lean Management implementation have improved their results and competitiveness, other companies have not achieved the results that they had anticipated, and failed transformations have been common. In this respect, the literature emphasizes that the transition to Lean Management is complex and, in general terms, has to overcome a large number of hurdles (Scherrer-Rathje et al., 2009). For this reason, a number of authors stress that more in-depth research needs to be conducted to enable some light to be shed on the reason why some companies do not achieve the results that they expected with Lean Management, and on the success factors that enable the transition to this management system to be a success (e.g., Turesky and Connell, 2010; Bhasin, 2012).

The literature also underscores that the steps that have to be taken in the transition to Lean Management are very different from one sector to another and that it is therefore crucial to address and evaluate the initial situation and context of the company before adopting this management system (e.g., Murman et al., 2002). Despite the importance given to considering these factors, research has redoubled its efforts to analyze the advanced stages of the transformation to Lean Management, and has paid little attention to either a pre-diagnosis or the adoption phase itself.

In the same vein, several authors emphasize that the main issues that arise during the transition to Lean Management are caused by the following: a) little attention is paid to companies' contingent factors and their context before initiating adoption; b) an analysis that focuses more on adopting practices and tools in the production area rather than a strategically-oriented approach; c) little concern for aspects relating to people and their role in a Lean transformation, and d) companies' lack of ability to deploy Lean principles and practices across the supply chain (e.g., Murman et al., 2002; Hines et al., 2004).

Firstly, with respect to the little attention paid to companies' contingent factors and their context before initiating adoption, the literature has tried to identify the causes and consequences of adopting Lean Management in industrial sectors other than the automotive sector, such as the aerospace sector (Browning and Heath, 2009). The rationality behind this is the role that industrial contingent factors play in a Lean transition. Despite this, researchers identify only a limited number of studies that address the role played by these contingent factors (e.g., Arlbjørn and Freytag, 2013) and emphasize that it is vital that this limitation should be overcome if the way for this management system to be successfully adopted in different contexts is to be established (Shah and Ward, 2003; Moyano-Fuentes and Sacristán-Díaz, 2012).

Secondly, regarding the narrow approach focusing on the operative adoption of Lean principles and practices in the production area, the literature highlights that is crucial to adopt Lean Management with a strategic and holistic approach if a successful transition is to be guaranteed (e.g., Shah and Ward, 2003; Hines et al., 2008). Despite this, at present identifying the factors that might play a crucial role in the adoption of Lean Management and potentially impact on the adaptation outcomes remains a priority for the companies that want to begin or are beginning to adopt this strategic management system (So and Sun, 2011).

In this regard, Hines et al. (2008) highlight that for Lean Management to be successfully adopted it is not only necessary to focus on the "more visible" elements of Lean, such as the adoption of its practices and tools, but also that "less visible" aspects are crucial, including the strategy and its deployment, leadership and people's behavior and commitment. These authors also stress that Lean should focus on creating value across the supply chain.

Therefore, thirdly, with respect to the lack of attention to the human aspect of Lean Management and its crucial role in a Lean transformation, the importance of this lies in that people act as the "glue" that holds the whole Lean Management system together. However, the literature highlights that there is a lack of studies that examine the changes that take place in Human Resource Management during the early phases of the transition. The study of the role played by people, cultural change, and the success factors of HR management in the transition process to Lean Management therefore remains a critical priority (Bonavía and Marín-García, 2011).

Lastly, various authors state that the deployment of Lean principles and practices across the supply chain continues to be an unmet challenge which defies many companies that want to move forward in Lean Management (Murman et al., 2002). In fact, their deployment has become a growing challenge due to the contingent factors and the increased complexity, length, and globalization of supply chains (Mollenkopf et al., 2010). However, there are few articles that consider the role of industrial sector-related contingent factors in the successful adoption of Lean Supply Chain Management and it is, therefore, crucial to identify the factors that play a key role depending on the industrial context before and during the adoption process.

The main objective of this doctoral thesis is to address these gaps by driving forward research into this management system in general, and into the aerospace sector in particular. To put it more precisely, this thesis intends to identify the factors that might play a key role in one of the lesser researched phases of the transition to Lean Management, namely, its adoption. The importance of identifying, evaluating and understanding the factors that could play a key role during this early phase stems from the fact that prior knowledge of these factors before taking the strategic decision of adopting Lean Management and their proper management could guarantee the success of the adoption process and could mean faster progress with fewer impediments in the subsequent implementation phases.

These factors are identified from a strategic and holistic focus that considers the context of the aerospace sector. The aim is to analyze the role that these factors play in the Lean Management adoption process, both internally, inside the organization, and on the level of the supply chain. Special emphasis is placed on the “soft side” of this management system, that is, the appropriate management of the key factors that might play a determinant role in the “human side” of a Lean transformation.

The specific research questions and objectives of this doctoral thesis are the following:

1) What are the most studied research aspects of two crucial strategies in the aerospace sector: Lean Management and Supply Chain Management?

   We aim to achieve the following objectives on the basis of this research question:

   - ✓ To identify the topic set studied and contribute a criterion for grouping and classifying the literature.
   - ✓ To discuss the empirical evidence and establish the challenges and opportunities faced by future research.

2) Why do companies in the aerospace sector adopt Lean Management and how do they so on the strategic and intra-organizational levels?

   We seek to reach the following complementary objectives:

   - ✓ To identify the success factors that play a crucial role in the adoption of Lean Management.
   - ✓ To propose a model that includes these factors and the relationships between them in order to explain the adoption of this management system.

3) How do aerospace companies successfully manage Human Resources and how does it facilitate and enhance the transition process to Lean Management?

   We intend to achieve the following objectives:

   - ✓ To identify the success factors that explain human resources management during the various phases of the transition process to Lean Management.
   - ✓ To propose a model that includes these main factors and the relationships between them during these phases with a view to understanding the cultural change associated with this management system.

4) Why and how do industrial sector-associated contingent factors affect the success of the deployment of Lean principles and practices throughout an entire supply network?

We aim to reach the following complementary objectives:

- ✓ To identify the contingent factors that act as facilitators or inhibitors for Lean Supply Chain Management adoption depending on how the supply network being evaluated is configured.
- ✓ To determine how different supply networks within the entire supply network address the various contingent factors that they are confronted with.
- ✓ To propose an interpretive model with the aim of explaining Lean Supply Chain Management adoption.

**II. Methodology**

An in-depth literature review was conducted in order to answer to the first research question of the thesis and achieve the objectives. The idea underlying this course of action was that the literature review is a crucial step in structuring a field of research, as it provides a firm basis for enhancing knowledge, facilitates the development of theory, delimits areas of research and uncovers areas where more in-depth research needs to be done. The specific methodology used was a Systematic Literature Review. This methodology is based on the principles of transparency and inclusivity, and is explanatory and heuristic in nature, and is therefore an explicit and reproducible focus which seeks to minimize bias and errors.

Qualitative methodology was used to respond to the remaining research questions and reach the main objectives, to be specific, a case study method in the aerospace sector. This method is appropriate as Lean Management adoption on both the intra-organizational and supply-chain levels in the aerospace sector is an emerging area of research. Compared to other research strategies, the case study is also the most suitable method for responding to “why” and “how” questions of the type raised in this doctoral thesis. Moreover, the case study lends itself to exploratory research, where the variables are still unknown, the phenomenon is not well understood and when a deeper understanding is required of the factors that influence on a relatively new reality.

Data collection was done at a series of production plants on different levels of the entire supply network of the Andalusian aerospace sector. This sector is highly suitable for achieving the aims of this thesis as it is at an early stage of the transition to Lean Management.

On the one hand, this situation is decisive from an empirical point-of-view as it has enabled the key factors to be identified both prior to Lean Management adoption and as this early phase advances. The choice of this sector has therefore made it possible to make new contributions to existing research which has focused mainly on factors during advanced phases of the Lean Management implementation, and on sectors with extensive experience of implementing the principles and practices of this management system. It has also enabled the role played by a range of contingent factors pertinent to the sector to be identified.

On the other hand, the relevance of this sector for studying the adoption of Lean Supply Chain Management lies in the fact that it began to adopt this strategy only recently and is still at an initial stage. Therefore, the supply network structure transition was also in process, which might enable us to obtain relevant findings regarding the role that it plays. This also facilitates analysis of how a network is built and evolves in uncertain circumstances and under contextual conditions. Similarly, as the adoption only began a few years prior to the data collection process, the way that the initial conditions evolved could be observed over a significant period of time.

To respond to the second and third research question and achieve the objectives proposed, we selected plants that began the adoption of Lean Management a minimum of 3 years ago and had made advances in its transition. A multi-case method was used with a total of five plants: two were final aircraft assembly lines (FALs) whilst the others were prime contractors devoted to manufacturing and assembling parts, subassemblies and large aerostructures, primarily for the FALs. All the plants were members of the *European Aeronautic Defence and Space Company* consortium (EADS).

In order to answer to the doctoral thesis' fourth and last research question and to achieve effectively the objectives, we selected plants operating at different levels of the aerospace supply network. These were, specifically, two final aircraft assembly lines, three prime contractors and seven tier 1 and three tier 2 supplier plants. The choice of four supply networks enabled us to develop a comprehensive knowledge of the adoption of Lean Supply Chain Management throughout the whole supply network.

Both primary and secondary information sources were used to triangulate data. The primary sources used were: in-depth semi-structured interviews, surveys, plant visits/factory tours and, in some cases, statements made by top management and blue-collar workers. The secondary sources used were: company documentation, company websites and similar sources. Thirty-three top managers and executives were interviewed in all.

A highlight of this thesis is that each of the chapters details the methodology used to achieve the specific objectives and respond to the research questions in each one.

**III. Structure of the Thesis**

The doctoral thesis is divided into four chapters which address the four main research questions stated above.

The first chapter evaluates the state-of-the-art of research into the links between Lean Management and Supply Chain Management in the aerospace sector. The reason for studying these two strategies jointly lies in the fact that this sector developed different principles and practices of Supply Chain Management prior to the adoption of Lean Management. Management in the sector has therefore had to face up to the challenge of aligning these two strategies. As a result, we seek to identify how these two strategies can be aligned effectively in order to achieve better results and, in the final instance, achieve a competitive advantage. A novel criterion for classifying the literature is put forward with the aim of facilitating the task for both researchers and management who want to delve deeper into these topics. We also aim to identify the sector-specific contingent factors that might play a key role in the transition to Lean Management and that justify the need for the chapters that follow.

The second chapter describes the key explanatory factors that might play a crucial role during the Lean Management adoption phase. It is vitally important to have prior knowledge of the determining factors that affect the success of the Lean Management adoption process before starting its adoption. A Lean Management model is developed in this context that includes the factors that have been identified and their interrelationships. In this way companies that are proposing to adopt this management system can put effective strategies in place to ensure its adoption is a success.

The third chapter identifies the changes that take place in human resource management and the types of explanatory success factors that might play a determinant role during the early phases of the transition to Lean Management. Prior research analyzes the transition process to Lean Management without considering the different roles of people during the different phases of the process. A model is also developed that includes these success factors and their interrelationships in order to understand and explain the sequence that leads to the cultural change associated with this management system. This could help managers responsible for a Lean initiative to draw up aligned and time-sequenced action plans for achieving and sustaining the results of Lean Management.

In the fourth chapter, the adoption of Lean Supply Chain Management throughout a complete supply network is investigated, or rather, across four different supply networks, to be specific. For this, a literature review is conducted with the aim of identifying a series of critical elements and characteristics associated with Lean Supply Chain Management. We shall later analyze empirically how these can act as initial facilitating and inhibiting factors depending on how the supply networks are configured. Finally, a model is constructed to explain the adoption of Lean Supply Chain Management that considers a range of factors and the deployment of a number of key Lean practices.

To conclude, we should like to say that the last three chapters begin with introductions that state the motives for the research, the gaps that exist regarding the main research question that is seeking to answer and the specific objectives that we seek to address. Subsequently, a theoretical framework is developed that explains the state-of-the-art of research in the issue under study. The methodology used is then presented with the aim of answering to the specific research questions and achieving the objectives in each chapter. Lastly, the findings are showed and discussed, as are the conclusions on the added value that each chapter contributes to the topic under consideration in the study, and the implications for management that result from these conclusions.

Finally, it should be pointed out that the bibliographical references at the end of each chapter correspond to those that are cited in the chapter itself. The tables, figures and footnotes are numbered separately for each chapter, which means that each of the chapters contains a separate numbering.

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# LEAN MANAGEMENT AND SUPPLY CHAIN MANAGEMENT: INTERRELATIONSHIPS IN THE AEROSPACE SECTOR

I

## 1.1. Introduction

Lean Management (LM) has evolved and expanded significantly since its dissemination (Womack et al., 1990). On the one hand, it has moved forward from being a production system focused primarily on reducing the waste and variability produced on the factory floor level to being a wider-ranging management system addressing these main objectives from both an internal and an external approach (Hines et al., 2004; Shah and Ward, 2007). LM has thus evolved towards being a holistic management system focusing on the adoption and further implementation of its guiding principles, practices and tools both inside an organization as a whole and across the entire supply chain.

On the other hand, and at the same time, LM has spread beyond its origins in the automotive sector and been embraced in an array of economic sectors, including a number of service and industrial sectors (Moyano-Fuentes and Sacristán-Díaz, 2012). Research has matched this change and sought to identify the causes and consequences of LM transition by analyzing it in industrial sectors other than the automotive sector. The rationality behind this is the contingent factors found in different industrial sectors that play a crucial role in the transformation (Crute et al., 2003; Pérez et al., 2010). One growing trend that merits special mention is the recent trend in doing research in LM in sectors, such as the aerospace sector (Ehret and Cooke, 2010), where Supply Chain Management (SCM) plays a key role in companies' competitiveness.

As far as SCM is concerned, this strategy has been a cornerstone for competing in the current environment for several decades. It is in fact well-known that companies no longer compete as individual organizations, but as complete supply chains (Frohlich and Westbrook, 2001). SCM is a broad concept that has evolved over time. A Supply Chain Integration (SCI) (Pagell, 2004; van Der Vaart and van Donk, 2008) focus can be detected as far back as a decade ago. This focus requires companies to strategically align and integrate both their internal and their external processes with those of their key partners in the supply chain. A large number of companies in a variety of sectors have therefore adopted this focus and made advances in their levels of supply chain integration. Despite this, various authors emphasize that a low level of integration is the norm and that further research is therefore required into the dynamic of key contingent factors to determine how the principles and practices of SCI can most effectively be adopted and implemented due to the impact that these factors have on results on the supply chain level (Ho et al., 2002; Flynn et al., 2010).

Despite the importance of considering the role of contingent factors in these two strategies, a number of studies highlight the fact that this is not the case. With regard to LM, various researchers underscore the importance of determining how become Lean in different contexts (Shah and Ward, 2003; Browning and Heath, 2009). Meanwhile, others emphasize the lack of attention paid to contingent factors in SCM research (van Der Vaart and van Donk, 2008; Giménez et al., 2012). In general terms, Sousa and Voss (2008) stress the urgent need for a contingent focus to be considered in Operations Management research. This is the reason why this chapter focuses on investigating the role of contingent factors in these two strategies in a specific sector, the aerospace sector.

The world aerospace sector has been subjected to several critical changes, such as the changing role of governments, dramatic reductions in the defense and space budgets, changes in commercial conditions, increasing global competition and the challenge of adapting to technological changes, among other issues (Murman et al., 2002; Crute et al., 2003). These competitive priorities are related to improving delivery reliability, delivery times and production quality, increasing productivity and reducing inventory and operating costs, inter alia (James-Moore and Gibbons, 1997; Smith and Tranfield, 2005).

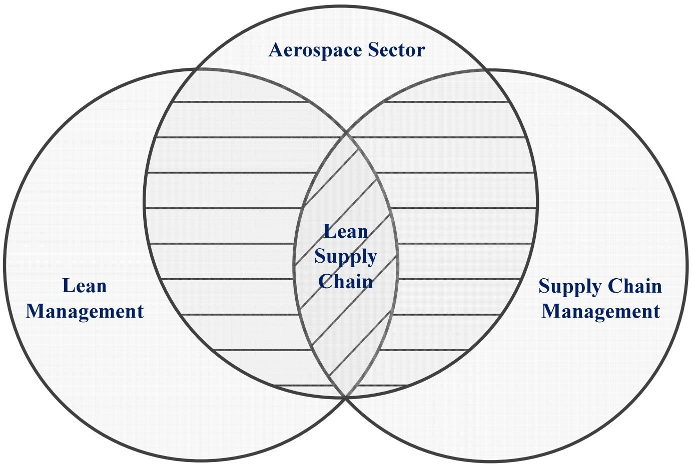
Despite this, an inability to respond to unforeseen changes in demand and delays in deliveries are still widespread problems. Competitiveness in this industry depends to a great extent on companies' internal flexibility, on adapting products to customers' needs and on improving SCM integration. These priorities can be achieved by adopting and implementing strategies like LM and SCM (Womack and Jones, 1996; Smith and Tranfield, 2005).

Given all this, and on the basis of some concerns regarding the simultaneous application of these strategies in this sector, the objective of this chapter is to evaluate the state-of-the-art of research into LM and SCM, and their interrelationships in the aerospace sector from a holistic focus. For this a Systematic Literature Review (SLR) has been carried out. Figure 1.1 shows the scope of the literature review; specifically, the shaded area where the circles intersect.

To be precise, the primary research question of this study is: *What are the most studied research aspects of two crucial strategies in the aerospace sector: LM and SCM?*

This primary question is supported by two complementary objectives: a) What are the interrelationships between LM and SCM and b) How can these two strategies be effectively aligned so as to achieve an improvement in results.

**Figure 1.1**
Objective of the Literature Review



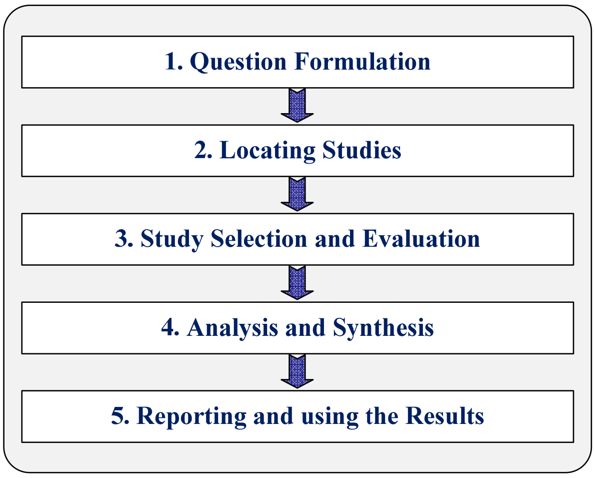

This chapter is divided into five sections, including this introduction. The second section is devoted to describing the systematic literature review methodology used and proposes a criterion for classifying the literature. The findings of the analysis and the synthesis of the literature are presented in the third section. These results are discussed in the fourth section and any gaps found are highlighted along with proposed future lines of research. The conclusions are set out in the last section with implications for academia and management.

### 1.2. Methodology

The method that we adopted was the "Systematic Literature Review" (SLR) as it guarantees a rigorous and structured literature review that can overcome the weaknesses of other traditional narrative review methodologies (Tranfield et al., 2003).

We have followed the five stages that Denyer and Tranfield (2009) proposed for the use of this methodology: 1) question formulation, 2) locating studies, 3) study selection and evaluation, 4) analysis and synthesis, and 5) reporting and using the results (See Figure 1.2).

**Figure 1.2**
Steps followed in the Systematic Literature Review.




Source: Adapted from Denyer and Tranfield (2009)

It is important to note that SLR methodology has been used successfully in other literature reviews in studies on topics related to this study, such as Supply Chain Management (Wong et al., 2012). Qualitative synthesis and analysis have also been carried out successfully in Lean Management (Moyano-Fuentes and Sacristán-Díaz, 2012) and Supply Chain Management-related (Gunasekaran and Ngai, 2005) studies. Each of the five stages is detailed in the following sub-sections.

### 1.2.1. Question Formulation

We were aided by an academician and two experts in the aerospace sector with the writing and tweaking of the research questions. The involvement of these types of stakeholders or potential users of the current chapter in the formulation of review questions can help to ensure that the literature review is well focused and that relevant questions are asked (Tranfield et al., 2003).

Using CIMO logic (Context, Intervention, Mechanisms and Outcomes), as established by Tranfield et al. (2003), we specified the critical aspects that needed to be investigated for the subsequent phases of well-built SLR methodology to be executed. By applying this logic to our context we were able to observe that the aerospace sector is contending with a number of changes that are impacting on its competitiveness. In this context, interventions of interest are represented by the adoption of LM and advances made in its implementation over the last two decades. It was also observed that a range of practices have been deployed in this sector with the aim of improving supply chain management and integration. There has also been a growing interest shown in the deployment of Lean principles and practices across the aerospace supply network. So, the mechanisms of interest are the deployment of effective principles, practices and tools within the company and across the complete supply chain which must be executed in keeping with an aligned strategy. The expected outcomes are enhanced operating and financial results, and the greater flexibility and reliability of aerospace companies and their supply chains.

The main topics of interest are, therefore: changes that have taken place in the sector and contingent factors in the sector (C), management strategies put in place (I), principles, practices and tools deployed and their proper alignment with business strategy (M), and improved results, increased flexibility and reliability across the whole supply network (O).

It should be pointed out that the experts stressed their concern for a practical problem in the aerospace sector which has been a challenge for senior management, and which needed to be evaluated in depth: how to align the LM principles and practices implementation effort with supply chain management and integration principles and practices. This challenge was a consequence of a range of supply chain management and integration principles and practices being put in place before LM adoption. In other words, the sector already had a number of aspects of supply chain management in place before undertaking the adoption of LM, as a result of which these two strategies needed to be aligned effectively. The chapter’s research questions were defined on the basis of this main challenge.

### 1.2.2. Locating Studies

The next step was to locate the most significant studies relating to the main research question. Two key decisions were taken for this: the search engines and search strings to be used.

The databases selected were: ABI Inform Complete (Proquest), SciverseHub (Scopus+ScienceDirect+Scirus) and ISI Web of Knowledge. These databases were considered to be the most suitable for addressing the scope of the study: LM and SCM. The literature was thus taken from journals in the areas of production management, operations management, operations research, general management, and supply chain management.

The search period in the databases was set for 1990 to April 2013. The starting point is justified by the fact that research into LM began in the year that the reference work entitled "The machine that changed the world" (Womack et al., 1990) was published. The beginning of research into SCM can also be traced back to the beginning of the nineteen-nineties (Hanna and Newman, 1995).

The keywords used in the searches conducted in the various databases were those frequently used in the literature to describe and delimit the area of study of LM, SCM and the aerospace sector. Brainstorming between the researchers was used to choose the keywords and a snowball effect subsequently added keywords to the searches as they were discovered in the literature. A total of 33 keywords were identified by this process (See Table 1.1).

**Table 1.1**
Keywords used in the searches conducted

| **Lean Management** | **Supply Chain Management** | **Aerospace Sector** |
|---|---|---|
| Lean, Lean Management, Lean Production, Lean Manufacturing, Toyota Production System, Lean Supply Chain Management, Lean Supply Chain, Lean Supply, Lean Distribution, Lean Supplier, Lean Customer, Lean Dealer | Supply Chain Management, Supply Chain Integration, Supply Chain, Customer Integration, Supplier Integration, Supplier Development, Relationships, Partnerships, Cooperation, Cooperative, Collaboration, Collaborative, Information Technology, Information Systems, Information and Communication Technologies, Virtual Networks | Aerospace, Aeronautics, Aeronautical, Aircraft, Aviation |

The keywords were combined with the aim of creating various strings which were then used to search in the different databases. Simple operators were used for this, such as truncation characters (*, ? and "exact phrase") and complex searches were constructed by combining Boolean operators (AND, OR) with brackets to avoid overly generic or broad results. These search strings were defined and improved by the authors. In this respect, the decision was taken to use these search strings in the searches in the databases in the first instance without filtering by document title, abstract, keywords, etc. However, this brought up too many results (e.g., a search for (lean OR "toyota production system") AND (aerospac* OR aircraft OR aeronautic* OR aviation) in the ABI Inform Complete database gave 74.404 results). The decision was subsequently taken to use the effective combinatorial search tactic, so as to make operations easier in the subsequent selection and evaluation stage. The combinatorial tactic and search strings used were as follows:

- TI (AB) (lean OR "Toyota Production System") AND TI (AB) (aerospac* OR aircraft OR aeronautic* OR aviation)
- TI (AB) ("supply chain" OR "customer integration" OR "supplier integration" OR "supplier development" OR relationship* OR partnership* OR cooperat* OR collaborat* OR "information technology" OR "information system*" OR "information and communication technolog*" OR "virtual network*") AND TI (AB) (aerospac* OR aircraft OR aeronautic* OR aviation)

### 1.2.3. Study Selection and Evaluation

The authors defined the criterion for including or excluding studies to ensure that the most relevant literature was evaluated. The stages included in this criterion were as follows:

1) The search streams were designed by requiring that selected articles contained at least two keywords (e.g., Lean and aerospace) in their title and/or abstract in order to ensure substantive relevance.

2) Only published double-blind peer-reviewed journal articles and paradigmatic books with managerial impact in the research field published in English were considered. Dissertations, text-books, conference proceedings, working papers, anonymous papers, and other unpublished works were excluded.

3) The search period was established as 1990 to April 2013.

4) Duplicate results were detected. For this the first database that was used for the searches was ABI Inform Complete and the results of this search were used as the basis for eliminating duplicate studies found in subsequent searches in the other databases.

5) Articles that were not indexed in Journal Citation Reports (JCR®) and Social Sciences Citation Index (SSCI®) were then excluded in order to include an objective quality criterion.

6) Substantive and empirical relevance was enhanced through reading all remaining abstracts for substantive context (i.e., LM, SCM, interrelationships between them) and empirical content (i.e., that mention quantitative and/or qualitative methodology, literature review).

7) Substantive and empirical relevance was ensured through reading all remaining articles in their entirety. With regard to substantive relevance, each of the articles was evaluated to ensure that its content was relevant from the perspective of the aims of our research. The paper's main contribution was verified to be was based around the study of LM and/or SCM in the aerospace sector. With respect to empirical relevance, it was verified that the studies specified the methodology used, and no paper was rejected on this basis. This enforced alignment between the selected articles and the review objectives.

8) It should be noted that during the reading of the full articles, the tactic of cross referencing was used for the selection of a series of relevant papers (i.e., cited several times in the previously selected articles and missed by the searches, but worthy of inclusion in the results) in order to make the literature review more comprehensive.

This process was carried out by each of the authors independently before the results were subsequently pooled. The end result was the selection and evaluation of 92 papers in total.

### 1.2.4. Analysis and Synthesis

This stage was qualitative and conducted jointly by the authors. Each study was analyzed for its descriptive, methodological and thematic content using a standard template. Our aim was to break down the individual selected studies into their constituent parts and describe how each relates to the others (Denyer and Tranfield, 2009). For this, the first step was to extract and store information for every study selected in a database.

The analysis enabled us to identify and categorize the studies' key thematic aspects. The subsequent synthesis enabled links to be established between parts identified in the individual studies. The authors then discussed the results together in order to classify and define these links in greater detail. For this the following procedure was used: 1) analysis of paper's research question identifying the key thematic aspects, 2) grouping of key thematic aspects of a similar nature and/or related to research topics, and 3) grouping of lines of research into main research topics according to the interrelationships that were found.

This process enabled the following three main research topics to be identified: a) Adoption and implementation of Lean Management, b) Development of Supply Chain Management, and c) Deployment of Lean principles and practices across the supply chain (Lean Supply Chain Management). Moreover, a number of more specific lines of research are also proposed that have been assigned to each of these three main research topics (See Table 1.2).

### 1.2.5. Reporting and using the results

The following sections present the results. Firstly, the results of the qualitative analysis of the articles content are given, and then the results are discussed stressing any gaps in the research and the challenges for future research.

## 1.3. Results

Table 1.2 sets out the proposed classification with the articles/books that were evaluated ascribed to each of the three defined topics of classification and listed by date of publication. It should be indicated that a small number of articles have been included under more than one topic/line of research as the research issue might, for example, emphasize the adoption of LM while at the same time it might have addressed the link between LM and results.

**Table 1.2**
Literature classification

| Main Research Topics | Research Lines | References |
|---|---|---|
| Adoption and Implementation of Lean Management | Lean Management Adoption Process | Womack and Jones (1996); James-Moore and Gibbons (1997); Jina et al. (1997); Michaels (1999); Philips (1999); Bamber and Dale (2000); Comm and Mathaisel (2000); Crabill et al. (2000); Mathaisel and Comm (2000); Greenwood et al. (2002); Murman et al. (2002); Nightingale and Mize (2002); Crute et al. (2003); Mathaisel (2005); Browning and Heath (2009); Akbulut-Bailey et al. (2012); Chang et al. (2013) |
| | Lean Management Implementation Process | Womack and Jones (1996); James-Moore and Gibbons (1997); Jina et al. (1997); Bamber and Dale (2000); Crabill et al. (2000); Mathaisel and Comm (2000); Murman et al. (2002); Nightingale and Mize (2002); Crute et al. (2003); Fitzpatrick and Looney (2003); Mathaisel (2005); McManus (2005); Modarress et al. (2005); Bhuiyan et al. (2006); Parry and Turner (2006); McKenzie and Jayanthi (2007); Browning and Heath (2009); Chakravorty (2009); Pessôa et al. (2009); Oehmen and Rebentisch (2010a, b); Rebentisch (2010); Beauregard et al. (2011); Akbulut-Bailey et al. (2012); Sacristán-Díaz et al. (2012); Chang et al. (2013) |
| | Results | Womack and Jones (1996); Greenwood et al. (2002); Murman et al. (2002); Crute et al. (2003); Mathaisel (2005); Parry and Turner (2006); Giddens (2007); McKenzie and Jayanthi (2007); Browning and Heath (2009); Beauregard et al. (2011); Akbulut-Bailey et al. (2012); Wang et al. (2012) |

**Table 1.2 (Continuation)**

Literature classification

| Main Research Topics | Research Lines | References |
|---|---|---|
| Development of Supply Chain Management | Integration Practices along the Supply Chain and Results | Graham and Pervaiz (2000); Reed and Walsh (2002); Russell and Hoag (2004); Bales et al. (2004); Emiliani (2004); Haywood and Peck (2004); Sinha et al. (2004); Farris et al. (2005); Zsidisin and Smith (2005); Gordon (2006); Morton et al. (2006); Brookes (2007); McAdam et al. (2008); Rose-Anderssen et al. (2008); Cooke and Ehret (2009); Kilpi et al. (2009); Rose-Anderssen et al. (2009a); Rose-Anderssen et al. (2009b); Bassani et al. (2010); Farooq and O'Brien (2010); Ponce-Cueto et al. (2010); Rose-Anderssen et al. (2010); Rose-Anderssen et al. (2011); Beelaerts van Blokland et al. (2012); Corallo et al. (2012); Evans et al. (2012); Ferretti and Parmentola (2012); Gopalakrishnan et al. (2012); Chaudhuri et al. (2013); Alfalla-Luque et al. (in press) |
| | Impact of Information Technologies on Supply Chain Management | Gulledge (2002); Williams et al. (2002); O'Sullivan (2003); Emiliani (2004); Ho et al. (2004); Russell and Hoag (2004); Towers et al. (2005); Laframboise and Reyes (2007); Lu et al. (2007); MacDonnell and Clegg (2007); Tannock et al. (2007); Zuckerman (2007); Alemanni et al. (2008); Osman et al. (2010); Alfalla-Luque et al. (in press) |
| Deployment of Lean principles and practices across the Supply Chain | Changes in the Supply Chain Configuration | Paliwoda and Bonaccorsi (1994); Anderson (1995); Frear and Metcalf (1995); Esposito and Passaro (1997); Bozdogan et al. (1998); Lefèbvre and Lefèbvre (1998); Stundza (1999); Giunta (2000); Graham and Pervaiz (2000); Moore et al. (2001); Murman et al. (2002); Reed and Walsh (2002); Bales et al. (2004); Smith and Tranfield (2005); Esposito and Passaro (2009); Rose-Anderssen et al. (2009a); Ehret and Cooke (2010); Ponce-Cueto et al. (2010); Rose-Anderssen et al. (2011); Alfalla-Luque et al. (in press) |
| | Implementation Cases and Results | O'Neill and Sackett (1994); Michaels (1999); Grant (2003); Bozdogan (2004); Smith and Tranfield (2005); Naudé et al. (2009); Ehret and Cooke (2010); Parry et al. (2010); Beelaerts van Blokland et al. (2012) |

### 1.3.1. Adoption and Implementation of Lean Management

#### 1.3.1.1. Lean Management Adoption Process

LM adoption came quite late to the aerospace sector. Some authors stated that although the sector is a leader in technological innovation in products and processes, historically it has not been a leader as far as innovating in management systems is concerned. The sector was identified as being some 15 years behind in LM adoption compared to the forerunner in LM adoption, the automotive sector (e.g., Crute et al., 2003). The literature analysis enabled us to identify the following main themes.

*a) Trigger factors*

Dramatic reductions in the defense and space budgets after the Cold War, and a fall in the sale of civil aircrafts during the early 1990s triggered significant changes in the sector with the purpose of reducing costs without sacrificing performance, quality and schedule (Murman et al., 2002[1]; Nightingale and Mize, 2002). These changes in the role of governments and the conditions of the commercial market, along with increasing global competition and the challenge of adapting to technological changes, among other issues, sparked a change in the sector's competitive priorities.

In fact, the literature identifies that the aerospace sector's competitive priorities have changed in the last two decades and are aligned with the general competitive priorities of other sectors, more precisely with those of the automotive sector (e.g., James-Moore et al., 1997; Akbulut-Bailey et al., 2012). These competitive priorities are mainly related to improving delivery times, delivery reliability, quality KPIs, reducing costs, inventory and time to market, among other goals (James-Moore and Gibbons, 1997; Philips, 1999). These changes acted as trigger factors for adopting LM.

Meanwhile, other researchers highlighted increasing global competition as a trigger factor of LM adoption (e.g., Mathaisel and Comm, 2000; Crute et al., 2003). Other authors identified high customer pressure and demand for suppliers to adopt LM as being key (Mathaisel and Comm, 2000; Crute et al., 2003; Akbulut-Bailey et al., 2012). Akbulut-Bailey et al. (2012) specifically found that the dependence of the key supply chain customer is one of the factors that determine the adoption of management system such as LM and Lean Six Sigma.

Moreover, Murman et al. (2002) identified that some aerospace companies with automotive divisions adopted LM in the aerospace divisions as a consequence of the results achieved in the automotive divisions. Thus, LM was embraced in aerospace divisions through rotational assignments of managers and other internal mechanisms for sharing Lean principles and practices.

*b) Applicability of LM*

A number of studies stressed that transferring LM from the automotive sector to the aerospace sector is difficult and complex (e.g., James-Moore and Gibbons, 1997). Despite this, Murman et al. (2002) stated that LM is well-suited to the aerospace sector, which is characterized by low production volumes, high-complexity products, and significant sources of instability. In this respect, they pointed to several successful Lean transformations in companies in diverse aerospace segments, such as: commercial and military aircraft, engines, avionics hardware and software, missiles, and space launch systems. However, other authors, such as Browning and Heath (2009) found that a variety of contingent factors in the sector, such as the high degrees of novelty, complexity and instability, must be comprehensively evaluated before LM is adopted, since these can potentially raise production costs.

There is, however, widespread agreement on identifying LM as a suitable management system in the aerospace sector, but that a range of contingent factors play a crucial role in the transition to LM and in the ensuing results. The literature specifically stressed that the steps in the transition to LM are very different from one sector to another, and it is therefore crucial to address, evaluate and manage the initial situation and context of the company before adopting LM (Jina et al., 1997; Bamber and Dale, 2000; Murman et al., 2002; Crute et al., 2003; Browning and Heath, 2009). In fact, the first applications of Lean practices and tools in this sector were in manufacturing, transferring the lessons from earlier initiatives in the automotive and electronics sectors into the aerospace context almost directly. Not considering the sector's contingent factors when adopting and adapting LM to the company's context is one of the root causes of failure (Jina et al., 1997; Murman et al., 2002).

Some advantages for LM adoption and implementation have also been detected in this sector. The "built-to-order" focus, for example, according to which products are only produced when they are needed by military, commercial and space customers, is closely linked to the LM´ pull principle. Low production volumes in the sector, especially in some suppliers, are more closely related to the Lean ideal of single piece flow compared to other sectors, such as the automotive sector (Crute et al., 2003).

Lastly, the following research focusing on the challenges of LM in the civil, defense and space industries deserves special mention. Murman et al. (2002) highlight some general challenges, such as: a) The multiple industries that make up the sector. It is important to stress the importance of evaluating the similarities, differences and interdependencies between the military, commercial and space industries. Special attention should be paid to the military-commercial dichotomy. Historically, military–commercial "spillover effects" have been the fountain head of innovation and benefited the commercial industrial base. The close interrelationships between the different segments in the sector and interdependence with other tangential sectors should be considered. b) A new product mindset. Over recent decades the sector has evolved towards complete customer solutions, and as such shifting to a lifecycle management approach has been a challenge for the companies in the sector. c) Complexity: complex product, complex organizational settings, and the complexity associated with substantial government regulatory control stand out. Regarding the complexity of products, aerospace systems are complex, with functional relationships and interactions that involve multiple challenges in innovation, design, technical aspects, materials, manufacturing and assembly processes. This complexity is heightened by the fact that the products are error-intolerant (they must operate with zero failures) and they usually have service lives extending for decades. Regarding complex organizational settings, this sector operates within a complex socio-political, regulatory, and institutional environment. The role of governments as regulators, customers and enablers of technological innovations warrants special attention. d) Global dynamics: international competition in every product line stands out, as does increased collaboration to develop new technologies and unlock new markets. "Offset obligations" also warrant special mention. Moreover, over recent decades the sector has seen increased collaboration between firms, both domestically and internationally, in order to compete more effectively.

Meanwhile, Mathaisel and Comm (2000) explore the relevance and applicability of LM in the space industry, specifically for the development and manufacture of satellites, the development and manufacture of launchers, and the operations of these systems from launch through operational life. They claim that LM is applicable, but that a number of contingent factors need to be addressed, including: a) a root-and-branch review of government procurement and supervision processes to bring them into line with commercial practices, b) a reduction in highly unstable customer, government and prime contractor requirements. It is also vital to evaluate technical limitations to processes and technologies, lower production volumes, and higher response to technology and maintenance reliability compared to their defense and civil industries counterparts. The importance of optimizing manufacturing processes, testing (e.g., product testing can approach 50 percent of the costs), warranty processes and product development (e.g., through "form/fit/function/interface" - F3I) are also crucial in this industry.

*c) LM Adoption Models*

Only one study has been identified that has developed models focusing exclusively on LM adoption. This model developed by Comm and Mathaisel (2000) has been successfully used for evaluating and benchmarking "Lean initiatives", specifically in the US defense and space industries. This model focuses on the phase prior to LM adoption and during the adoption phase itself by building what is called a "Lean consortium" (comprising the public administration, companies in the sector and academic partners) with the aim of the adoption being a success and progress being made in the transition to LM. Table 1.3 presents the features of this LM adoption model.

Meanwhile, other models have been identified that focus primarily on LM implementation but which have nonetheless analyzed this initial phase of the transition to LM tangentially (Crabill et al., 2000; Murman et al., 2002; Nightingale and Mize, 2002; Mathaisel, 2005).

**Table 1.3**

Main characteristics of the LM adoption model

| Model | Main Focus | Industry | Main Phases/Practices & Tools/Main Factors | Strengths & Weaknesses |
|---|---|---|---|---|
| Comm and Mathaisel (2000) | Pre-phase of LM adoption and the adoption phase itself in a complete sector | Defense industry | **1)** Building the "Lean consortium" (Government, companies and academic partners); **2)** Targeting potential stakeholders: 2.1) Building a team which presents the project, 2.2) Gathering information about the selected companies; **3)** Deciding on the research agenda in the selected companies; **4)** Testing the previous research focus (Development & Assessment of SWOT matrix); **5)** Development of benchmarking techniques; **6)** Analyzing and assessing the findings, showing the results in workshops and making recommendations to the members about the possibilities for improvement offered by Lean; **7)** Implementing the concepts; **8)** Establishing controls to see if desirable results are achieved. | **S:** Was tested in a case study with positive results. Is especially useful for the launch and development of a Lean initiative in any sector. |

Crabill et al. (2000) and Murman et al. (2002) considered a stage focusing on the strategic decision to adopt LM in their general LM implementation models. Firstly, the adoption stage consists of the following aspects: a) constructing a Lean vision, b) establishing the need to adopt LM and create a sense of urgency, c) fostering lean learning, d) making the commitment, and e) obtaining senior management commitment and leadership. They also considered a preparation stage or strategic planning comprising the following issues: a) integration with the enterprise level, b) establishing an operations lean implementation team(s), c) developing an implementation strategy, d) developing a plan to address workforce changes, e) addressing site-specific cultural issues, f) training key people, g) setting targets.

Nightingale and Mize (2002) included two stages focusing on LM adoption: a) determining the strategic imperative: integrating enterprise transformation into the strategic planning process, focusing on stakeholder value and articulating the case for transformation, and b) engaging enterprise leadership: cultivating enterprise thinking among leadership, obtaining senior leadership commitment, and establishing executive coordination and oversight.

Lastly, Mathaisel (2005) stated that it is necessary to develop a strategic plan that should encompass three elements: supporting infrastructure, lean operations philosophy, and personnel change management.

*d) Prerequisites*

Some of the first and main challenges of LM adoption that companies in the sector face are its acceptance and knowledge of its potential benefits (Mathaisel and Comm, 2000). Some authors found that one of the general hurdles to be overcome is the belief that LM is, up to a point, the automotive industry's idea and that it is difficult to transfer it to the aerospace sector. Other authors found that another common belief is that LM is just another passing management fashion or another version of total quality management (Comm and Mathaisel, 2000; Greenwood et al., 2002; Crute et al., 2003).

In the same vein, Murman et al. (2002) commented that it is commonly believed that LM is only applicable to the production area, and so it is vital for senior management to understand that LM is an integrated management system that can be applied to all the other areas of a company. They also stated that the fear exists of LM being identified as a measure for eliminating jobs. For this reason, some authors recommended a partnership agreement with unions. However, such formal agreements on job security were not found in all adoptions of LM (Womack and Jones, 1996; Mathaisel and Comm, 2000; Murman et al., 2002).

For all these reasons, therefore, the management of people's initial skepticism and resistance is a crucial prerequisite to the adoption of LM (Comm and Mathaisel, 2000; Akbulut-Bailey et al., 2012; Chang et al., 2013). Similarly, it is crucial not to lose sight of the fact that LM is constructed by people and that they are a keystone in the success of a Lean initiative (Bamber and Dale, 2000; Murman et al., 2002).

For their part, Womack and Jones (1996) stressed that it is impossible to adopt LM without strong leadership and commitment from senior management. This finding was widely supported by other authors (e.g., Murman et al., 2002; Akbulut-Bailey et al., 2012; Chang et al., 2013). Moreover, the support of all management staff is crucial for achieving a successful LM adoption. For instance, if managers do not understand LM, its principles, practices, tools and potential benefits, they will not then support the initiative or will not contribute effectively to the successful adoption of LM (Womack and Jones, 1996). Thus, the lack of prior management staff training in LM acts as a barrier and it is, therefore, necessary to plan adequate training programs in Lean (Bamber and Dale, 2000). Chang et al. (2013) have recently stressed the crucial role played by the lean leader in successful LM adoption.

Notwithstanding, several authors identified that the aerospace sector, in general, requires a very different set of institutional arrangements, infrastructure, and cultural mindset. These "old blocks" are important "monuments" (Murman et al., 2002, pp. 55, chapter 3). Therefore, managers at all levels must understand and assess these "monuments", which act as barriers or inhibitors, and address these challenges in order to achieve a successful LM adoption.

Moreover, different researchers have highlighted that the adoption of LM in this sector must focus on an "enterprise" approach (e.g., Michaels, 1999; Murman et al., 2002; Crute et al., 2003). Specifically, Murman et al. (2002) emphasized that it is crucial to focus on the efficient creation of value for multiple enterprise stakeholders (end users, shareholders, workforce, unions, suppliers and partners, society, etc.). This migration from a simple focus on a reduction in waste to a focus on value opens up a new outlook on value creation in Lean theory. In other words, "eliminating waste must always serve a larger purpose; it must be oriented towards value creation" (Murman et al., 2002, pp. 6).

Murman et al. (2002, pp. 12-14) therefore broadened the LM principles laid down by Womack and Jones (1996) when they set out the principles of "Lean Enterprise Value": 1) create lean value by doing the job right and by doing the right job, 2) deliver value only after identifying stakeholder value and constructing robust value propositions, 3) fully realize lean value only by adopting an enterprise perspective, 4) address the interdependencies across enterprise levels to increase lean value, 5) people, not just processes, effectuate lean value. It should be highlighted that these principles can be applied at the level of an individual program or platform, and apply as well at the level of a multi-program enterprise (corporation or government agency), and at national and international levels.

Table 1.4 summarizes the main themes and key aspects examined in the LM adoption line of research. Associated bibliographical references are also shown in chronological order.

**Table 1.4**
Main themes and key aspects of LM Adoption

| Main Themes | Key aspects | References |
|---|---|---|
| **Trigger Factors** | - Changes in the role of governments: Dramatic reductions in the defense and space budgets (1990)<br>- Changes in commercial conditions: Fall in sales of civil aircrafts (1990)<br>- Increasing global competition<br>- Challenge of adapting to technological changes<br>- Changes in competitive priorities: improved delivery times, reliability of deliveries, customer responsiveness, quality KPIs, reduced costs, inventory and time to market<br>- Pressure and demands from customers to improve KPIs<br>- Dependence of the primary customer in the Supply Chain<br>- Success of LM in other sectors (e.g., automotive)<br>- Incorporation of managers from other sectors (e.g., automotive) | James-Moore and Gibbons (1997); Philips (1999); Mathaisel and Comm (2000); Murman et al. (2002); Nightingale and Mize (2002); Crute et al. (2003); Akbulut-Bailey et al. (2012) |
| **Applicability of LM** | - Key contingent factors (production area): low production volumes, high-complexity products, highly differentiated products, significant sources of instability, low repeatability, conspicuous novelty<br>- Facilitating factor: built-to-order (pull)<br>- Contingent factors must be addressed and assessed prior to LM adoption as they could impact negatively on reduction costs and other LM goals | James-Moore and Gibbons (1997); Jina et al. (1997); Bamber and Dale (2000); Mathaisel and Comm (2000); Murman et al. (2002); Crute et al. (2003); Browning and Heath (2009) |
| **LM Adoption Models** | - Models focusing exclusively on LM adoption | Comm and Mathaisel (2000) |
| | - Models focusing primarily on LM implementation, but analyzing the adoption phase tangentially | Crabill et al. (2000); Murman et al. (2002); Nightingale and Mize (2002); Mathaisel (2005) |

**Table 1.4 (Continuation)**

Main themes and key aspects of LM Adoption

| Main Themes | Key aspects | References |
|---|---|---|
| **Prerequisites** | - Senior management commitment, involvement and leadership<br>- Acceptance of LM and knowledge of its potential benefits (The concept of LM should be positive, and possible benefits explained)<br>- Management of people's initial skepticism and resistance<br>- Strategic Planning: change management, setting the direction, vision, aligning people, creating a sense of urgency, and motivating and inspiring<br>- Assessment of the initial situation and context of the organization (What type of practices/tools would be most appropriate for the business activity?, possible barriers or inhibitors, prepare the way towards LM)<br>- Creating and communicating a shared vision at all levels of the organization<br>- Support of all management staff<br>- Prior training of all management staff and key people<br>- Adoption focusing on an "enterprise" approach<br>- Do not lose sight of fact that LM is constructed by people and people are a keystone (human side of LM) | Womack and Jones (1996); Michaels (1999); Bamber and Dale (2000); Comm and Mathaisel (2000); Crabill et al. (2000); Mathaisel and Comm (2000); Greenwood et al. (2002); Murman et al. (2002); Nightingale and Mize (2002); Crute et al. (2003); Mathaisel (2005); Akbulut-Bailey et al. (2012); Chang et al. (2013) |

### 1.3.1.2. Lean Management Implementation Process

The literature review has enabled studies to be grouped together that focus both on the development of implementation models and on case studies during LM implementation.

*a) LM Implementation Models*

As commented previously, the transition to LM came late to the aerospace sector, and in fact some supply chain agents have still not initiated, or are only at an initial stage of their transition (Sacristán-Díaz et al., 2012). One of the reasons for this is that the strategy for LM implementation is not clear for many senior managers (e.g., Comm and Mathaisel, 2000).

Research has developed LM implementation models especially for this sector. Table 1.5 gives the typologies and distinguishing features of each, showing the main focus, crucial phases, practices/tools and factors, strengths and, in some cases, weaknesses, together with the industry in which they were developed.

**Table 1.5**
Main Characteristics of LM adoption models

| Model | Main Focus | Industry | Main Phases/Practices & Tools/Main Factors | Strengths & Weaknesses |
|---|---|---|---|---|
| Murman et al. (2002) | Strategic change to a Lean enterprise | Defense industry | **Enterprise Transition-To-Lean Roadmap**<br>**1. Entry/Re-entry Cycle:** 1.1. Adopt Lean paradigm, 1.2. Enterprise strategic planning;<br>**2. Long Term Cycle:** 2.1. Initial Lean vision: focus on the value stream, 2.2. Detailed Lean vision: develop Lean structure & behavior;<br>**3. Short Term Cycle:** 3.1. Lean implementation framework: create & refine implementation plan, 3.2. Enterprise level implementation plan: implement Lean initiatives, 3.3. Outcomes of enterprise metrics: focus on continuous improvement, 3.4. Environmental corrective action indicators. | **S:** Is a good guide to preparing and planning the strategic change associated with LM transition across the whole enterprise. |
| Crabill et al. (2000) | LM adoption & implementation focusing on production operations | Defense industry | **0) Adopt Lean Paradigm:** 0.1. Build vision, 02. Establish need, 0.3. Foster lean learning, 0.4. Make the commitment, 05. Obtain senior management commitment;<br>**1) Prepare:** 1.1 Integrate with enterprise level, 1.2. Establish an operations lean implementation team(s), 1.3. Develop implementation strategy, 1.4 Develop a plan to address workforce changes, 1.5. Address site specific cultural issues, 1.6. Train key people, 1.7. Establish target objectives (metrics);<br>**2) Define Value:** 2.1. Select initial implementation scope, 2.2. Define customer, 2.3. Define value - quality, schedule, and target cost;<br>**3) Identify Value Stream:** 3.1. Record current state of value stream, 3.2. Chart product and information flow, 3.3. Chart operator movement, 3.4. Chart tool movement, 3.5. Collect baseline data;<br>**4) Design Production System:** 4.1. Develop a future state value stream map, 4.2. Identify takt time requirements, 4.3. Review make/buy decisions, 4.4. Plan new layout, 4.5. Integrate suppliers, 4.6. Design visual control system, 4.7. Estimate and justify costs, 4.8. Plan TPM system;<br>**5) Implement Flow:** 5.1. Standardize operations, 5.2. Mistake proof processes, 5.3. Achieve process control, 5.4. Implement TPM, 5.5. Implement self inspection, 5.6. Eliminate/ reduce waste, 5.7. Cross -train workforce, 5.8. Reduce set-up times, 5.9. Implement cell layout, 5.10. Implement visual controls;<br>**6) Implement Total System Pull:** 6.1. Select appropriate production system control mechanism, 6.2. Strive for single item flow, 6.3. Level and balance production flow, 6.4. Link with suppliers, 6.5. Draw down inventories, 6.6. Reassign people, 6.7. Redeploy/dispose of assets,<br>**7) Strive for Perfection.** | **S:** Is a useful model for adopting and implementing LM at the production operations level.<br>Has interrelationships with other enterprise areas and external processes.<br>**W:** Does not consider key aerospace contingent factors. |
| Mathaisel (2005) | Product life cycle, systems engineering, enterprise transformation | Defense industry (MRO) | **Transformation Life Cycle:**<br>**0)** Need and motivation for adopting LM;<br>**1)** Conceptual & preliminary design;<br>**2)** Detailed design and development;<br>**3)** Implementation/construction;<br>**4)** Enterprise use & improvement.<br>**Phases:**<br>**1)** Transformation strategic planning;<br>**2)** Transformation acquisition and integration phase;<br>**3)** Launch into detailed planning and implementation (planned, executed, and monitored). | **S:** Is useful for the Lean transformation across an enterprise. Focuses on MRO activities and product life cycle.<br>**W:** Does not consider performance indicators. Needs to consider other processes at the enterprise level (logistics, workforce, etc.) |

**Table 1.5**
Main Characteristics of LM adoption models

| Model | Main Focus | Industry | Main Phases/Practices & Tools/Main Factors | Strengths & Weaknesses |
|---|---|---|---|---|
| Nightingale and Mize (2002) | Tool to assess LM enterprise transformation | Defense industry | **Section I – Enterprise Transformation/Leadership**<br>**I.A**. Determine strategic imperative (3 enterprise practices); **I.B.** Engage enterprise leadership in transformation (3 enterprise practices); **I.C.** Understand current enterprise state (2 enterprise practices); **I.D**. Envision and design future enterprise (2 enterprise practices); **I.E.** Develop enterprise structure and behavior (8 enterprise practices); **I.F.** Draw up transformation plan (2 enterprise practices); **I.G.** Implement and coordinate transformation plan (4 enterprise practices);<br>**I.H.** Nurture transformation and embed enterprise thinking (6 enterprise practices).<br>**Section II – Lifecycle Processes**<br>**II.A.** Acquire, develop, and leverage enterprise capabilities; **II.B.** Optimize network-wide performance;<br>**II.C.** Incorporate downstream customer value into enterprise value chain; **II.D.** Actively engage upstream stakeholders to maximize value creation; **II.E.** Provide ability to monitor and manage risk and performance.<br>**Section III – Enabling Infrastructure**<br>**III.A.** Organizational enablers (5 enterprise practices); **III.B.** Process enablers (3 enterprise practices). | **S:** Was tested in 20 study cases showing its utility, effectiveness and ease of use; is very useful for assessing the current state of the enterprise and its desired future state (degree of LM implementation). |
| Rebentisch (2010) | Lean product development: waste, VSM and risk management in product development | Defense industry | **1)** Planning organization.<br>**2)** Integrated organization.<br>**3)** Responsible organization.<br>**4)** Learning organization.<br>1. Workload leveling; 2. Strong project manager; 3. Specialist career path; 4. Responsibility-based planning and control; 5. Cross-project knowledge transfer; 6. Simultaneous engineering;<br>7. Supplier integration; 8. Product variety management; 9. Rapid prototyping, simulation and testing;<br>10. Process standardization; 11. Set-based engineering. | **S:** Is a powerful guide to adopting and implementing the lean concepts to the product development. Must be used in conjunction with the guides and frameworks developed by McManus (2005) and Oehmen and Rebentisch (2010a, b). |
| Bhuiyan et al. (2006) | Sustainability, continuous improvement, other enterprise areas (development) | Engines for defense and civil industries | **1) Process improvement and waste elimination tools:** 1.1 5S + 1 (visual workplace),<br>1.2. Process management and standard work, 1.3. Process certification, 1.4. Setup reduction,<br>1.5. Total productive maintenance.<br>**2) Problem solving tools:** 2.1. Market feedback analysis, 2.2. Quality clinic process charts,<br>2.3. Relentless root cause analysis, 2.4. Mistake proofing.<br>**3) Decision making tools:** 3.1. Passport process.<br>**4) Sustaining ACE:** ACE protocol. | **S:** Is useful for achieving sustainability. Applicable to production and other business processes (e.g., design and development), key performance indicators system.<br>**W:** Does not consider the role of aerospace contingent factors. |
| Chang et al. (2013) | LM transition focusing on production operations, continuous improvement | Aerospace manufacturing suppliers | **1) Human resources:** 1.1. 5S, 1.2. Personnel training;<br>**2) Machine:** 2.1. TPM; **3) Method:** 3.1. TQM, 3.2. Automation; **4) Process:** 4.1. Just in Time;<br>**5) Environment:** strengthens enterprise's management performance.<br>Complemented with the PDCA cycle: **1)** Plan: 1.1. Mindset change, 1.2. 5S/TPM; **2)** Do: 2.1. Stream flow line/takted assembly line, 2.2. Operation standardization; **3)** Check: 3.1. Aligning the IT system (KPIs, visibility); **4)** Action: 4.1. Strategic/system transformation (Organization and functional group integration, personnel training). | **S:** Is useful for manufacturing activities and other manufacturing industries.<br>**W:** Does not consider the role of aerospace contingent factors. Does not develop key performance indicators. Has a narrow focus on production practices/tools. |

To begin with, the implementation models developed by the LAI[1] should be highlighted. This initiative has developed a set of models, guides and tools that together constitute a powerful means for achieving the objectives of LM, creating value for the stakeholders over the lifecycle of aerospace systems. These developments could be used as a systematic framework for initiating, sustaining, and continuously improving a Lean enterprise transformation, thus preventing the creation of islands of improvement.

Firstly we highlight the Enterprise Transition-To-Lean (TTL) Roadmap (Murman et al., 2002). This was developed after the design of the Lean Enterprise Model (LEM). The LEM provides a taxonomy of lean principles and practices but does not reflect any order or precedence to LM implementation across the whole enterprise. Therefore, the TTL was developed with the aim of including the overall "flow" of action steps required for initiating, sustaining, and continuously improving a Lean enterprise transformation based upon Lean principles and practices. This includes strategic issues, internal and external relationships with key stakeholders, and structural issues. The roadmap has three interrelated cycles: entry/re-entry, long term, and short term.

For their part, Crabill et al. (2000) developed an LM implementation model made up of eight systematic phases mainly directed at the company production area. However, given the importance of the LM implementation focus at the "enterprise" level, engineering, human resources, and business viewpoints are incorporated into the model. The phases are also interconnected with other internal and external enterprise business processes. Moreover, its continuous improvement aspect should also be highlighted along with the fact that it was tested in several aerospace companies.

As previously stated, it is crucial to address and evaluate the initial situation and context of the company before adopting LM. For this, Nightingale and Mize (2002) developed a self

[1] See http://lean.mit.edu/ for detailed information on: Lean Enterprise Model, Enterprise Strategic Analysis and Transformation; Enterprise Transformation Roadmap; Enterprise Transition-To-Lean Roadmap; Production Operations Level Transition-To-Lean Roadmap; Lean Product Development, Product Development Value Stream Mapping and Systems Engineering Leading Indicators.

assessment tool (*Lean Enterprise Self Assessment Tool*, LESAT) based upon a capability maturity matrix in order to assess the current state of the enterprise and its desired future state. It should be mentioned that the LESAT tool was updated at the end of 2012 (LESAT 2.0®). At present, the assessment tool includes fifty-four practices for assessing the level of LM implementation based on a five-level scale. The evaluation process provides information about a company's strengths, weaknesses, and opportunities regarding the LM transition and acts as a guide for making further progress in the implementation.

Meanwhile, Mathaisel (2005) designed an implementation model called "Lean Enterprise Architecture" (LEA), which integrates lean thinking, enterprise architectures, and systems engineering principles for an enterprise-wide Lean transformation. This is structured on the transformation life cycle phases in order to initiate, transform, sustain, and continuously improve a Lean initiative. The model considers strategic issues, internal and external relationships with key stakeholders, and structural issues that should be addressed before and during the implementation initiative.

Given the importance of product design and development in the sector and of product life-cycle management the LAI has recently developed a series of models, guides and tools focusing on Lean Product Development. The adaptation of the types of waste in the production system as defined by Ohno (1988) to product development (wastes focused on information flows) (McManus, 2005) stands out. Moreover, there is a useful adaptation of value stream mapping to the development activities (Oehmen and Rebentisch, 2010a). Meanwhile, Rebentisch (2010) developed a useful implementation roadmap for Lean product development, and Oehmen and Rebentisch (2010b) provided a risk management guide during this phase of the product lifecycle.

The *Achieving Competitive Excellence* (ACE®) continuous improvement methodology developed by the United Technologies company (i.e., Pratt and Whitney and Sikorsky) aimed at bringing about an in-depth culture change in an organization deserves mention. Bhuiyan et al. (2006) validated this hybrid LM-Six Sigma methodology with satisfactory results in an engine manufacturing company. ACE is based upon three main categories of process improvement and waste elimination tools, decision-making tools, and problem solving tools, which can be applied in both production environments and other organizational processes in order to achieve a sustainable improvement over time.

Lastly, Chang et al. (2013) recently developed a Lean model tested in an aerospace manufacturing supplier that underlines workforce-related aspects. This Lean model focuses primarily on shop-floor transformation. It comprises five phases and is complemented by the PDCA continuous improvement cycle for Lean transformation.

*b) Implementation Cases*

There is a major group of studies focusing on implementation cases in the sector which underline the key factors that should be managed. We specifically highlight the factors that can facilitate or inhibit implementation and the contingent factors pertinent to the sector that affect in the implementation.

With respect to contingent factors, James-Moore and Gibbons (1997) focused on a comparative study between the methods and practices that were being adopted at that time in the aerospace sector and those in the automotive industry. They found a series of factors with a low level of implementation (44% of the total), related to: a) new product refinement for manufacture, b) customer interface, c) ability to control costs, and d) operations management. Among the reasons that they found to explain this phenomenon were various contingent factors, such as: technical development issues, long product lifecycle, product complexity, late changes to specifications, prescriptive method of defining quality, and problems with labor stability due to cyclicity. In spite of this they stated that the findings could be influenced by a delay in the dissemination of LM due to the dynamic nature of innovation dissemination, and to some of the practices in the automotive industry requiring a totally different focus from the aerospace sector.

In the same vein, Bamber and Dale (2000) stated that transforming an organization to LM is a dynamic process that is unique to each separate organization, as a result of which Lean practices and processes should be adapted to the sector and the organization itself. However, they also found that there are several Lean techniques that are not as powerful in a manufacturing aerospace Tier 1 as they are in the automotive industry due to the environment and the demand characteristics, including: kanban, SMED and cellular manufacturing.

One of the biggest challenges in this respect to progressing in LM implementation is knowledge of which of its practices and tools should be used and how they can be effectively applied to a company's context. For this, companies must carefully assess which Lean practices and tools they can use directly and which need to be adapted to meet their specific realities (Jina et al., 1997; Browning and Heath, 2009). McKenzie and Jayanthi (2007) emphasized that it is crucial to analyze the trade-offs that come from decisions to reduce batch size and costs in the sector and for this developed a model for decision-taking in a range of demand scenarios.

Redundancy programs in the sector due mainly to cyclicity demand deserve special mention. Murman et al. (2002) identified that layoffs caused by the downsizing and rightsizing focuses of the 1990s created tensions with the remaining workforce that made achieving the vital employee commitment required in any Lean transformation more complicated. Bamber and Dale (2000) also found a major layoff-related difficulty for implementing LM caused by reductions in demand. In the same vein, Womack and Jones (1996) found that this factor is a major barrier to people commitment and involvement during LM implementation.

On the other hand, a large number of studies found that many of the difficulties found in LM implementation in the aerospace sector are more related to generic factors than to sector-specific factors (e.g., Womack and Jones, 1996; Bamber and Dale, 2000; Crute et al., 2003). The role of the customer in the level of LM implementation is highlighted. Crute et al. (2003) found that high levels of customer pressure for improvements to be made affect the degree of LM implementation. Notwithstanding, Sacristán-Díaz et al. (2012) found that the degree of LM implementation is more related to the degree of the senior management's commitment and motivation than with the degree of customer company dependence. Despite this, Akbulut-Bailey et al. (2012) found that an “open doors suggestion" policy for incorporating customer needs is one of the key drivers of progress in LM implementation.

Meanwhile, Crute et al. (2003) found that difficulties in LM implementation in the aerospace sector are related mainly to the individual plant context and the role of management. After a comparative study of the degree of LM implementation in two plants in the same company, these authors found that the results were mainly the consequence of cultural differences. Likewise, Bamber and Dale (2000) highlighted difficulties for implementing LM related to the human role.

A large number of authors have also identified the role of people as crucial in LM implementation (e.g., Womack and Jones, 1996; Bamber and Dale, 2000; Murman et al., 2002; Crute et al., 2003; Akbulut-Bailey et al., 2012). Firstly, the highest levels of senior management commitment and long-term leadership are keystones to making progress in LM implementation. Moreover, the ongoing support of all management staff has to be counted on. Womack and Jones (1996) stressed that a lack of all-round senior management commitment and support is a major obstacle to moving forward in LM implementation. These authors even found active resistance to LM among middle managers, which resulted in any advances made initially being quickly lost as managers and workers returned to their “old” ways.

This could be explained by a historical lack of employee education and training in LM (Womack and Jones, 1996; Bamber and Dale, 2000; Akbulut-Bailey et al., 2012). Bamber and Dale (2000) underscored the lack of training in LM, even among the majority of senior managers. They also found that one of the failures of the initial Lean training program was that it was not deployed to shop-floor workers. This was then solved by having it deployed by consultants. However, worker training failed as it did not focus on the underlying Lean principles. Teamwork and problem solving were initiated by consultants, but as soon as they stopped the activity, achievements fell away. This means that LM requires ongoing changes in attitudes and behavior, a cultural change, and not only by senior management but also by shop-floor workers and all people of the organization. It is therefore fundamental to manage the change in organizational culture (Bamber and Dale, 2000; Crute et al., 2003; Fitzpatrick and Looney, 2003). Precisely, some authors pointed to ongoing training in LM being key to successfully achieving a continuous learning capability (e.g., Crute et al., 2003; Akbulut-Bailey et al., 2012).

Browning and Heath (2009) found that some wastage elimination initiatives (e.g., a mobile assembly line developed to achieve flow) were the cause of some problems at first, however, thanks to the efforts made by work-teams, the root cause of the problems were discovered, thus showing the effectiveness of these teams. This is why some authors recommended that LM should be implemented at the beginning with tools like VSM and 5S (Fitzpatrick and Looney, 2003; Akbulut-Bailey et al., 2012; Chang et al., 2013). Chang et al. (2013) specifically underlined the great suitability of 5S for achieving changes in people's behavior and habits. This is why setting up multifunctional and empowered work teams is seen to be a key facilitator for LM and for creating a common culture (Bamber and Dale, 2000; Akbulut-Bailey et al., 2012).

Problems have also been found with organizations' hierarchical structures (Womack and Jones, 1996; Bamber and Dale, 2000). These authors found that a departmentalized, centralized, and multilayered organizational structure impedes effective communication, which is a keystone of LM. It is vital for the rigid hierarchical structures to be replaced by more flexible structures that facilitate communication. It was also identified that visual process management allows significant improvements in communication throughout the whole company and processes to be monitored and charted (Crute et al., 2003; Modarress et al., 2005; Parry and Turner, 2006; Chakravorty, 2009; Akbulut-Bailey et al., 2012).

In fact, the lack of an appropriate measurement system adapted to the company's needs is one of the reasons why some Lean initiatives fail (Bamber and Dale, 2000; Crute et al., 2003). In this line, some researchers stressed that financial indicators often contradict the operational improvements achieved, i.e., that improvements achieved in operational results are not reflected in the financial results. This could lead to the company questioning whether implementation is worth the effort and, in the final instance, is also demotivating with respect to the implementation process. It is therefore fundamental that appropriate operational and financial indicators are developed. Modarress et al. (2005) highlighted the suitability of applying "*kaizen costing*" methodology to develop a series of operational and financial indicators to monitor and chart the Lean implementation process.

In other respects, as previously stated, it is crucial that LM should be implemented with an "enterprise" focus. In this regard, the product development process is a crucial part of the product lifecycle and the total costs (Mathaisel and Comm, 2000; Crute et al., 2003). A number of studies examined cases of Lean Product Development (LPD) implementation (Pessôa et al., 2009; Beauregard et al., 2011). Pessôa et al. (2009) developed a systematic method focusing on the prioritization of waste reduction in LPD instead of a focus that merely identifies it. For their part, Beauregard et al. (2011) developed a multi-attribute engineering task value model (MAVT) aimed at one of the product lifecycle phases, post-certification. This model is especially useful for assessing the influence of factors such as multitasking, concurrency, task size, task value, and post-certification budget on lean engineering PD performance (e.g., lead time and waste).

Table 1.6 summarizes the contingent factors, facilitators and inhibitors in the implementation process with bibliographical references in chronological order.

**Table 1.6**

Key factors to be managed during the LM implementation process

| Factors | Key aspects | References |
|---|---|---|
| Contingent Factors | - Continuous consideration of contingent factors during LM implementation: low production volumes, high-complexity products, highly-differentiated products, significant sources of instability, low repeatability, conspicuous novelty, technical aspects, long product lifecycle, late changes to specifications, prescriptive method of defining quality, reduction of batch size (trade-off)<br>- Challenges to advances in LM implementation: what are the most suitable Lean practices/tools and how should they be effectively adopted and adapted to the company's context?<br>- Labor stability and redundancy programs | Womack and Jones (1996); James-Moore and Gibbons (1997); Jina et al. (1997); Bamber and Dale (2000); Murman et al. (2002); Crute et al. (2003); McKenzie and Jayanthi (2007); Browning and Heath (2009) |
| Facilitating Factors | - Key role of customer<br>- Open doors suggestion policy<br>- Highest levels of commitment and long-term leadership of senior management<br>- Highest levels of commitment and long-term leadership of all management staff<br>- Continuous management of people´s resistance (at all levels)<br>- Ongoing Lean training<br>- Begin implementation with VSM and 5S.<br>- Setting up of multifunctional and empowered work teams<br>- Visual process management<br>- Kaizen costing<br>- Ongoing focus on people (managing the organizational culture)<br>- Lean enterprise approach (e.g., Lean Product Development, LPD) | Bamber and Dale (2000); Mathaisel and Comm (2000); Murman et al., (2002); Crute et al. (2003); Fitzpatrick and Looney (2003); Modarress et al. (2005); Parry and Turner (2006); Chakravorty (2009); Pessôa et al. (2009); Beauregard et al. (2011); Akbulut-Bailey et al. (2012); Sacristán-Díaz et al. (2012) |
| Inhibiting Factors | - Historical lack of employee education and training in LM<br>- Prior organizational culture<br>- Role of consultants in LM (it is necessary an internal cultural change)<br>- Organizations' hierarchical structures<br>- Inappropriate systems for measuring results<br>- Losses in production and increased waste during the Lean learning curve | Womack and Jones (1996); Bamber and Dale (2000); Crute et al. (2003); Parry and Turner (2006); Browning and Heath (2009) |

#### 1.3.1.3. Results

There is a line of research in the literature that focuses on LM's impact on performance.

On the one hand, some authors have found that operating results have improved as a result of LM. Womack and Jones (1996) found that the application of Lean principles and practices/tools in different production areas of an aircraft engine manufacturing company enabled improvements to be made to the following operating results: reduced scraps and reworks, space needed, batch size, inventory level, changeover time, cycle time, lead time for physical production and total manufacturing cost, and increased labor productivity. Meanwhile, Murman et al. (2002) pointed to a series of successful Lean transitions in companies in several aerospace segments. To be precise, they found that LM impacted on the following operating results: reduced inventory level, non-conformity costs, cycle time, lead time, defects per million opportunities and manufacturing costs. Other authors found improvements in these results in other segments of the sector, such as: jets assemblers (Greenwood et al., 2002), parts suppliers (Crute et al., 2003; Akbulut-Bailey et al., 2012), engine manufacturers (Wang et al., 2012), prime contractors (Parry and Turner, 2006) and even in MRO processes (Giddens, 2007). These studies found improvements in the following KPIs: reduced lead, cycle, throughput and setup times, non-value added times, unnecessary movements, inventory levels, factory floor space, scraps and reworks, batch size and costs, and improved inventory turnover, flexibility, first-time quality, delivery reliability, and productivity.

Besides these typical operating results, several authors highlighted several improvements to the results in product design and development. They found reduced lead times, throughput times and engineering changes, among other things (Womack and Jones, 1996; Murman et al., 2002; Beauregard et al., 2011).

Despite all this empirical evidence Browning and Heath (2009) found that some contingent factors in the sector, such as novelty, complexity, external and internal instability, and buffers, moderate the impact of LM on production costs. Their results specifically showed that costs can even go up. This phenomenon also depends on the timing of the LM implementation, learning curve disruption, and on the scale and degree of interconnection between the tasks and processes to which LP is applied. In this line, McKenzie and Jayanthi (2007) found that decisions on reducing the batch size can put up costs, as a result of which it is crucial to analyze various scenarios to adapt the company's demand characteristics to overcome these trade-offs.

Akbulut-Bailey et al. (2012) also found increases in wastage and costs during the learning curve. However, once the learning curve had been got over, the benefits were worth waiting for. Thus, these authors found improvements to financial results in indicators such as increased customer satisfaction, market share, sales and profits.

### 1.3.2. Development of Supply Chain Management

One of the characteristics of this sector is the non-linear relationships between the different levels of the supply chain and the complexity of organizational relationships between partners in different echelons, competitors, governments, and stakeholders (Lefèbvre and Lefèbvre, 1998; Williams et al., 2002; Bales et al., 2004; Laframboise and Reyes, 2007; Alfalla-Luque et al., in press). This, together with the change in competitive priorities and the delays in the introduction of new aerospace programs, has meant that SCM and its improved integration are a "crucial cornerstone" in the sector (Bales et al., 2004; Ehret and Cooke, 2010; Rose-Anderssen et al., 2009a, 2011; Alfalla- Luque et al., in press).

Research on SCM in this sector has mainly focused on evaluating general trends relating to supply chain configuration over the last two decades (Paliwoda and Bonaccorsi, 1994; Anderson, 1995; Frear and Metcalf, 1995; Esposito and Passaro, 1997; Lefèbvre and Lefèbvre, 1998; Stundza, 1999; Giunta, 2000; Graham and Pervaiz, 2000; Moore et al., 2001; Reed and Walsh, 2002; Bales et al., 2004; Esposito and Passaro, 2009; Rose-Anderssen et al., 2009a, 2011). Several recent researches identify that these evolutionary trends can be explained through the Lean implementation across the supply chain in the sector and it have resulted in what has come to be known as Lean Supply Chain Management. Due to the attention that this has received from researchers, it has given rise to the topic that will be analyzed in Section 1.3.3.

Two lines of research are examined here that have focused their attention exclusively on SCM in the sector: the first one deals with the adoption of integration practices across the supply chain and their results and the second one with the impact of information technologies on supply chain management.

#### 1.3.2.1. Integration Practices along the Supply Chain and Results

Firstly, we highlight the risk-sharing partnerships that have become one of the most widespread association models during the reconfiguration of the supply chain in the sector, especially the partnerships between the prime contractor and the Tier 1s (Rose-Anderssen et al., 2009a, 2011). We take an in-depth look at how these types of association are formed and the primarily innovation-related benefits that they provide. Rose-Anderssen et al. (2008) found that these types of partnerships are a suitable model for sharing skills, expertise and capabilities in the design and development of new aerospace systems. They also found that these types of partnerships improve the partner companies' capabilities for innovation and enable synergies to be produced with the aim of achieving a radical innovation. Rose-Anderssen et al. (2009b) examined three different learning levels for knowledge transformation with the aim of improving innovation capabilities and find that risk-sharing partnerships enable a competitive advantage to be achieved in the supply chain. Lastly, Rose-Anderssen et al. (2010) recently noted that integration and coordination practices through communicative interaction can produce innovative solutions.

Another series of papers focused on collaborative product development (Reed and Walsh, 2002; Morton et al., 2006; Brookes, 2007; McAdam et al., 2008; Bassani et al., 2010; Corallo et al., 2012). Despite the many benefits found, Reed and Walsh (2002) stated that formal supplier development processes had little direct impact on the supplier's technological capability, but that they did have a major indirect effect, mainly through strengthening communication channels, facilitating innovation processes and the anticipation of technology. Meanwhile, Brookes (2007) stressed that social networks play an invaluable role in developing these relationships. Therefore, the social capital of NPD teams provides a useful approach to improving global performance. In the same vein, Morton et al. (2006) noted the importance of trust in underpinning successful internal and inter-organizational relationships before embracing a NPD initiative. For their part, Bassani et al. (2010) highlighted the importance of an adequate assessment tool for supporting decision making in collaborative NPD, and they developed and implemented an assessment tool based on the balanced scorecard for NPD.

The aerospace supply chain has become much more complex with the recent changes made to its configuration (Bales et al., 2004). A number of authors state in this respect that effective reference models are needed to provide a management tool for decision making. Thus, several models have been developed to enable supply risk to be managed in early supplier involvement (Zsidisin and Smith, 2005; Chaudhuri et al., 2013), technology selection (Farooq and O'Brien, 2010), quality problem-solving (Gordon, 2006), resolve conflicting objectives in multiple supply chains (Sinha et al., 2004) and to enable the management of generic critical success factors (Haywood and Peck, 2004). For instance, we highlight the following researches. Zsidisin and Smith (2005) find that NPD implementation not only provides the benefits linked to early supplier involvement in product development, but that a reduction in supplier supply can also be achieved. Meanwhile, Sinha et al. (2004) developed a methodology to mitigate risks to suppliers when they compete in businesses with multiple customers, which is common in this sector. Lastly, Gordon (2006) developed a methodology for monitoring suppliers that could help to mitigate quality-related problems across the supply chain.

Another research current focused on the role that the aerospace regional clusters play in aspects such as innovation and the possibilities of winning new contracts, although the results are not conclusive (Emiliani, 2004; Cooke and Ehret, 2009; Ferretti and Parmentola, 2012). Ferretti and Parmentola (2012) observed that the literature noted how the presence of a leading firm in a cluster positively affected cluster development, however they found that in some cases the presence of a focal firm (prime contractor) might actually hinder cluster development. Cooke and Ehret (2009) found that while regional and cluster knowledge spillovers are not key locational magnets for Tier 1s, they are for Tier 2s and 3s, however. Nonetheless, being in a cluster does not guarantee new contracts, but rather the key factors in outsourcing are knowledge and skills.

Apart from the papers that exclusively analyze SCM from a focus on one or other of its specific practices, there are other authors who examine it from a holistic perspective (e.g., Bales et al., 2004; Rose-Anderssen et al., 2010; Gopalakrishnan et al., 2012; Alfalla-Luque et al., in press). Bales et al. (2004) performed an integrated analysis of how supply chain configuration has evolved with three focuses: a) partnerships, b) information exchange and c) evolving supply chain structure, finding that there was a progressive transition from an adverse mentality to an integrated network. Alfalla-Luque et al. (in press) performed an integrated analysis of the level of SCI between a Tier1 and its suppliers and primary customers and provided an umbrella view of the degree of SCI through three main dimensions: information integration, coordination and resource sharing, and organizational relationship linkage. The same authors identified weaknesses relating to suppliers' low levels of innovation, collaborative planning and joint demand and replenishment forecasts with prime contractors, low access of Tier 2s and upstream agents to ERP systems, and shared decision-making with suppliers.

Another series of problems and barriers have been found apart from the low level of SCI (Graham and Pervaiz, 2000; Beelaerts van Blokland et al., 2012). Beelaerts van Blokland et al. (2012) highlighted the need for further research to understand why the sector has recently been experiencing problems with its supply chains. It is also evident that the literature has ignored the importance of people in achieving successful integration across the supply chain and very few papers have analyzed the role that they play in this sector (Russell and Hoag, 2004; Beelaerts van Blokland et al., 2012; Evans et al., 2012).

Ehret and Cooke (2010) noted that there are still significant efficiency losses due to communication failings and high levels of mistrust between companies in the sector. This is one of the reasons why there is still a low level of SCI, broadly-speaking, with the most affected relationships being those between Tier 1s and other lower levels. This could be the result of many suppliers' low levels of internal integration.

Finally, it should be stated that no paper was found that conducted an empirical analysis of the entire supply chain, but that research maintains its tight focus on dyadic relationships, especially those between prime contractors and Tier 1s.

#### 1.3.2.2. Impact of Information Technologies on Supply Chain Management

The movement towards e-supply chains in the aerospace sector is not new (Laframboise and Reyes, 2007). However, the rise of web-based IT has enabled the high costs and manifold disadvantages of legacy "proprietary systems" to be overcome and this has led to an improvement in SCI in this sector (Williams et al., 2002; Tannock et al., 2007).

Several researchers have in fact found that implementing certain IT, such as web-based ERP, Internet-based EDI and Internet-based e-commerce, brings many benefits. The following specific benefits stand out: improvements to costs, time-to-market, flexibility and global efficiency in collaborative product design and development, synchronization of production across the supply chain, greater skill-set and advantages of e-commerce, improved information flows, and greater interconnection and visibility of inter-organizational global aerospace supply chain processes (O'Sullivan, 2003; Russell and Hoag, 2004; Towers et al., 2005; Laframboise and Reyes, 2007; Alemanni et al., 2008; Alfalla-Luque et al., 2012).

However, a series of limitations have also been detected regarding the degree of IT implementation in the sector due to the complexity of the implementation process caused by technological and organizational factors (O'Sullivan, 2003; Russell and Hoag, 2004; Towers et al., 2005).

*a) Social and organizational factors*

Russell and Hoag (2004) noted that effective management of several factors, such as users' perceived attributes of the innovation, organizational culture, and communication channels used to spread knowledge of the innovation and leadership, is crucial for mitigating risks linked to IT adoption and level of use or implementation.

O'Sullivan (2003) similarly found that certain key risks exist that need to be managed despite the benefits achieved by forming virtual groups in NPD. This author specifically highlights the importance of an understanding shared by teams in both technical and social aspects.

Laframboise and Reyes (2007) found that inter-organizational processes integration, TQM and close-relationships with key partners enabled better results to be achieved in the supply chain electronic integration initiative. Their findings demonstrate the need for the efforts made to implement IT to be leveraged with the company's existing resources, as this will enable all the advantages of e-integration with chain partners to be gained.

In other respects, papers have been indentified that found that a series of e-initiatives had not been greatly adopted in the sector and that some had even failed (Gulledge, 2002; Emiliani 2004; MacDonnell and Clegg, 2007). Emiliani (2004) stated that the use of reverse auctions has not resolved the global supply issue and brought about the cost reductions that were anticipated. The author even stresses that their use could have a negative effect on the buyer's performance in the long-term by producing an atmosphere of mistrust among its suppliers. The factors that were found to be key to their low take-up and even failure were more the result of organizational and contingent factors in the sector than technical issues. It was highlighted that reverse auctions would not offer real benefits to either buyers or sellers in power-based negotiations.

Gulledge (2002) corroborated the above results by finding that transactions in B2B e-marketplaces focusing primarily on cost reductions in the supply chain make it difficult for SMEs to become involved. The main reason for this is that this focus is a threat that suppliers who provide the least added value will be replaced by another e-market competitor and this normally results in lower profit margins for suppliers.

*b) Technological factors*

Several companies belonging to different layers of the supply chain have to contend with being involved in several different e-integration initiatives, often with multiple and incompatible IT solutions, depending on the supply chains that they are members of. Suppliers are therefore faced with an overload of IT systems and communication standards which means that their participation is often made difficult from the technological perspective. This also means that the adoption, maintenance and integration of a range of IT systems are very costly, demanding immense efforts in terms of both resources and time. Furthermore, some IT solutions are beyond the bounds of both the human and financial capacity of some companies, such as SMEs. In some cases this has led to resistance to e-initiatives (Gulledge, 2002; Ho et al., 2004).

As a result, several researchers have developed prototype systems for the automation of commercial transactions (Ho et al., 2004, MacDonnell and Clegg, 2007). Ho et al. (2004), for example, designed and developed a prototype based on XML hub architecture and web technologies which is implemented in a Tier 1 to create an effective interconnection between the Tier 1 and its main customers and suppliers. It can also be integrated into legacy IT systems, giving SMEs an incentive to participate in e-integration initiatives.

In this line, other IT systems implemented in the sector should be mentioned, such as collaborative e-platforms based on web-technologies (e.g., Exostar[2]), which provide an effective interconnection between multiple partners, thus overcoming some of the limitations of legacy IT systems. These types of collaborative e-platforms are open and secure allowing an interconnection with back-end ERP systems. They can therefore facilitate e-commerce and e-collaboration across supply networks, and improved e-SCI (Tannock et al., 2007; Zuckerman, 2007).

Lastly, other researchers have developed simulation and algorithmic models that have been tested in aerospace e-supply chains (Lu et al., 2007; Tannock et al., 2007; Osman et al.,

[2] http://exostar.com

2010). These could be of great interest and use for senior management in the sector given the complexity, uncertainty and variability of their supply chains, as they enable the dynamic performance of supply chains to be assessed and ultimately, aid decision-making concerning their design, effectiveness and efficiency.

Table 1.7 summarizes the main benefits of IT implementation and the types of limitations found. Associated bibliographical references are also shown in chronological order.

**Table 1.7**
Benefits and factors linked with IT implementation in the sector

| Aspects | References |
|---|---|
| **Benefits:**<br>- Improved capability, costs, time-to-market, responsiveness, flexibility to engineering change orders, problem-solving, and global efficiency in collaborative product design and development<br>- Synchronization of production across the supply chain<br>- Increased capabilities and benefits from e-commerce<br>- Improved information flows<br>- Greater interconnection and visibility of inter-organizational processes in the global aerospace supply chain | O'Sullivan (2003); Russell and Hoag (2004); Towers et al. (2005); Laframboise and Reyes (2007); Alemanni et al. (2008); Alfalla-Luque et al. (in press) |
| **Social and organizational factors**<br>- Intra and Inter-organizational culture (shared social structure)<br>- Users' (partners) perceived attributes of the innovation<br>- Communication channels used to spread knowledge of the innovation<br>- Leadership<br>- Complementarity with human resources and other resources (TQM, LM)<br>- Product Development: lack of prior experience in collaborative NPD (starting from scratch). Shared understanding between teams, management of multiple team interdependencies, standardization for content (adoption and on-going adaptation of novel, loosely-coupled organizational forms requires standardization) and work planning, synchronization, are crucial. Prerequisite: long-term commitment to suppliers.<br>- Derail of reverse auctions: contingent and social factors (higher costs associated with dual sourcing, long delays in securing net savings, suppliers were often unable to meet KPI -price, quality, delivery- or other requirements, deficiencies in technical information)<br>- Distrust of some IT systems (manage resistance): other failed IT projects, confidentiality reasons, strategic problems.<br>- Key condition: shared-benefits among partners (narrow focus on costs savings) | Gulledge (2002); O'Sullivan (2003); Emiliani (2004); Russell and Hoag (2004); Laframboise and Reyes (2007); MacDonnell and Clegg (2007) |

**Table 1.7 (Continuation)**

Benefits and factors linked with IT implementation in the sector

| Aspects | References |
|---|---|
| **Technological Factors**<br>- Different e-integration initiatives<br>- Incompatible IT systems (lack of inter-connectivity; e.g., ERP systems are not interconnected<br>- Problems with legacy IT systems | Gulledge (2002); Ho et al. (2004); MacDonnell and Clegg (2007); Tannock et al. (2007) |

### 1.3.3. Deployment of Lean principles and practices across the Supply Chain

Finally, we focus on the interrelationship between LM and SCM, i.e., the deployment of Lean principles and practices across the supply chain, also known as Lean Supply Chain Management (LSCM).

The study of LSCM in this sector merits special mention due both to the role played by the previously-mentioned generic factors connected with the importance of the effective integration of the supply chain in this sector (Lefèbvre and Lefèbvre, 1998; Alfalla-Luque et al., in press) and the importance of adopting a “Lean enterprise” focus in order to create value in an integrated way for the multiple stakeholders in the company (Murman et al., 2002). Contingent characteristics of aerospace supply chains also set numerous challenges for successfully achieving the transition to LSCM (Ehret and Cooke, 2010).

The main lines of research identified related to this research topic are set out below.

#### 1.3.3.1. Changes in the Supply Chain Configuration

The nineteen-nineties marked the beginning of a new competitive environment in the aerospace sector. Trigger factors, such as reductions in public budgets, a change in competitive priorities and growing global competition resulted in a restructuring of the sector (Anderson, 1995; Stundza, 1999; Bales et al., 2004; Smith and Tranfield, 2005). The sector reacted by restructuring its supply chains, mainly to achieve substantial cost reductions (Smith and

Tranfield, 2005; Ehret and Cooke, 2010). However, it should be noted that during its initial phase this restructuring was mainly focused on downsizing/rightsizing, outsourcing, mergers/acquisitions and regulatory reforms. Thus the immediate objective of companies in the sector, mainly the prime contractors, was to avoid a short-term fall in business volume. Despite this, these initiatives had limited success and none solved the general long-term challenges and problems in the sector (Murman et al., 2002).

Thus, the inability to respond to unforeseen changes in demand and huge delays in delivery are still frequent occurrences in the sector. As such, the sector is increasingly focusing on deploying LSCM.

Below we show the general trends in supply chain configuration in the sector bearing in mind the interrelationships between LM and SCM. In other words, these general trends are analyzed from both an SCM focus (e.g., Giunta, 2000; Bales et al., 2004) and from the more recent LSCM focus (Smith and Tranfield, 2005; Ehret and Cooke, 2010). This shows how the supply chain configuration in the sector has evolved in an integrated way.

The structural changes in the sector of two decades ago triggered increased investment requirements for aerospace organizations, especially for prime contractors and, as a consequence, a need for the high financial risks of the new aerospace programs to be shared. Aerospace systems have also become more and more complex, requiring greater knowledge, and physical and financial resources for their design, development and manufacture. All this led to the creation of risk-sharing partnerships, mainly between prime contractors and Tier 1s, and triggered an increase in outsourcing in the sector (Murman et al., 2002).

The prime contractors thus began to focus more and more on their core competences and on outsourcing a major part of their manufacturing and design activities. Prime contractors are therefore focusing more and more on integrating the end product and on the following core competences: coordinating the program, developing the final system, final assembly and interaction with the market (Reed and Walsh, 2002; Beelaerts van Blokland et al., 2012). However, on many occasions outsourcing has not achieved the expected improvements to efficiency and neither has it been free of criticism and associated issues (Murman et al., 2002). "Offset" requirements have arisen, especially in the commercial industry, due to its increasingly global nature; in other words, the outsourcing of aerospace company activities within buying countries as a condition of sale.

However, the impact of outsourcing on the sector is real, as the supplier base manufactures and even designs a high percentage of the final aerospace systems (Ehret and Cooke, 2010; Parry et al., 2010). This has changed the way the supply chain is configured in the sector. Whereas in the past supply chains in the sector were organized vertically, this vertical system is now breaking down and this is having an effect on all the members of the supply chains (Bales et al., 2004).

The prime contractors are rationalizing their supply chains and establishing long-term agreements, mainly with their Tier 1s. There has therefore been a shift in responsibilities and risks towards suppliers in the supply chain, especially in the direction of the Tier 1s (Michaels, 1999; Beelaerts van Blokland et al., 2012). This has meant that the prime contractors have to make great strategic efforts to consolidate their supply base and forge long-term partnerships; to integrate their key suppliers in the development of new products, and to adopt LM and deploy it to the supply base (Stundza, 1999; Smith and Tranfield, 2005; Ehret and Cooke, 2010).

Moreover, suppliers are transitioning from "mere outsourcers" in the short-term to strategic partners in the long-term. As a result, value has shifted from the OEM towards the supply chain. In fact, Beelaerts van Blokland et al. (2012) highlight prime contractors' increased leveraging of value, producing part of the total value required of the chain, and leveraging the remaining value on the supply chain. This necessitates a change in the roles and responsibilities both of the OEMs and of the supplier network (Bales et al., 2004; Parry et al., 2010).

A tendency towards the purchase of systems and subsystems as modules has been detected rather than the individual purchase of parts, and also the greater involvement of suppliers in the initial stages of new aerospace programs and closely-integrated customer-supplier teams (Paliwoda and Bonaccorsi, 1994; Moore et al., 2001; Grant et al., 2003; Beelaerts van Blokland et al., 2012). With regard to the creation of these customer-supplier teams, it is worth highlighting that they have facilitated the early integration of suppliers in the new product design and development process, frequent information- and personnel-sharing, and a greater degree of joint innovation (Bozdogan et al., 1998). Their training is due to their potential for providing significant results in costs, quality, time to market, and access to new technologies and experiences (Grant et al., 2003).

In other cases, the prime contractor has used supplier development policies with the aim of broadening suppliers' competences, abilities and their degree of innovation (Frear and Metcalf, 1995). By executing Lean supplier policies, especially with Tier 1 suppliers, said suppliers have had to shoulder growing responsibility for technology and innovation, for the integration of subsystems and systems, and for the management of their own supply chains (Smith and Tranfield, 2005). The ability of Tier 1s to establish and manage their own supply chain (Tier 2s) should be noted in this respect (Ehret and Cooke, 2010).

This transition from traditional relationships to collaborative relationships with a high degree of cooperation, mainly between the prime contractor and its Tier 1s, has enabled the latter to likewise focus on their core competences with high degrees of specialization and the outsourcing of ancillary services (Giunta, 2000). These changes are also affecting upstream suppliers in the supply chain. Tier 1 suppliers have made new supply agreements with their suppliers which have led to the suppliers acquiring greater technical and management capabilities (Giunta, 2000). It has also been detected in this respect that the Tier 1s are following the trends established by the prime contractors in managing their lower-level suppliers, seeking to consolidate their chains based on the prerequisites of quality and prices (Ehret and Cooke, 2010).

All these changes have led to the supply chain being rationalized with a reduction in the number of suppliers, the greater size of these and their greater abilities to innovate in production and process. This has also been achieved in other cases through mergers, acquisitions, joint ventures, consortia and shared-risk associations (O'Neill and Sackett, 1994; Stundza, 1999). The shared-risk associations have mainly been established between the prime contractors and their Tier 1s, which have greater financial capabilities (Rose-Anderssen et al., 2009a).

Although the trends in supply chain configuration have mainly been found by the SCM-based literature (e.g., Paliwoda and Bonaccorsi, 1994; Esposito and Passaro, 1997), various authors identify that these trends can be explained with LSCM theory (e.g., Smith and Tranfield, 2005; Ehret and Cooke, 2010). In this sense, Rose-Anderssen et al. (2009a, 2011), who studied the strategic changes in the civil industry supply chain, highlight this evolution towards LSCM.

In fact, Smith and Tranfield (2005) found support for the three key principles of LSCM (Lamming, 1993): 1) A smaller number of more capable and talented Tier 1 suppliers that gradually take on a major role in final aerospace system product and process innovation. The prime contractors thus focus on their core competences, changing from high integration to Lean assemblers of subsystems supplied by Tier 1 suppliers. 2) The growing importance of Tier 1s and clear differentiation between supply chain levels. A larger number of shared-risk associations and own-supply chain management. 3) Initiation of mutually-supportive long-term relationships between prime contractors and Tier 1 suppliers. Deployment of Lean supplier development policies. However, they do not support the principle that they should work as equals from the outset. In fact, the prime contractors continue to dominate the supply relationships.

Ehret and Cooke (2010) find in this regard that the LSCM strategy has really been introduced into the sector from an early phase of final system design and development, with leading-edge programs such as the A380, A350 and the B-787.

Table 1.8 summarizes the main changes in supply chain configuration from an integrated approach.

**Table 1.8**

Main changes in supply chain configuration (SCM & LSCM approach)

| Changes | References classified according to the approach used |
|---|---|
| - Downsizing/rightsizing, outsourcing, mergers/acquisitions and regulatory reforms<br>- Subcontracting of non core-competences (some R&D and manufacturing processes)<br>- Vertical de-integration<br>- Rationalizing and consolidating of supply base (lower direct suppliers –tier 1s– pyramidal echelons structure)<br>- Greater size of supplier base (mainly, tier 1s), suppliers with greater innovation capabilities in high added value processes<br>- Mergers, acquisitions, joint ventures, consortiums<br>- Risk-sharing partnerships – long-term relationships<br>- Customer-supplier teams closely integrated (LPD, early supplier integration in new products design and development)<br>- Supplier development policies (from a standard focus to a Lean supplier one)<br>- Change from being "mere outsourcers" ("short-term") into strategic suppliers ("long-term")<br>- Supply of complex products (systems and subsystems)<br>- Management of their own supply chains (mainly, tier 1s)<br>- LM adoption across supply chain (especially, in tier 1s)<br>- Focus from "arm´s length" to "partnering' –risk partnering'– relationships. Time horizon: long term | SCM approach: Paliwoda and Bonaccorsi (1994); Anderson (1995); Frear and Metcalf (1995); Esposito and Passaro (1997); Stundza (1999); Giunta (2000); Graham and Pervaiz (2000); Moore et al. (2001); Reed and Walsh (2002); Bales et al. (2004); Esposito and Passaro (2009); Rose-Anderssen et al. (2009a, 2011); Alfalla-Luque et al. (in press)<br><br>LSCM approach: Bozdogan et al. (1998); Murman et al. (2002); Smith and Tranfield (2005); Ehret and Cooke (2010); Ponce-Cueto et al. (2010) |

In the following we look at the papers that have looked at studies into LSCM implementation in the sector and the ensuing results.

### 1.3.3.2. Implementation Cases and Results

One of the first steps in constructing LSCM is that the key partners across the supply chain have to have adopted LM. Therefore, LM is a driver of LSCM (Lamming, 1993).

A particular feature of this sector is that the number of prime contractors is extremely small and, in some cases, they are government owned or part-owned and controlled. Suppliers are therefore heavily dependent on them (Sacristán-Díaz et al., 2012). In this respect, Mathaisel and Comm (2000) found that the role of the primary customer in the supply chain is crucial for suppliers to adopt and move forward in the degree of LM implementation and, subsequently, in the success of the transformation to LSCM. Apart from this, they found that it was essential for the sector to move forward towards LM as a whole, i.e., that customers, government and prime contractors should all have faith in LM and that there should be no contradictory or changing requirements demanded by them.

Two studies have been identified that have developed models focusing on several aspects of LSCM adoption. Naudé et al. (2009) developed a process-oriented solution for making progress in LSCM and understanding how to manage the search for solutions in complex supply chains by creating a committee made up of the research partners (e.g., Universities and researchers) and governmental organizations for disseminating Lean knowledge to the client companies and advancing in the deployment of LSCM. These authors developed this model because earlier initiatives for advancing in LSCM did not bring the expected results for all the agents in the supply chain. Moreover, these authors noted that the network actors need to consider the parallel relational processes complementary to the process-centric view in order to achieve co-creating collective solutions and to advance in LSCM.

Meanwhile, Bozdogan (2004) developed a model focused on the construction of a Lean supplier network. It should be noted that this model can be of great utility for client companies wishing to execute a supplier development policy, as it shows several tensions, barriers and enablers and also develops an assessment tool.

It was detected that much of the literature has focused primarily on developing these so-called Lean supplier development policies (e.g., Womack and Jones, 1996; Michaels, 1999; Smith and Tranfield, 2005; Akbulut-Bailey et al., 2012). For instance, Smith and Tranfield (2005) found that after Lean supplier development, suppliers, especially Tier 1s, changed from being "mere outsourcers" into suppliers with innovation capabilities in high added value processes. Michaels (1999) meanwhile found a series of benefits from the principles of LM being extended by supplier development strategy. However, a variety of barriers connected with the legacy of past practices and cultural and behavioral attributes were also found that were a curb to these suppliers implementing LM and the subsequent construction of an LSC. In this same line, Bamber and Dale (2000) found that the customer's lack of experience and knowledge of LM and the limited application of a series of merely operational tools led to the supplier development policy not achieving all the benefits that were anticipated.

In other respects, despite the major importance of product development in the sector, only two studies were found to have focused on LPD on the supply chain level (Bozdogan et al., 1998; Grant, 2003). Grant (2003) found that key supplier integration from an early stage of the design process provided significant improvements to project results, including quality, costs (design, manufacturing and product support) and to development times. Other results included more accessible and transparent information-sharing, enhanced supplier response capabilities, and proactive communication. Concerning shared responsibility for value creation (Lamming, 1993), which is a keystone of LSCM, Beelaerts van Blokland et al. (2012) stressed that creating value through LSCM requires a balance between what the customer wants (demand), the unique contribution made by the focal company, and the suppliers (SC). These authors developed a series of indicators to measure "value leverage", empirically testing the value leveraged by the OEM towards the supply chain.

A series of studies can be observed that look at the role of contingent factors in the deployment of the LSCM strategy. Firstly, it should be highlighted that LSCM theory stresses that in many cases traditional outsourcing presupposes the existence of qualified suppliers with the requisite capabilities to assume these new responsibilities (Murman et al., 2002; Ehret and Cooke, 2010; Parry et al., 2010). Ehret and Cooke (2010) identified that Lean theory denies the importance of knowledge in outsourcing and therefore stresses the need for knowledge to be recognized as a key explanatory parameter of Lean outsourcing theory. As such, supplier knowledge and technological ability must be incorporated into LSCM theory. These authors specifically find that the higher the knowledge content, the closer the relationship with suppliers, and the lower it is, the more hierarchical relationships are.

Parry et al. (2010) similarly found that aerospace companies that are making advances in LM implementation are increasingly focusing on strategies to eliminate wastage from their processes, maximize the utility of their own resources, and outsource non-core activities to the supply chain. However special note should be made of the importance of risk analysis in outsourcing activities in this sector. They develop a methodology for this that enables the risk of damaging key company resources and abilities to be evaluated through “Core Competence” theory and LSCM performance.

Meanwhile Mathaisel and Comm (2000) and Ehret and Cooke (2010) found a range of contingent factors pertinent to the sector that impeded the proper deployment of LSCM. These included above all: a) problems linked to acquisition by the customer and government supervision, b) highly changeable requisites for products, quality and production programming, c) the need for suppliers of aerospace goods and services to be approved by the prime contractors and the large Tier 1 suppliers, d) high quality and safety demands subject to both internal and external control, e) offset obligations.

### 1.4. Discussion, Gaps and Future Research Lines

We next discuss the empirical evidence that has been evaluated and identify a number of gaps in the research. We also propose a series of challenges for future research. Each of the research topics is discussed separately.

*a) Adoption and implementation of Lean Management*

Research in LM in this sector has not only focused on its study in the production area and on a particular supply chain level, the Prime Contractors to be specific, but also on other internal areas of the organization and on several levels of the supply network. LM has been seen to have spread to other organizational processes and, especially, to new product development and design (Crute et al., 2003). LM has similarly been determined to have spread to Tier 1 and even Tier 2 suppliers (Smith and Tranfield, 2005; Ehret and Cooke, 2010). The application of LM to service processes on other levels of the supply chain, such as after sales, should also be noted, and especially to maintenance, repair and overhaul (MRO) processes, due to the great importance that managing the whole product lifecycle has in this sector (Mathaisel, 2005). Despite this, the literature still predominantly emphasizes manufacture and assembly operations rather than other organizational processes, such as design and services. As far as space is concerned, greater research can be seen in the defense and civil industries.

Focusing on the discussion of the empirical evidence and beginning with the line of research focusing on LM adoption, a number of factors were found that triggered a structural change in the competitive priorities of this sector and, subsequently, the adoption of LM. One of the most important competitive priorities was the role of delivery times and reliability, as on the whole they are still a challenge in this sector.

In other respects, there is agreement on the applicability of LM in the sector. It is nonetheless essential to understand the role that a range of contingent factors play in LM and to address them. Specifically, it is crucial to address and evaluate the initial situation and context of the company before adopting LM (Murman et al., 2002; Crute et al., 2003; Browning and Heath, 2009). A series of prerequisites and key factors have been identified in LM adoption where the role of people stands out (e.g., Womack and Jones, 1996; Bamber and Dale, 2000; Murman et al., 2002; Akbulut-Bailey et al., 2012). One of the main challenges that companies in the sector are facing is the acceptance of LM and knowledge of its potential benefits (Mathaisel and Comm, 2000). The management of people's initial skepticism and resistance is therefore crucial. Moreover, understanding, assessing and addressing the "monuments" of the sector, which act as barriers for LM adoption, is a vital step in achieving a successful LM adoption (Murman et al., 2002). Other people-related factors, such as the leadership and commitment of senior management, the support of all management staff, and training have been identified as crucially relevant to the success of LM adoption (e.g., Womack and Jones, 1996; Bamber and Dale, 2000; Murman et al., 2002; Akbulut-Bailey et al., 2012).

However, despite the importance of understanding, assessing and addressing both the contingent factors and other factors that might play a crucial role in the LM adoption process, the literature has ignored the development of LM adoption models. In fact, most of the models developed have focused on advanced phases of LM implementation and analyzed its adoption tangentially (e.g., Crabill et al., 2000; Mathaisel, 2005).

With respect to the line of research that focuses on LM implementation and with specific regard to the development of implementation models, many of these have been identified as addressing the “Enterprise focus” (e.g., Crabill et al., 2000; Murman et al., 2002; Mathaisel, 2005; Bhuiyan et al., 2006). Models focusing on LPD have also been identified (e.g., Rebentisch, 2010; Oehmen and Rebentisch, 2010 a, b). This is due to the fact that product design and development represents a large part of the product life cycle and total costs in this sector (Crute et al., 2003).

Nevertheless, despite the importance of implementing LM with an “enterprise” or holistic focus, it has been determined that the implementation cases have not followed this approach, and that most of the studies address LM implementation with an exclusive focus on the production environment (e.g., Bamber and Dale, 2000; Crute et al., 2003) or examine isolated Lean tools and practices (e.g., Parry and Turner, 2006; Chakravorty, 2009). Moreover, implementation cases have been identified which vaguely analyze which Lean practices and tools should be used and how they can be effectively adapted to the company’s context (James-Moore and Gibbons, 1997; Bamber and Dale, 2000; McKenzie and Jayanthi, 2007). The research has been seen to have continued to emphasize the idea that companies must carefully assess which practices and tools they can use directly and which need to be adapted to meet their specific contexts.

Finally, with respect to the line of research focusing on an analysis of the results afforded by LM, it should be stressed that there is not much empirical evidence and what there is not conclusive. The studies done show that LM improves KPIs related to operating results in various industries and segments in the sector (e.g., Womack and Jones, 1996; Murman et al., 2002; Crute et al., 2003). Despite this, other studies find that various contingent factors moderate the impact of LM on production costs (McKenzie and Jayanthi, 2007; Browning and Heath, 2009). Meanwhile, the impact of LM on the financial results has hardly been analyzed at all (Akbulut-Bailey et al., 2012).

A series of lines of future research are now proposed on the basis of the gaps detected. Firstly, it is proposed that LM adoption models be developed that identify the key factors that need to be managed both before and during the adoption process. A number of authors state that the transition to LM is not clear for many senior managers and that it is therefore crucial to establish how this management system can be adopted successfully while at the same time attending to contextual factors.

We propose that a greater research effort be made into the factors that could play a key role in other areas of the company apart from production, such as design and development, after sales processes and MRO. Companies could then manage these factors appropriately in order to prevent 'islands of improvement' being created.

It should be said that the problems with LM implementation in this sector are not necessarily any worse than in any other sector. The challenges are different, but no more difficult. However, the challenges to its implementation are real. One of the main challenges that companies have to confront is knowing which Lean practices and tools to use and how to effectively apply them to their own particular contexts. In effect, the transfer of Lean practices and tools to specific contexts has not been completely disseminated. In the same line, further research is proposed to analyze the reasons why certain LM-related principles, practices and tools are not applied in companies in the sector, and what role contingent factors play in this.

Although the literature stresses the role of people and cultural change in the success of LM implementation, there are no studies that investigate in depth the role of people in LM, LM-related human resource practices, or how LM affects people and their degree of adaptation to this management system. We therefore propose that a more in-depth look be taken at the factors that could play a key role in the management of human resources, people and the cultural change required by this management system.

We also propose more in-depth research be conducted into both operating and financial results due to the non-conclusive findings regarding the impact that LM has on results. The moderating effect of contingent factors must be considered for this in order to shed light on inconclusive results achieved with LM implementation. Research should also be carried out on the impact of Lean accountancy systems on financial results. Finally, it would be useful to develop a methodology to examine LM's impact on results in this sector and to find out which factors enable the outcomes of LM to be sustained over time.

Lastly, it is essential for contingent factors to be considered in future research if advances are to be made in Lean theory.

*b) Development of Supply Chain Management*

The literature has analyzed SCI through a number of isolated practices that have achieved an improvement in results only through 'islands of improvement'. Research has been seen to focus primarily on risk-sharing partnerships (Rose-Anderssen et al., 2008), collaborative product development (Reed and Walsh, 2002), decision-making models (Zsidisin and Smith, 2005), and the role of aerospace regional clusters (Ferretti and Parmentola, 2012). However, only a small number of studies have used integrated or holistic frameworks to analyze SCI strategy (e.g., Bales et al., 2004; Alfalla-Luque et al., in press).

With respect to the results, although the implementation of various isolated practices has enabled improvements to be made to a number of KPIs, a low level of SCI and a series of issues and barriers to effective integration have been detected overall (Graham and Pervaiz, 2000; Ehret and Cooke, 2010; Beelaerts van Blokland et al., 2012; Alfalla-Luque et al., in press).

Other shortfalls in the literature also stand out. These include the consideration of the role of people in the success of an SCI initiative. Only a few studies have analyzed their role in this sector (Russell and Hoag, 2004; Beelaerts van Blokland et al., 2012; Gopalakrishnan et al., 2012).

With respect to the impact of IT on SCI, it has been determined that web-based IT systems have made it easier to achieve multiple benefits, such as improved information and physical flow integration (Laframboise and Reyes, 2007; Alfalla-Luque et al., in press). Improvements in the integration of inter-organizational processes, such as product development, should be singled out (O'Sullivan, 2003). However, the literature has paid little attention to the role of IT systems in integrating other inter-organizational processes, such as collaborative production planning. A series of limitations and challenges relating to both technological and social factors have also been identified, with social factors predominating (O'Sullivan, 2003; Russell and Hoag, 2004; Towers et al., 2005). Apart from this, the low adoption and even failure of some e-initiatives have been found (e.g., reverse auctions).

A series of lines of future research are proposed below on the basis of the gaps detected. Firstly, it is important for research to consider robust frameworks when analyzing the level of SCI. New research should also be conducted to explore and explain why the sector still has low levels of SCI. It would be important in this respect to study other relationships apart from prime contractors-Tier 1s, both upstream and downstream in the chain and, especially, considering the supply chain as a network.

It is necessary to look deeper into the roles played by organizational culture and people in this strategy. It would also be important to know what role the level of internal SCI is playing in achieving external SCI. This could bring a new outlook to research on SCM strategy as a whole.

With respect to the impact of IT on SCI, the sector still has a long way to go before it reaches the point of “digital extended enterprise” (Laframboise and Reyes, 2007). Despite some authors stating with regard to technical aspects that new advances in web-based IT systems have enabled the limitations of legacy “proprietary systems” to be overcome (Tannock et al., 2007), others point to the low uptake of e-initiatives both downstream (MacDonnell and Clegg, 2007) and upstream (Alfalla-Luque et al., in press).

We therefore propose further research to find out the degree to which these types of e-initiatives have spread both upstream and downstream (end customers, after sales processes and MRO) and to discover the associated explanatory factors. Further research is also proposed into the impact of IT on the integration of other inter-organizational processes apart from product development. Also, as collaborative design has changed due to the introduction of recently developed aerospace programs, it would be interesting to know whether the IT systems used are meeting these new technological and human demands.

*c) Deployment of Lean principles and practices across the Supply Chain*

The research has analyzed the way that supply chain configuration has evolved over recent decades from both the perspective of SCM and LM. This approach has enabled us to conclude that the changes that have taken place to the present today can be explained through LSCM theory (e.g., Smith and Tranfield, 2005; Ehret and Cooke, 2010). So, after their vertical de-integration, the supply chains are consolidating simultaneously with the aim of mitigating increases in the complexity of supply chains and management resources (Bales et al., 2004).

Despite this, we detected that while some authors take “snapshots” of the current status of the supply chain configuration, accurately describing its different echelons, for example (Ponce-Cueto et al., 2010; Alfalla-Luque et al., in press), others nonetheless emphasize its ongoing ‘evolving’ nature as adapting to the environment so as to proactively respond to increased competition (Bales et al., 2004; Rose-Anderssen et al., 2009a; Ehret and Cooke, 2010). Despite this, the literature has focused on analyzing and describing these trends in supply chain configuration without investigating the impact of this continual development on the adoption and deployment of LSCM strategy.

With regard to the line of research on implementation cases and results, it should be stated that this is still at a very early stage. This is logical however, as LM is a driver of LSCM (Lamming, 1993) and the first echelon to adopt LM in the sector was the prime contractors, and that was only a few years ago (Ehret and Cooke, 2010).

In fact, this managerial phenomenon is reflected in academic research. The few studies that do exist focus on developing models for its adoption (Bozdogan, 2004; Naudé et al., 2009). As well, the study of LSCM practices focuses on the deployment of Lean supplier development policies (Michaels, 1999; Smith and Tranfield, 2005; Akbulut-Bailey et al., 2012) and LPD (Bozdogan et al., 1998; Grant, 2003). Thus, the deployment of more advanced principles and practices, such as “open-book” policies and pull systems, has not been detected.

It can be stated that the sector has still not managed to spread LSCM widely. In fact, Ehret and Cooke (2010) suggest that much still has to be done before LSCM is widely implemented. The sector is in fact only taking its first steps towards deploying Lean principles and practices across its supply chains (Ponce-Cueto et al., 2010) and it is a difficult and challenging task (Rose-Anderssen et al., 2009a, 2011). This can be explained by the fact that the prime contractors have been less supportive of their Tier 1s and other suppliers than it was thought that they would be (Smith and Tranfield, 2005), by the suppliers’ slow dissemination and implementation of LM principles (Alfalla-Luque et al., in press) and the complex SC structure and generalized conservative mindset (Rose Andersen et al., 2009b).

The literature has considered the role of a variety of contingent factors in LSCM (Murman et al., 2002; Ehret and Cooke, 2010). The factors that stand out are those that could hinder LSCM adoption: exhaustive regulation, inflexible quality certification procedures, legal requirements, outsourcing risks (offset obligations), organizational culture, supply chain configuration, role of the primary customer, power relationships and demand cycle and conservative mindset. Dyadic relationships have also been studied, principally between prime contractors and Tier 1s, but there is virtually no, or extremely little, research on LSCM on other levels of the supply chain across the whole supply chain.

The following lines of research are proposed from a holistic approach (LM & SCM) on the basis of LSCM-related gaps and the gaps that have previously been identified regarding developments in Supply Chain Management.

Firstly, in a context of uncertainty and dynamism, we stress that there is an imperious need to explore the factors that explain the adoption of LSCM and the crucial factors that might play a role in its successful deployment. Moreover, it would also be interesting to know what role supply chain configuration plays in the adoption of the strategy.

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As the suppliers are currently acting as “outsourcees” we propose that they should be looked at to ascertain whether the contracts that they have with their own supplier base are long-term or not, and to see what strategies and practices they are employing to improve the efficiency of these new supply chains.

Research into LSCM has evidently not considered the role of IT, unlike the topic focusing on SCM development. It would therefore also be of interest to discover the role that they play, especially web-based IT, in the deployment of Lean principles and practices across the supply chain, and which LM elements most benefit. Research is also proposed to discover whether current IT is sufficiently capable of advancing in both the adoption and the implementation of LSCM and, subsequently, of enabling the adoption of some specific Lean practices (e.g., e-kanban, pull system) and to what point in the supply chain, both up- and down-stream.

How cyclicality in demand affects progress in LM implementation on the internal level and the deployment of Lean principles and practices across the supply chain needs to be addressed. We therefore propose not only the study of redundancy programs during times of reduced demand or troughs, but also the effect of prolonged peaks in demand.

In general terms, research needs to go into the specific contingent factors in the sector’s defense, civil and space industries in greater depth and, more specifically, to take a closer look at how the factors pertinent to each of the segments in the sector prove to be either facilitating or inhibiting factors for LM, SCM and LSCM adoption and implementation. Research should also consider the role of people and intra- and inter-organizational culture in the study of both internal integration initiatives, such as LM, and external integration initiatives, such as SCM and LSCM.

### 1.5. Conclusions and implications

The purpose of this chapter has been to move forward in LM and SCM by evaluating existing research in the two strategies in a specific industrial context, the aerospace sector. The role played by contingent factors in the transition to these two strategies has been especially highlighted. Moreover, given some academic and professional concerns regarding the simultaneous application of these strategies in the sector in question, we have looked at the interrelationships between the two from a holistic focus.

For this we conducted a Systematic Literature Review. This enabled us to classify existing literature according to three main topics: a) Adoption and implementation of Lean Management, b) Development of Supply Chain Management, and c) Deployment of Lean principles and practices across the Supply Chain. A number of more specific research lines have also been proposed as belonging to each of these three main research topics. We seek in this way to help the state-of-the-art of research to be understood and facilitate the work of new researchers who wish to make a start in the area, while also providing some guidelines for senior management.

We should stress that although our focus is on the aerospace sector, our results and conclusions could be useful for other industrial sectors, especially those with similar contingent factors. This paper has therefore identified both contingent and generic factors that are crucial for completing a successful transition to LM, SCM and LSCM.

In this regard, we have identified major factors for both the LM adoption and implementation phases that might be useful for managers responsible for this management system, depending on the situation or point of progress in LM implementation that they are at. Also, as previously stated, the transition to LM is not clear for many companies, as a result of which the wide range of LM adoption and implementation models that we have analyzed could be of great utility for management responsible for a Lean initiative.

Meanwhile, with regard to SCM, a range of practices have been found aimed at improving supply chain integration. A number of key generic and contingent factors have been found apart from these practices. This could be of interest for senior management who are seeking to improve integration in their supply chains. However, these focuses have to be adopted with an integrated focus, instead of focusing on isolated practices. With respect to the impact of IT on SCI, senior management must evaluate a series of technical and organizational factors before launching an e-initiative.

Finally, in relation to LSCM we have shown the general trends in supply chain configuration over the past two decades from a holistic approach. We have detected that although this evolutionary trend has primarily been researched through the SCM approach, it can be explained by LSCM theory. We subsequently identified a series of models that have been developed and the deployment of a number of practices for building LSCM. We have also detected and synthesized the role that a multitude of both generic and contingent factors could play in the deployment of the strategy. This is all useful for managers responsible for LSCM initiatives as it will enable them to focus on the key factors before proceeding with adoption.

Our findings show that historically the two research topics of LM and SCM have advanced independently from one another in the aerospace sector. However, some common points and synergies between them have been detected recently. Specifically, LSCM strategy has been seen to have emerged as a research topic and as a logical extension to Lean practices and principles across the supply chain. As a specific strategy in the global SCM framework, LSCM will foreseeably take a dominant role in research into the supply chain in this sector in coming years.

Nevertheless, our results highlight the synergies between LSCM and SCM that must be leveraged to achieve more efficient and effective aerospace supply chains. So, whereas in the past research into SCM was seen to focus exclusively on analyzing the general trends in the sector and the study of isolated practices, it has now been found that one of the reasons for the low level of aerospace SCI is low internal integration of upstream chain agents. Despite this, the SCM practices deployed can act as a factor to leverage LSCM adoption, as long as this new strategy is adopted with an integral focus across the whole supply network, and leveraging the large number of practices that have previously been deployed.

It should also be highlighted with regard to the gaps identified that a series of future lines of research have been proposed that can help researchers focus on the most relevant elements that light needs to be shed upon.

With these gaps as its starting point, and with the goal of moving forward in research into this management system in general and in the aerospace sector in particular, this doctoral thesis seeks to address the following critical aspects:

In the next chapter we seek to develop an LM adoption model that enables the key factors that need to be managed both before adoption and during the adoption phase itself to be determined holistically.

Chapter III addresses the role that people play in this management system. It specifically explores the factors that might play a crucial part in human resources management, people and the cultural change that this management system demands.

Finally, Chapter IV focuses on research into the factors that explain the adoption of LSCM and the crucial factors that must be managed in order to achieve a successful adoption of this recently-formulated strategy in the aerospace sector.

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# KEY DETERMINANTS OF THE LEAN MANAGEMENT ADOPTION PROCESS II

## 2.1. Introduction

There has been a significant evolution and expansion of Lean Management (LM) adoption outside its origins in the automotive industry (Womack et al., 1990). Thus, in the past two decades, companies in different industrial and service sectors have adopted LM, enabling them, in many cases, to improve their results and competitiveness (Womack and Jones, 2005; Hines et al., 2008).

However, although there are many companies that have adopted LM successfully, others have failed in the adoption process and have not achieved the expected results (Bhasin and Burcher, 2006; Staats et al., 2011). In fact, adopting LM is a complex task that generally comes up against many obstacles (Scherrer-Rathje et al., 2009). Identifying the factors that explain LM adoption and potentially impact on the adaptation outcomes is, therefore, a priority for the companies that are beginning to adopt this innovative management system (Forrester et al., 2010; So and Sun, 2011).

In this respect, there is a major current of research that has identified a series of factors that can act as facilitators or inhibitors during the LM implementation process (Karlsson and Åhlström, 1996; Bruun and Mefford, 2004; Hines et al., 2008; Fullerton and Wempe, 2009; Serrano-Lasa et al., 2009). There are, however, few studies that have analysed the factors that might explain the reasons why companies adopt LM (Sohal and Egglestone, 1994; Kojima and Kaplinsky, 2004) and which prior factors are required to manage adoption successfully (Kochan et al., 1997; Achanga et al., 2006).

Identifying why and how companies adopt LM is, therefore, fundamental for ensuring that the adoption process is successful. In fact, having a prior knowledge of these explanatory factors before beginning LM adoption is crucially important (Rich et al., 2006), since it could mean faster progress accompanied with fewer impediments in the subsequent implementation process (Zutshi and Sohal, 2004).

For these reasons, this study's generic research question is: *Why and how do firms adopt LM?*

From this approach, we aim to achieve the following complementary objectives:

1) The identification of factors that might play a key role in the adoption of LM.

2) A proposal for a model that incorporates these factors and their interrelationships.

This chapter has been structured in seven sections, beginning with this introduction. The second section is devoted to analysing the background of this research. The third section describes the methodology used in this research. The results are set out in the fourth section, whereas in the fifth, we present a discussion of the results. The sixth section describes the conclusion of the research and, finally, we present the implications for management and the challenges that future research will have to address.

## 2.2. Literature Review

### 2.2.1. Lean Management Adoption

LM is a direct descendant of the Toyota Production System and has been evolving over a long period of time and will continue to do so in the future (Hines et al., 2004; Moyano-Fuentes and Sacristán-Díaz, 2012). LM is an integrated socio-technical system with the main objective of achieving maximum efficiency by carrying out operations at a minimum cost and with zero wastage. For this, the variability of the whole system needs to be minimised (de Treville and Antonakis, 2006; Shah and Ward, 2007).

LM adoption has spread to companies in different industrial and service sectors (Womack and Jones, 1996, 2005; Hines et al., 2008). However, the challenges of LM adoption are complex and difficult for many companies. In fact, LM adoption is a complex task that generally comes up against a large number of obstacles and is not usually properly achieved the first time (Scherrer-Rathje et al., 2009; Green et al., 2010). This has driven interest in research into the factors that explain LM adoption and into the prerequisites needed to enable companies to successfully manage its adoption (Jayaram et al., 2008; So and Sun, 2011).

In this respect, the prior literature has found a series of factors that are linked to the adoption of LM. On the one hand, the potential benefits that can be achieved with LM (Sohal and Egglestone, 1994), the search for a series of competitive advantages (James-Moore and Gibbons, 1997; Crute et al., 2003), relationships with other companies that have begun LM adoption and a company's own readiness to embark upon improvement and training programmes (Kojima and Kaplinsky, 2004) have all been identified as triggers for its adoption.

On the other hand, with regard to the factors that are required beforehand for adoption to be successfully managed, prior research has identified the management's commitment to the Lean initiative (Sohal and Egglestone, 1994; McLachlin, 1997), a prior assessment of the company's situation and its context (Harrison and Storey, 1996; Kochan et al., 1997) and the prior building of close relationships with the main partners in the supply chain (Jayaram et al., 2008).

However, most prior research has focused on analysing the influence that isolated factors have on LM adoption (Sohal and Egglestone, 1994; Jayaram et al., 2008; So and Sun, 2011) and it have not applied an integrated framework that could also show any interrelationships among these factors in the adoption process.

### 2.2.2. Lean Management in the Aerospace Sector

Over the past decade, the world aerospace sector has been subjected to increasing global competition and the challenge of adapting to technological changes. Whilst in the past competitiveness in the sector was principally based on differentiation and technical issues, in recent years, a series of competitive priorities have arisen that are turning into an enabling factor for competing in this. These competitive priorities are related to improving delivery reliability, delivery times and production quality, and increasing productivity and reducing inventory and operating costs, among other issues (James-Moore and Gibbons, 1997; Smith and Tranfield, 2005).

Nevertheless, the inability to respond to unforeseen changes in demand and the long delays in delivery times in the sector demand greater flexibility and adaptation to customers' needs and the guarantee that personnel are as fully-trained as possible (James-Moore and Gibbons, 1997; Crute et al., 2003). To achieve these objectives, companies in the aerospace sector have begun to adopt LM and this, in many cases, has enabled them to improve their results and their competitive abilities (Womack and Jones, 1996; Smith and Tranfield, 2005; Browning and Heath, 2009). However, prior research has identified that one of the general barriers to adopting LM in this sector is the lingering perception that LM is, to a certain extent, an "automobile industry idea" and difficult to transfer to the aerospace sector.

In this regard, the little research that exists into LM in this sector has focused on examining its applicability. There is a consensus that LM is appropriate in the aerospace sector, which is characterised by highly differentiated and hugely complex products, low production volumes and low repeatability (James-Moore and Gibbons, 1997; Murman et al., 2002; Crute et al., 2003).

Nevertheless, LM transition challenges are real and difficult for many companies in this sector (Bamber and Dale, 2000; Crute et al., 2003), and it is necessary to address and evaluate the initial situation and context of the company before adopting LM (Murman et al., 2002). Notwithstanding, Crute et al. (2003) found that difficulties in LM implementation in the aerospace sector are more related to the context of the production plant and the management role than to sector-specific factors. Likewise, Bamber and Dale (2000) found two major difficulties for implementing LM in this sector related to the human role (historical lack of employee education and training) and the redundancy programme (characteristics of customers demand). However, they emphasise that there are several Lean techniques that are not as powerful in the aerospace environment as they are in the automobile industry.

Another stream of research has focused on developing Lean implementation models in the aerospace sector to provide a systematic guide consisting of a series of phases for the transition to LM (Crabill et al., 2000; Mathaisel and Comm, 2000; Murman et al., 2002; Mathaisel, 2005).

There have been, however, very few studies that have analysed the factors that explain LM adoption in this sector and the prior factors required to manage LM adoption successfully. Moreover, the few studies that have identified success factors during the LM adoption process in this sector have a narrow focus on isolated Lean techniques (Parry and Turner, 2006), instead of a holistic one (Crute et al., 2003). In this respect, the literature advocates more research on how companies in the sector learn how to be Lean (Smith and Tranfield, 2005), the exploration of how LM is transferred to the aerospace sector (Crute et al., 2003) and on the factors that might influence on the LM adoption (Murman et al., 2002).

## 2.3. Research Methodology

### 2.3.1. Research Design

The adoption of LM in a variety of industrial sectors, such as the aerospace sector, is an emerging research area and case studies are, therefore, an appropriate research method in this context. There is little empirical evidence on the adoption of LM in this sector. This research on LM adoption is, therefore, exploratory in nature. The use of case studies is well established in operations management as a qualitative research method for exploratory studies and generating new knowledge (Voss et al., 2002).

The case study lends itself to exploratory research, where the variables are still unknown, the phenomenon is not well understood and when a deeper understanding is required of the factors that influence on a relatively new reality (Benbasat et al., 1987; Meredith, 1998). Moreover, the case study is especially useful to study longitudinal change processes (Eisenhardt, 1989), to gain a holistic view of a phenomenon rather than a reductionist one (Gummesson, 2000), when the phenomenon cannot be understood independently from its context, or to explain complex causal relationships (McCutcheon and Meredith, 1993; Yin, 2003).

In fact, Yin (2003) argues that case studies are more suitable for answering "why" or "how" questions than other research strategies. Thus, the case study method seems appropriate as it provides the necessary depth for exploring and describing why and how companies have adopted LM.

A multi-case method is used to explore these issues and build theory since it is appropriate for observing and describing a complex research phenomenon (Meredith, 1998; Eisenhardt and Graebner, 2007). The multi-case method enables strengthen internal validity and findings to be replicated, thus driving up the external validity of the research (Eisenhardt, 1989), guarding against observer bias (Handfield and Melnyk, 1998; Meredith, 1998; Voss et al., 2002), aiding triangulation, improving the generality of findings (Voss et al., 2002; Yin, 2003) and making the overall research more robust (Herriot and Firestone, 1983).

### 2.3.2. Case Selection

To ensure the validity of the findings, the selection of the case studies was a major decision (Stuart et al., 2002; Yin, 2003).

We used a theoretical sampling model (Eisenhardt, 1989; Voss et al., 2002; Yin, 2003). The conditions used in this study were designed to elicit those firms that offered an optimal "opportunity to learn" (Stake, 1995; Yin, 2003) so that the resulting case studies would offer powerful and meaningful insights. Our strategy was based on achieving literal replication (Yin, 2003), using information-rich cases that were distributed for maximum variation (Miles and Huberman, 1994; Stuart et al., 2002). We, therefore, selected production plants that belonged to the prime contractors in the aerospace sector that had begun LM adoption and had made advances in its implementation over a minimum period of 3 years. That the basic unit of analysis was the plant, even when plants could belong to a single group, is due to the fact that the key determinants of LM adoption might vary due to each production plant's own organisational factors. Plants have also been included that differ both in size and in products manufactured. The company database provided by the *"Fundación Hélice"*[3] was used to identify all the companies that make up the population of prime contractors in the Andalusian aerospace sector. Said database was refined for the aims of our research.

This population had the ideal number of cases, which ranges between 4 and 10 (Eisenhardt, 1989). Moreover, sampling proceeded until theoretical saturation was achieved, which occurs at the point where incremental learning is minimal (Strauss and Corbin, 1998).

As a result of this process, we obtained a total of five production plants as case studies. Two are final aircraft assembly lines (FALs) and the others are prime contractors devoted to manufacturing and assembling parts, subassemblies and large aerostructures, primarily for the

[3] "Fundación Hélice" is a member of the *European Aviation Clusters Partnership*.

FALs. All plants studied are members of the consortium *European Aeronautic Defence and Space Company* consortium (EADS).

### 2.3.3. Data Collection

Before beginning the field work, a case study protocol was designed. This included the data collection instruments, procedures and general rules that should be followed in the case study method (Yin, 2003). The protocol was updated and improved with each visit that took place (de Weerd-Nederhof, 2001), affording the research greater reliability (Yin, 2003).

A preliminary interview guide (Eisenhardt, 1989) was designed based on an LM literature review. Furthermore, before beginning the field work, a preliminary version of the interview guide was tested with two renowned researchers in Operations Management and two experts with extensive experience in the aerospace sector. Finally, we conducted a pilot study in a manufacturing plant. As a result of this process, new questions were added and some changes were made to the wording to eliminate any potential problems with interpretation during the in-depth interviews.

We used a survey as a primary information source of evidence in order to triangulate information from the in-depth interviews and the above-mentioned process was repeated to test the preliminary version of the questionnaire.

Both primary and secondary information sources were used in order to triangulate data sources. This helped to ensure the construct validity of this research (Easterby-Smith et al., 2002; Yin, 2003). The primary sources used were: in-depth semi-structured interviews, surveys, plant visits/factory tours and, in some cases, statements made by the management. The secondary sources used were: company documentation, company websites and similar sources.

Various respondents (two to three key respondents) were interviewed in all cases to ensure the construct validity. In all cases, the plant manager was interviewed and the person in charge of LM in the plant and other Lean experts were also involved. We interviewed a total of

12 managers. We also had the opportunity to discuss various aspects of LM adoption with shop-floor workers on some factory tours. This helped to improve our understanding of how LM had been adopted.

We also used multiple interviewers. To be precise, the lead researcher was accompanied by a second researcher in all cases, which allowed data to be collected independently and ambiguous issues to be clarified during the data collection process. This also improves convergence of observations and raises confidence in the findings (Eisenhardt, 1989). The use of various interviewers also helped to limit any observer bias (Voss et al., 2002).

Data were collected between October 2010 and March 2011. Each semi-structured face-to-face interview lasted between 75 and 105 minutes. All the interviews were recorded and transcribed immediately afterwards. A database was developed that contained all the interview transcriptions, questionnaires, documents and extensive notes. This also helped to ensure reliability as it provided an easily auditable trail of events. Thus, the data collection strategy employed helped to control for the construct validity of the research.

Table 2.1 gives a description of the production plants selected as case studies.

**Table 2.1**
Description of the plants selected

| | Plant 1 (P1) | Plant 2 (P2) | Plant 3 (P3) | Plant 4 (P4) | Plant 5 (P5) |
|---|---|---|---|---|---|
| **Size** (number of employers) | 650 | 300 | 909 | 350 | 715 |
| **Year of LM Adoption** (Plant Level) | 2007 | 2007 | 2006 | 2005 | 2005 |
| **Year of LM Adoption** (Corporation Level) | 2007 | 2007 | 2007 | 2007 | 2007 |
| **Key Respondents** | Plant Manager, Plant Lean Manager | Plant Manager, Plant Lean Manager | Plant Manager, Plant Lean Manager, Corporation Lean Manager | Plant Manager, Plant Lean Manager | Plant Manager, Plant Lean Manager, Plant Lean Expert |
| **Interview Duration** (minutes) | 75 | 78 | 105 | 86 | 84 |

### 2.3.4. Data Analysis

The basic objective of the analysis is to drive conclusions from the data, keeping a clear chain of evidence. Therefore, we have adopted a range of measures to ensure the validity of the data analysis and interpretation process (Yin, 2003). Both within-case and cross-case analysis was conducted. Within-case analysis helps the researcher to start the process of progressively making sense out of the large amount of data collected (Eisenhardt, 1989). The emerging topics for exploration and explanation were identified in the analysis of the interview and the data, and the relationships among the variables that were identified were explored and defined in the subsequent interviews (Miles and Huberman, 1994).

Thus, triangulation has been sought both within cases (e.g. by comparing primary and secondary data) and across cases (e.g. by comparing the responses of manufacturing plants). The external and internal validity of the research was controlled by confirming the findings of each case in subsequent cases (Yin, 2003).To be precise, data analysis followed several stages based on the coding paradigm proposed by Strauss and Corbin (1998) using open, axial and selective coding to ensure conceptual development and density. The core idea of using this coding paradigm is to draw a connection between the raw text and the research objectives in a structured manner (Binder and Edwards, 2010).

In the open coding phase, these data were coded, analysed and conceptualised. Codes with the same meaning were subsequently grouped into concepts. Then, these concepts were grouped into subcategories and more abstract initial (tentative) conceptual categories. In the axial coding phase, the subcategories and categories that resulted from the open coding of the data were interconnected. In the selective coding phase, we identified the central category: the adoption process of LM. The categories and subcategories were refined and interconnected in order to build a theoretical framework. The results from these three stages were constantly compared, since they are mutually interdependent and iterative. The process ended when theoretical saturation was achieved.

The concepts, subcategories and categories were conceptually linked by the use of concept maps (Novak, 2010). The use of this visual representation tool is extremely effective for progressively developing these interrelationships (Miles and Huberman, 1994; Maxwell, 2005).

To ensure the consistency of the findings, the authors of the study then analysed the data separately and subsequently held several meetings to compare the results. Furthermore, some details were also confirmed by respondents after the interview (e.g. telephone conversations were held with managers to clarify some issues), which helped to control the construct validity of the research. The manual analysis of transcripts was complemented by use of a qualitative research software package. Table 2.2 summarises the methodology used in this research.

**Table 2.2**
Summary of methodology used

| | |
|---|---|
| **Research Question** | – Why and how do firms adopt Lean Management? |
| **Research Design** | – Qualitative methodology. Multi-case study. Exploratory. |
| **Case Selection** | |
| • Unit of Analysis | – Productive plant. |
| • Cases | – Theoretical sampling (literal replication). 5 plants in the Andalusian aerospace sector. Final assembly lines and prime contractors that have adopted LM and have made advances in its implementation over a minimum period of 3 years. |
| **Data Collection** | |
| • Protocol | – Design of data collection instruments, procedures and general rules.<br>– Pre-test and pilot study. |
| • Information Sources | – Primary sources of evidence: In-depth semi-structured interviews, surveys, plant visits/factory tours and, in some cases, managers' statements and conversations with blue-collar workers.<br>– Secondary sources of evidence: Company documentation, company websites and similar sources. |
| • Key Respondents | – All Cases: Plant Manager and Plant Lean Leader.<br>– Other Cases: Corporate Lean Leader and Plant Lean Experts.<br>– Total number: 12 managers. |
| • Data Collection Period | – October, 2010 – March, 2011. |
| **Data Analysis** | – Within and Cross-Case. Open, axial and selective coding. Atlas.ti software. |

## 2.4. Research Findings

Each of the factors identified is illustrated with a quotation from the interviews. Table 2.3 gives the explanations of the key concepts that we have identified regarding the factors found. These factors have been classified into three major categories: (a) trigger factors, (b) success factors, and (c) control factors.

*a) Trigger factors*

In the majority of the plants analysed, the interviewees stated that the decision to adopt LM was taken in response to a series of external or environmental factors. To be specific, they mentioned as key determinants of LM the pressure and growing demands from their customers.

> “Customers are a pull factor (…) In our plant we also had a production area where the customer demanded we got up to speed in LM… the customers required us to set the bar increasingly higher for a number of objectives, basically, cost reductions, improved delivery times, and quality KPIs. And that’s when we decided to adopt LM”. Plant Manager (P3).

Another external factor that was identified as leading to adopting LM was the rivalry among existing competitors.

> “We have more and more external competition, that’s obvious. We can see the need for change. So, it’s obvious, that’s why we’ve got to get better and be more cost-effective and adopt LM”. Lean Manager (P5).

The last external factor that was identified was the threat of new competition in the sector.

> “… What’s more, you can see there’s going to be… in a few years time, the situation’s going to change completely. Companies are going to come in from outside and so there is a need to adopt LM”. Lean Manager (P5).

These external factors led to LM being adopted in the production plants analysed in two ways. First, in three of the plants, internal motivation within the plant came first. However, we identified that internal motivation was sponsored and coincided in time with the need to change the management system (LM) in all plants in the group first being advanced at corporate level. In this respect, plant motivation resulted in pilot projects focusing on improvement initiatives through the implementation of targeted LM tools.

> "The first thing that motivated us to adopt LM was the will to improve, on the plant level. The feeling came up among the management that we had to improve using some structured strategy and we got wind of LM. That was really our starting-point… However, the adoption of LM at plant level was a kind of experiment that we ran in three plants and focused on improvement initiatives". Plant Manager (P3).

> "When we decided to adopt LM at plant level they were already pushing the need to change our management system at corporate level". Plant Manager (P5).

The second way, in the other two plants, came directly from the strategic decision to adopt LM on the corporate level.

> "The motivation behind our adopting LM came from a decision on the group level". Plant Manager (P2).

What is true is that the strategic decision to adopt LM on the corporate level had important repercussions for adopting LM at all the plants as it gave the initiative a strategic vision.

> "With the Lean adoption initiative on the division level, you set out to provide a conceptual model for the organisation of LM, the LM department is then created – we hadn't had one up to then (…) During the first years of adoption it was a kind of experiment that we were running on the plant level and basing ourselves purely on improvement. But when the initiative got backing at division level, that's when we began to structure it, and now we're talking about something different to what we had initially

been thinking about, which was improving, what we proposed was a change to our management system”. Plant Manager (P3).

*b) Success factors*

We detected that a prior culture in the plant with deep roots in total quality acted as a catalyst for the LM adoption process.

“In the past in this plant there have always been lots of total quality-related improvement processes… I started an improvement team focused on continuous improvement and on the back of that it was the catalyst for adopting LM. That meant that when we adopted LM we already had a core group of people who were dedicated to it full time…, we already had continuous improvement teams out there all in line with a vision that we generated at that time”. Plant Manager (P5).

In all the cases that were analysed, the interviewees stated that the commitment and leadership of top management were factors of vital importance for LM adoption.

“When it was adopted here, it was because the new Plant Manager was convinced that it was the way to go”. Lean Manager (P5). “The commitment of the top managers is fundamental. You either go for it and show that you’re really convinced or no one’s going to change the way they behave… And if the top managers don’t support it and don’t show they support it day-in, day-out, nothing changes; it’s no good for anything”. Plant Manager (P5).

Another factor identified as influencing adoption was the setting up of a Lean organisational structure.

“If you haven’t got the resources, you can’t get LM to work. Several of us heads here at the plant had practically been making these changes part time previously… and we used some of our own time for it, too; but it’s really obvious that an initiative like LM is only possible if you’ve got resources 100% set aside for it. So, creating a Lean organisational structure has been one of the success stories in its adoption”. Plant Manager (P4).

The role of the Lean leader was also identified as one of the factors for a successful adoption.

"The people in charge of LM at every plant have played a major role in LM adoption. For me it's one of the factors that has most driven the change". Lean Manager (P2).

Another factor that was identified was institutional support from the Public Administration.

"The facilities are new and we got support from the Public Administration. This allowed us to make a layout oriented towards Lean. We had a blank sheet to work on during the design stage and that let us design the layout for Lean. In the old facility we were pretty restricted when it came to reconfiguring the processes and creating flow". Lean Manager (P4).

"The Public Administration is backing our activity heavily. In fact, when we came to these new facilities we got support, you know, with the industrial land, etc., for industrial development. And we also changed the layout as we were already thinking in a more Lean way". Lean Manager (P2).

*c) Control factors*

Apart from the trigger factors and the factors that were found to impact on the success of LM adoption, we also identified a number of factors that companies have had to control during the adoption phase. The first control factor identified is linked with unionisation.

"There's a really important factor and that's social representation. In fact, we've been doing the whole implementation in close association with social representation right from the outset (…) Then we set up a number of committees to carry out this whole LM implementation process. They're joint committees, between social representation and the management, to do things in a harmonious and agreed way. In fact, it was the Chairman of the Works Committee who kicked the presentation on Lean Management off to the workers and I was the one who finished it, at the same meeting, the both of us together. The force of that is really tremendous!". Plant Manager (P3).

The second control factor that was identified was people's initial resistance and scepticism and this was stated in all the cases under study.

"At the beginning people think that LM is just a fad, something new you want to implement, and the same thing as always will happen, you've wanted to implement something and it'll go out of fashion. At the beginning, there's this bemusement, resistance and scepticism". Lean Manager (P2).

**2.5. Discussion**

A model can be deduced from the analysis that includes all the factors that were identified and their respective interrelationships. As can be seen in the model, all the factors that were identified can interact with each other and at the same time with the decision to adopt LM. This model is shown in Table 2.3 and Figure 2.1, both of which classify the various concepts identified for the three major factors.

*a) Trigger factors*

We have identified three external factors that acted as triggers for the adoption of LM: the bargaining power of customers, the competitive rivalry within the aerospace sector and the threat of new entrants. Increasing customer demands, mainly for improved delivery times, delivery reliability, quality key performance indicators and reduced costs were important triggers for adopting LM. Likewise, pressure and requirements from customers to adopt LM were crucial trigger factors. We also identified that the increasing competition in the sector and the threat of new competitors from emerging countries were triggers for adoption.

These external factors led to LM being adopted in the plants in two ways: in the manufacturing plant and through corporate motivation.

First, in three of the plants, internal motivation to adopt LM came from the top managers of the plants in pursuit of a series of competitive priorities, mainly: improved efficiency, delivery times, delivery reliability, quality and usage of plant capacity, increased profits for both company and customers, higher productivity, more motivated and engaged plant personnel, and reductions in costs and inventory levels. However, the motivation for the adoption of LM at plant level resulted in partial and isolated improvement Lean tools-linked initiatives.

In the other two plants, motivation came about as a direct result of the strategic decision to adopt LM on the corporate level (Table 2.1). However, the strategic decision to adopt LM on the corporate level had important repercussions for the adoption of LM at all the plants. Thus, plants that adopted LM through internal motivation have changed their initial concept of LM focused on isolated improvement initiatives to one of a more strategic vision. Apart from above-mentioned pursuit of competitive priorities, the company also sought to change the corporation business model with the corporation strategic initiative. To this end, the corporation first carried out an initial Lean assessment in all plants and developed a common LM adoption strategy in the plants, not only in manufacturing but also in other organisation areas (e.g. Lean procurement and design). The adoption process was provided with a Lean organisational structure formed by a Lean leader on the corporate level, a LM department on the corporate level and at each of the plants and, specific human resources for the LM adoption process (Lean leaders, Lean experts, change agents and team leaders) and, in some cases, the change of plant CEO.

*b) Success factors*

The first success factor was a deep-rooted culture of total quality. The initiative to implement a total quality initiative came from the top manager at the plant. Thus, a cause-effect relationship was identified between the role of top management as a driver of the total quality initiative and this preceding deep-rooted culture. This pre-existing culture meant there could be a critical mass of people with organisational culture for improvement, a higher degree of teamwork maturity and multifunctional integration as facilitators for LM adoption.

The top management role was another important factor in the success of LM adoption. The commitment and leadership of top management were catalysts for LM adoption and of vital importance in the adoption process, setting an example to the rest of the organisation and spreading a Lean culture in the organisation.

Another crucial factor was the setting up of a Lean organisational structure that was closely linked to the initiative on the corporate level. The Lean organisational structure acted as a driver of success in the adoption process, since it enabled human resources to be involved in the initiative full time.

The setting up of a Lean organisational structure converged in time with the creation of the figure of Lean leader; therefore, this relationship is shown with a double-headed arrow in Figure 2.1. The role of the Lean leader in the adoption of LM was one of the factors that most drove the process, convincing the rest of the organisation of the need for change and of the benefits of LM adoption.

Finally, institutional support was an important factor for LM adoption, since the support of the public administration facilitated modernisation of the sector (including suppliers) and the overcoming of prior structural inertia. Institutional support for the siting of new facilities acted as a facilitator for the adoption of new management systems, enabling layout reconfiguration and the elimination of inefficiencies and wastage in the plant design phase.

*c) Control factors*

The first control factor is unionisation. This factor had to be addressed by the top management before beginning LM adoption. Top management established joint management-social representation committees in order to modify historical-social aspects that might hinder the adoption process and achieve agreements with unions on LM adoption. We, therefore, detected a cause-effect relationship between the top management role and unionisation.

The second control factor is people's initial scepticism and resistance. The initial thinking that LM is just another fad or fashion cannot be applied to the aerospace sector; the link to other previous initiatives that failed and the lack of confidence in the management's track record were the main aspects associated with this factor. These were overcome by the leadership and commitment of the top management and the Lean leader. Both top management and Lean leaders altered their roles, increasing communication, transparency and contact with the staff. Training programs were also carried out directed at changing people's mentalities and overcoming their initial resistance and scepticism. We, therefore, identified a cause-effect relationship between the role played by top management, the plant's Lean leader and the control of unionisation and this factor.

Figure 2.1 has three distinct parts. In the first part, at the top of the figure, we can see the trigger factors for the adoption of LM. In the middle are the factors that play an important role in the success of the adoption process. Finally, in the bottom half of the figure are the control factors that were identified. In Table 2.3, we have also included the key determinants of LM adoption and the associated key concepts.

**Table 2.3**
Factors linked to Lean Management adoption

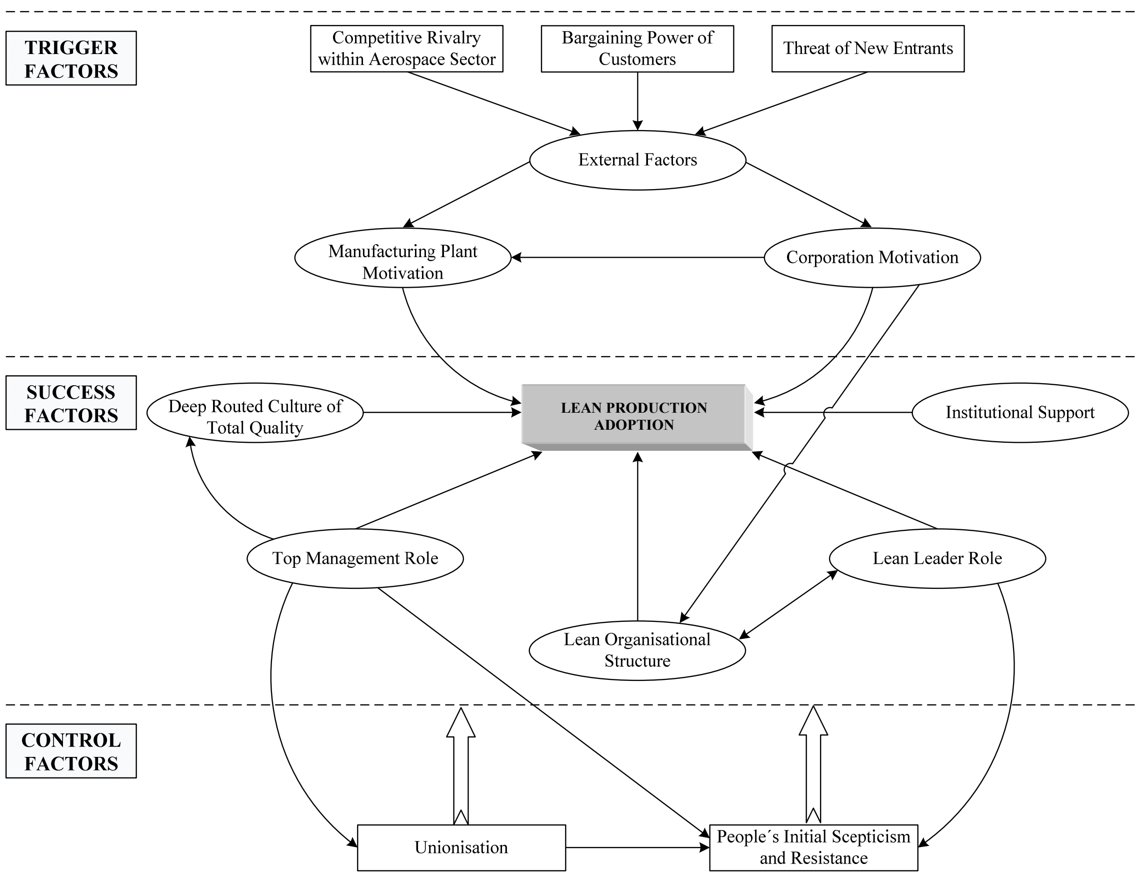
| Key Determinants of LM Adoption | Key Concepts |
|---|---|
| **a) Trigger Factors** | |
| **External Factors** | |
| Bargaining Power of Customers | • Increased customers' demands for LM adoption.<br>• Customers pressuring for LM adoption. |
| Competitive Rivalry within Aerospace Sector | • Increased competition in aerospace sector. |
| Threat of New Entrants | • Future threat of new competitors from emerging countries. |
| **LM Adoption Motivation Level** | |
| Manufacturing Plant Motivation | • Decision by plant top management to adopt LM.<br>• Experience of plant manager in implementing LM in the global aerospace sector.<br>• Reasons: need for improvement and to achieve a series of competitive priorities. |

**Table 2.3 (Continuation)**

Factors linked to Lean Management adoption

| Key Determinants of LM Adoption | Key Concepts |
|---|---|
| **LM Adoption Motivation Level** | |
| Corporation Motivation | • LM adopted in plant due to decision to adopt on corporate level.<br>• Over time, the initiative to adopt LM on the company level in all plants.<br>• Provision of Lean organisational structure.<br>• In some cases, change of plant CEO (P2), and contracting of personnel (Lean Leaders, Lean Experts, Change Agents) experts in implementing LM in the automotive sector. |
| **b) Success Factors** | |
| **Deep-Rooted Culture of Total Quality** | • Prior initiative by Plant Manager to adopt total quality initiatives as catalyst for LM adoption.<br>• Critical mass of people with organisational culture for quality. |
| **Top Management Role** | • Full commitment and leadership of top management as catalyst for Lean Management adoption.<br>• Leadership and engagement of top management in the adoption process. |
| **Lean Organisational Structure** | • Creation of Lean organisational structure and having full time resources involved in the initiative acted as a factor for success in LM adoption. |
| **Lean Leader Role** | • Role of Lean Leader as one of the factors that has most driven the change, convincing the rest of the organisation of the need for change and of the benefits of LM adoption. |
| **Institutional Support** | • Support from public administration for siting of new facilities.<br>• Industrial development of sector as a whole (including suppliers) as a facilitating factor for overcoming inertia. |
| **c) Control Factors** | |
| **Unionisation** | • Need to control unionisation before adoption of LM is initiated.<br>• Creation of joint management-social representation committees prior to LM adoption. |
| **People's Initial Scepticism and Resistance** | • Role of top management and Lean Leader in convincing rest of organisation of need for change and of benefits of LM.<br>• Change in role of top management.<br>• Training programmes directed at overcoming initial resistance and scepticism. |

**Figure 2.1**
LM adoption model




## 2.6. Conclusion

Our aim with this research is to contribute to prior research on the key factors for LM adoption. For this, we conducted a case study in five aerospace prime contractors that have spent several years implementing LM with excellent results. Thus, LM adoption factors found have special relevance to academic research and for managers involved in the LM adoption process.

Our results identify three major factors that play a key role in the LM adoption process.

First, with respect to trigger factors, we have identified three of Porter's (1980) five competitive forces that have led to the adoption of LM. Nevertheless, we found a greater consensus among respondents that adoption was triggered by an increase in customer demands and pressure to adopt LM. We also identified the search for a series of competitive priorities ratifying and broadening those found in the literature as triggers of LM adoption (James-Moore and Gibbons, 1997; Crute et al., 2003).

Moreover, our findings show that the successful adoption of LM requires a holistic and strategic vision instead of an adoption focused on specific improvement initiatives (Hines et al., 2008).

Second, in relation to success factors, we have identified five factors that play a major role in the LM adoption process. The first factor was a deep-rooted culture of total quality, corroborating the previous results obtained by Yamamoto and Bellgran (2010). However, once companies had reached a high degree of maturity in total quality management they opted for adopting LM as a competitive strategy to drive up their competitive capacities. Another vitally important factor for LM adoption identified was the leadership and commitment of top management, corroborating previous findings (Sohal and Egglestone, 1994; Crute et al., 2003).

We detected two factors that facilitate the adoption of LM that have received less attention in the literature. To be specific, the creation of a Lean organisational structure and the figure of Lean leader that were drivers of LM adoption.

We also detected another factor that has received little attention in previous research: institutional support. Support from the public administration gave the sector a boost and accelerated its industrial development and modernisation. This was seen to be an important facilitator for overcoming inertia and for adopting new management systems such as LM (Sousa and Voss, 2008).

Finally, regarding control factors, we have found two factors that companies controlled before adoption. The first was unionisation, which was managed by top management and social representation. This finding sheds light on the role played by unionisation in LM adoption in prior research, which did not show any conclusive evidence (Kochan et al., 1997; Shah and Ward, 2003). In this regard, we found that the management of unionisation before commencing adoption is a prerequisite for guaranteeing that LM is adopted successfully.

The second control factor was people's initial scepticism and resistance. Our findings complement the results of other studies that highlight the importance of the initial role played by people in the transition to LM (e.g., Smith and Tranfield, 2005; Hodge et al., 2011). The companies managed this factor mainly through the role played by top management and the Lean leader in convincing the rest of the organisation of the need for change and the benefits derived from LM. The control of unionisation also had an effect on the ability to overcome initial resistance and scepticism.

### 2.7. Managerial Implications and Future Research

The development of effective strategies for successfully implementing LM remains a priority for companies in a range of industrial and service sectors that are considering adopting this management system. In this respect, in the following we offer a series of implications that might be useful for managers responsible for the LM adoption process. These implications could provide a potential guide for managers for identifying and managing successfully the challenges of this early stage of LM implementation.

First, companies with a prior total quality culture that wish to augment their competitive capacities have great drive that might facilitate their LM adoption process. Second, company top managers who are proposing to adopt LM must from the outset demonstrate their leadership and full commitment to the initiative. This is absolutely essential if the adoption is to be successful. As a mechanism for ensured success, companies that embark on a LM initiative can accelerate the adoption process by creating a Lean organisational structure or, at least, by having a series of people like Lean leaders at their disposal who are devoted full time to the adoption process and its structuring and deployment.

We suggest that public administrations wishing to increase the competitiveness of a strategic industrial sector adopt industrial policies that help to overcome prior structural inertia, since these policies may be important facilitators for the adoption of new management systems like LM.

Before initiating the LM adoption process, companies should also attend to a series of factors, which, if not appropriately managed, could hinder or curb the adoption process. In this respect, we especially highlight achieving joint and agreed negotiation with unionisation as a prerequisite for LM adoption. Similarly, we issue a call to managers who decide to adopt LM to pay special attention to initial scepticism and resistance and to use a variety of mechanisms to overcome these and ensure the success of adoption, as without the engagement and commitment of the whole organisation to LM, the initiative is doomed to failure.

Our study is not without limitations. First, it is an observational approach and, therefore, the generalisation of our findings is limited. Second, this research has been carried out in the aerospace sector, which is a limitation on the results being extended to other sectors. Moreover, we have analysed only one level of the aerospace supply chain, specifically, the prime contractors. However, there is no reason for us to believe that the factors found may not be applicable on other levels or in other contexts. Third, we have also managed to identify a series of interrelationships among the factors found, but it has not been possible to measure their intensity. Moreover, we cannot measure the correlation of the factors identified on an independent metric of Lean success through case study research. However, operational results were improved after LM adoption in all cases. In this respect, we asked companies about the evolution of operational KPIs (safety, quality, cost and delivery) derived from Lean in the semi-structured interviews and we measured these KPIs quantitatively in the surveys (variation in percentage after LM adoption). Finally, the model has been devised in a particular geographical context. It is worth noting that the model developed is a proposition, since our study is exploratory and we cannot measure the relationships between the factors detected through the methodology used.

These limitations do open up interesting avenues for further research. Suggested future research would, therefore, be the validation of the model in other industrial and geographical contexts, according to replication logic (Yin, 2003). It would also be appropriate to examine whether this LM adoption model could be applicable or should be adapted to other levels of the aerospace supply chain, for example, to aerospace Tier 1 suppliers. Further research is also proposed to assess the intensity of the interrelationships among the factors that were identified and the impact of these factors on operational and financial indicators of Lean success. Finally, it would be advisable to combine qualitative and quantitative methodologies to solve the issues by enlarging on the above results. Specifically, we suggest using structural equation modelling and/or system dynamic simulation to validate the proposed relationships.

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# CHANGES IN HUMAN RESOURCE MANAGEMENT IN THE TRANSITION TO LEAN MANAGEMENT

# III

## 3.1. Introduction

Lean Management (LM) has been adopted by companies in various economic industries in recent decades and these companies have subsequently gone on to make advances in its implementation. In many cases this has enabled them to improve their results and competitiveness (Hines et al., 2004). However, empirical evidence shows that the transition to LM is a complex task that generally runs up against a large number of obstacles (Scherrer-Rathje et al., 2009).

LM adoption entails significant organizational change which requires companies to properly manage the key factors that impact on the success of the adoption process. Although the literature highlights the crucial role of people (e.g., Sawhney and Chason, 2005; de Treville and Antonakis, 2006; de Menezes et al., 2010), there is a lack of studies that examine the changes that take place in Human Resource (HR) management during the adoption process (Needy et al., 2002).

Despite LM involving significant changes in HR practices (Biazzo and Panizzolo, 2000), the role of people during the LM implementation process has not been sufficiently analyzed either (Bonavía and Marín-García, 2011), and there is no consensus in the literature on the way that LM might affect people (Conti et al., 2006; de Treville and Antonakis, 2006), or the role of HR practices during the LM implementation process (Liker and Hoseus, 2010; Bonavía and Marín-García, 2011).

This is a widespread issue within Operations Management research, resulting in more studies focused on technical aspects than on human and organizational behavioral issues (Boyer et al., 2005). Consequently, it is important to deal in depth with the role that people play during the different phases of the transition process to LM, which includes both LM adoption and implementation. Therefore, our main research question is: *How do companies successfully manage HR during the transition process to LM?* We intend to achieve different aims:

1) To identify the HR explanatory success factors during the different phases of the transition process to LM.
2) To group the explanatory success factors associated with HR management into main factors linked to human resource management during each of the transition process phases to LM.
3) To include these main factors and the relationships between them in a theoretical model in order to gain a better understanding of the cultural change linked to LM transformation.

This chapter has been structured in six sections, beginning with this introduction. The second section deals with the background of this research. The third section describes the methodology used. The research findings are set out in the fourth section. After that, we present the discussion of the results and the conclusions. Lastly, we present the implications for management and the challenges that future research will have to address.

## 3.2. Literature Review

### 3.2.1. Lean Management

LM is a direct descendant of the Toyota Production System and has been evolving over a long period of time and will continue to do so in the future (Hines et al., 2004; Moyano-Fuentes and Sacristán-Díaz, 2012). LM is an integrated socio-technical system with the main objective of achieving maximum efficiency by carrying out operations at a minimum cost and with zero wastage. For this, the variability of the whole system needs to be minimised (de Treville and Antonakis, 2006; Shah and Ward, 2007). When they embrace LM, companies adopt a management philosophy based on continuous improvement which involves all levels of the organization and provides an opportunity to improve results (Womack and Jones, 1996).

LM has spread to companies in diverse industries with different results (Moyano-Fuentes and Sacristán-Díaz, 2012). Although numerous companies have successfully advanced in the LM transformation, others have not achieved the results that they anticipated, and failed transitions are common (Staats et al., 2011), as is the inability to maintain results over the medium and long term (Lucey et al., 2005).

The transformation to LM is, therefore, a complex task with a number of obstacles that make its transition process difficult (Scherrer-Rathje et al., 2009). Prior research has identified a series of factors that facilitate the LM adoption and implementation processes and there is a broad consensus that HR and cultural change are critical factors for the success of Lean initiatives (Emiliani, 2006) and their sustainability over time (Bateman, 2005).

Literature points to the success of Lean transformation not only depending on the application of tools and techniques (*hard side*) but also the appropriate management of the human factor and the establishment of a culture that sustains the Lean transformation (*soft side*). Success depends on the application of both of these simultaneously and systematically (Liker and Hoseus, 2010; Badurdeen et al., 2011).

### 3.2.2. Lean Management and HR Management

Literature that links LM and HR management has focused on describing the HR practices associated with LM (e.g., Forza, 1996; Niepce and Molleman, 1996; Pil and MacDuffie, 1996; Biazzo and Panizzolo, 2000; Olivella et al., 2008), the impact that LM implementation has on people (e.g., Forrester, 1995; Niepce and Molleman, 1996; Conti et al., 2006; de Treville and Antonakis, 2006) and the influence that LM-associated HR practices have on performance (e.g., Shah and Ward, 2003; Bonavía and Marín-García, 2011).

However, despite the importance of managing HR for LM, a greater emphasis can be seen in the literature on technical aspects than on the roles of people and cultural change in the transition process to LM. Thus, while a range of studies have analyzed the general success factors in LM adoption and implementation (e.g., Worley and Doolen, 2006; Turesky and Connell, 2010; Pedersen and Huniche, 2011), there are few that analyze the success factors of HR management in detail.

There is no consensus on what the main success factors are in these studies, although certain factors are suggested by different authors. Olivella et al. (2008) identify LM-oriented work organization strategies, including standardization, ongoing training, teamwork, participation and empowerment, versatility, commitment to company values, and contingent rewards. Meanwhile Bonavía and Marín-García (2011) point to LM-oriented companies promoting flexibility and versatility, investing in training and committing to contingent compensation. The literature on high performance work practices (e.g., Huselid, 1995; MacDuffie, 1995; Delaney and Huselid, 1996; Pil and MacDuffie, 1996) identifies HR factors that fit in well with LM, including teamwork, job rotation, ongoing training, contingent rewards, job security, empowerment, versatility and suggestion programs.

Most studies consider the transition process to LM as a whole and assume that the role played by people is uniform with no difference between the adoption and implementation phases. LM adoption entails significant organizational change which means that companies should manage the role of HR appropriately (Sawhney and Chason, 2005; de Treville and

Antonakis, 2006). LM is especially complex due to the high degree of worker involvement required to organize the work (Pil and MacDuffie, 1996). In addition, cultural change and management support are two of the greatest challenges to LM being accepted by personnel (Sawhney and Chason, 2005; Beauvallet and Houy, 2010) and might slow the adoption process down (Emiliani, 2006). With regard to the LM implementation phase, recent studies show that there has been insufficient research done into the human aspect (Angelis et al., 2011; Bonavía and Marín-García, 2011). Although LM entails HR practices being reconfigured (Forza, 1996; Biazzo and Panizzolo, 2000) there is no consensus with regard to the way that LM could affect personnel (Conti et al., 2006; de Treville and Antonakis, 2006) or to the role that HR practices play during the process (Liker and Hoseus, 2010; Bonavía and Marín-García, 2011) or, more specifically, to the role that they play during the process for personnel adapting to LM.

## 3.3. Research Methodology

### 3.3.1. Research Design, Case Selection and Data Collection

LM adoption and implementation in a range of industrial sectors, such as the aerospace sector, is an emerging research area, which means that case study is a suitable research method. Our study is exploratory because there is little empirical evidence of the role of HR in the transition process to LM, and even less differentiating among its different phases. According to Yin (2003), case study research is a more appropriate approach than other strategies for exploring “why” and “how” questions. Therefore, we consider case study research is suitable for answering how companies successfully manage HR during the LM adoption and implementation processes.

A multi-case method is used to explore these issues and build theory since it is appropriate for observing and describing a complex research phenomenon (Meredith, 1998; Eisenhardt and Graebner, 2007). This reinforces internal validity and enables the findings to be replicated, thus increasing the external validity of the research (Eisenhardt, 1989), guarding against observer bias (Handfield and Melnyk, 1998), aiding triangulation (Voss et al., 2002), improving the generality of findings (Yin, 2003) and making the overall research more robust (Herriot and Firestone, 1983).

A theoretical sampling model was used (Eisenhardt, 1989; Yin, 2003) with companies selected that provided an optimum "chance to learn" (Stake, 1995). Using the "*Fundación Hélice"* (a member of the *European Aviation Clusters Partnership*) company database, we selected production plants that belonged to the prime contractors in the Spanish aerospace sector. A total of five plants were selected: two are final aircraft assembly lines (FAL) whilst the others are prime contractors devoted to manufacturing and assembling parts, subassemblies and large aerostructures, primarily for the FALs. All the plants are members of the *European Aeronautic Defence and Space Company* consortium (EADS).

Before beginning the field work, a case study protocol was designed. This was updated and improved with each visit that took place (de Weerd-Nederhof, 2001), affording the research greater reliability (Yin, 2003). A tentative semi-structured interview guide was developed based on a review of the literature on LM in general, and on LM in the aerospace sector in particular. Before beginning the field work, a preliminary version of the interview guide was tested with two researchers in Operations Management and two experienced experts in the aerospace sector. We also conducted a pilot study in a manufacturing plant. Both primary and secondary information sources were used in order to triangulate the data (Easterby-Smith et al., 2002). The primary sources used were: in-depth semi-structured interviews, surveys, plant visits/factory tours and, in some cases, statements made by the management. The secondary sources used were: company documentation, company websites and similar sources.

Various respondents were interviewed in all cases to ensure construct validity. In some plants a number of blue-collar workers were also interviewed about the changes that people had experienced during the transition to LM. We also used multiple interviewers with one of the team researchers always being involved in all of the interviews.

### 3.3.2. Data Analysis

Both within-case and cross-case analysis was conducted (Miles and Huberman, 1994). The internal and external validity of the research was controlled by confirming the findings of each case in subsequent cases. Thus, triangulation has been sought both within cases and across cases (Yin, 2003).

To be precise, the coding paradigm proposed by Strauss and Corbin (1998) was used to analyze the data. Open, axial, and selective coding was used to ensure development and conceptual density. In the open coding phase, data were coded, analysed and conceptualised. Codes with the same meaning were subsequently grouped into concepts. Then, these concepts were grouped into tentative subcategories and categories. In the axial coding phase, relations between subcategories and categories were identified. For this, we used the "paradigm" analytic tool in order to integrate structure with process (Strauss y Corbin, 1998; pp. 127). Specifically, the global process is the HR management during the transition to LM, the sequences of action/interaction (subprocesses) are the several key factors managed according the structure or conditions (different phases of the LM transition process). In this way, subcategories and categories (key factors) were simultaneously interconnected with each of the four phases identified.

In the selective coding phase, we identified the central category: the adoption process of LM. The categories and subcategories were refined and interconnected in order to build a theoretical framework. Thus, this process allowed us to identify how the subcategories were related to the categories. The results from these three stages were constantly compared, since they are mutually interdependent and iterative. The process ended when theoretical saturation was achieved.

Furthermore, some details were also confirmed with the interviewees at a later date (by telephone or email), which helped to control construct validity. The manual analysis of the data was complemented by use of a qualitative research software package (Atlas.ti).

### 3.4. Research Findings

Our analysis identified four phases closely linked to the role of HR in the transition process to LM: 1) Management of the labor relations framework prior to LM adoption; 2) LM adoption in pilot areas; 3) LM adoption deployed throughout the whole plant; and 4) LM implementation. Within each phase we found various explanatory success factors that, in the case of the adoption and implementation phases (phase 2, 3 and 4), were grouped into five main factors: training, communication, rewards, job design, and work organization. Table 3.1 shows the main factors, the explanatory success factors and the key concepts that have been identified. All the explanatory factors are illustrated with one or more quotations from the interviews, providing examples of coded text that support their validity.

Figures 3.1, 3.2 and 3.3 also show a graphic model that includes the relationships between the main factors and the explanatory success factors of HR adaptation during each of the phases of the transition process to LM.

**Table 3.1**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 1. Management of the labor relations framework prior to LM adoption** | | |
| **Role of Trade Unions** | | |
| Forming of Joint Management-Social Representation Committees | Preparing the ground, joint negotiation with Unions prior to LM adoption.<br>Need to control the role of the Unions before initiating LM adoption, to modify past social aspects to the benefit of adoption and to achieve agreements on Lean adoption and implementation. | "When we decided to adopt Lean, one of the really essential things was to pave the way for it, to do the groundwork, and that was all linked to the social agents modifying certain aspects that were in place here in an organized way but which didn't go with the new philosophy (…) One of the key things at the very beginning was the agreements with the Unions which were set out in the labor agreement on those things we had to organize from the bottom up." (Lean Manager, P4). |
| **Phase 2. LM adoption in pilot areas** | | |
| **Objectives:** to ensure adoption is successful in the area, to focus resources, motivate people in the area, and in the organization after success achieved, to learn from the experience in the initiative, standardize it, improve it, to serve as an example and to achieve a knock-on effect in other areas and spread it to the rest of the plant. | | |
| Initial factor: operators' initial attitude of skepticism and resistance towards LM | Initial belief that Lean is just another passing fad, that it cannot be applied to the aerospace sector, linking it to previous failed initiatives and distrust due to past role of management. | "At the beginning there was resistance, it's normal, it's logical, it's human to come across resistance to change, skepticism... and at the beginning they think it's just another fad." (Plant M., P3). |
| **Training** | | |
| More philosophical, aimed at changing the mindsets of a critical mass of people | Training programs, initially in pilot areas and subsequently in deployment areas. Training focused on changing the mindset of a critical mass in the organization to facilitate change. | "Training was essential. What's more, the first training we did was designed to change people's mindsets…, the first thing you have to do is change the mentality of a critical mass of people in the organization. I think it was essential that the first training program wasn't designed to give them tools, but to change the way they thought. It was fundamental." (Plant M., P5). |
| Aimed at practice, focused on simpler and easily applied tools | More practical training, methodology applied to LM (*on-the-job training*), focused on simple and easily applied tools. | "There's been more practical training in the sense that it was aimed at pointing the workers straight in the direction of the concept, with no unnecessary frills and theory, quite hands-on and easily understandable stuff, and we got really good results with that type of training." (Lean Expert, P5). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| | **Phase 2. LM adoption in pilot areas (Continued)** | |
| **Communication** | | |
| Changes in the roles of top and middle management (greater accountability, transparency and contact) | Change in management behavior: communication, transparency and contact with the shop floor, less information flow stagnation and continuous management support along with greater accountability to workers. | "The management began to have a lot more contact with the plant, meetings right on the shop floor, and it hadn't been like that before, we started having a lot more contact with the shop floor…, before the management used to be a lot more hermetic, for a long time before" (Lean Manager, P2). "There's been a complete change in the way the management behaves… communication, transparency and contact, I think those are the three things that sum up the change there's been." (Plant M., P2). |
| Top-down persuasion | Management presentation of Lean Objectives, top-down mind-set change. | "The first move to get involved has to come from the management. Then the management set out the objectives to the pilot teams and then the work team worked hard to achieve those Objectives." (D. Plant, P3). "Bit by bit we changed our mentality from the top to the bottom." (Plant M., P5). |
| Content focused on need for change and benefits of Lean | Meetings focusing on need for Lean adoption and its benefits, not only for the company but stressing direct worker benefits. | "The workers didn't trust Lean, but we got over that by having meetings where we explained to them that Lean means making savings, increasing efficiency and not only for the company, but it makes their job better." (Plant M., P1). |
| Visibility of improvements to rest of plant | Communication to other plant sections of advantages gained in pilot area, motivation of people in pilot area, serving as an example to other areas of the organization, achieving a knock-on effect in other areas of the plant. | "The reason why the first Lean tools were put in place (5S, VSM and Visual Management) in a pilot area was to make the improvements much easier for the rest of the plant to see, so it was an example, getting to learn by experience and creating a knock-on effect for the other areas and motivating the rest of the plant personnel." (Corporate Lean Manager). |
| **Recognition** | | |
| Non monetary (consideration/study and implementation of workers' proposals by management) | Taking workers' opinions and proposals into account, valuing their proposals to motivate them, implementing proposals or, should they not be applicable, explaining why. | "When we first adopted Lean we asked all the workers to work with us to see what could be improved and we listened to what they said. But it wasn't easy because before that we (the Management) didn't use to pay them any attention, and they didn't trust us… but now we've changed and we think about what they say because their opinions count." (Plant M., P1). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 2. LM adoption in pilot areas (Continued)** | | |
| **Job design** | | |
| Physical changes caused by applying accessible and easily-understood Lean tools that are useful and provide the worker with immediate positive results (VSM, 5S, Visual Management) | Initially, tools that workers can easily access and understand, such as 5S, VSM and visual management to improve the work environment and ergonomics, resulting in direct benefits to the worker. Objective: people see that there are direct and positive benefits for them (daily work made easier, improved ergonomics) and to their work environment. Spreads to other sections of the plant (contagion). | "We started off with 5 S and visual management in the pilot teams… we used 5 S with the workers to improve the work environment, the ergonomics, to make it better and pleasanter, and that ends up benefiting the worker (…) The seating, for instance, was designed to help people and cut out unnecessary movements." (Plant M., P1). |
| Work standardization | Importance of standardizing the work station as a cornerstone of Lean, through step-by-step standardization of work procedures, with the goal of reducing variability. Standardization by workers themselves: structured method and increased sense of ownership. | "Right from the beginning we tried to standardize work, that's one of the cornerstones of Lean." (Plant M., P1).<br>"At the kaizen events for standardizing the work station, the workers did it themselves, and if they do it, they don't only keep it like that…, what I mean is, right from the get-go they can do it well or badly, but it's them who do it, right? And they're the ones who do it on a daily basis and they're the ones who know all about the problems involved and the ins and outs of what they do down on the shop floor of theirs… and they say to you, I did it and I've sworn to look after it, and what's more, I'm happy because I know I've got rid of all the problems I used to have." (Lean M., P3). |
| **Work organization** | | |
| Forming of work teams with multifunctional support | Importance for creating first seeds of work team. First step: forming work teams with help of support departments (production, engineering, quality, maintenance, supply chain, etc.) to achieve objectives jointly. Do work by team and get workers used to working in this way. | "We've always taken different factors into account, right from the time the adoption started. One key factor is the work team, that is, the objectives we want to achieve, it's the team on the production line that achieves them (…) So a major concept is giving the production line back-up, getting the production line perfectly supported by the support departments… Then we create a team of people, both on the shop floor level, the operators I mean, and at the level of the people who were involved from the other departments (…) And that way when the first analyses were done of the value stream in a specific area, the work team with multifunctional support worked hard to achieve the targets that had been set." (Plant M., P3). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 3. Deployment of LM adoption to the whole plant** | | |
| Initial factor: operators' initial attitude of skepticism and resistance towards LM | Initial way of thinking is that Lean is just another passing fashion that cannot be applied to the aerospace sector and it is linked to earlier initiatives that failed, lack of trust in management due to their track record. | "We came up against some scepticism among some of the workers in the deployment phase because people like to have their shelves full to feel easy and when they see they're empty, they feel a bit uneasy and start to worry that they might be going to lose their jobs, I mean, comments that are quite..., when we walk past, because of that." (Lean Manager, P4). |
| **Training** | | |
| Training given by internal experts | First training session with external consultants. Subsequently, internal training after contracting experts in Lean implementation from other sectors (automobile) for it to be carried out in a deeper, strategic way and to achieve the greater engagement of people and cultural change. | "During the phase when the training was rolled out to the whole of the plant we decided not to bring in someone from outside like we did at the beginning but to do some internal training." (Corporate Lean M.).<br><br>"The Lean training was transmitted to the whole of the personnel through a Lean Academy set up on the corporate level." (Plant M., P2). |
| Specific by-level Lean training (Lean Leaders, Team Leader, Operators) | Training adjusted to different levels. Focused on the role that each member of the organization plays in the Lean environment. Training given to Lean Leaders Collective on how to engage personnel, recognizing the importance of workers' knowledge, intelligence and experience. Workers do not take on the job of Team Leader until they have received the proper training. | "During the second Training Phase, the training is total, what I mean is, when the Lean Training was rolled out to the personnel in all the plant, the training that was done, it wasn't just about Lean, but about what part, what roles all the workers would play in the Lean environment, and that was crucial." (Corporate Lean Manager).<br><br>"The training plans were deployed by level, in other words, there's specific Lean training for Team Leaders and for operators." (Plant M., P4). |
| More philosophy aimed at changing the mindsets of a critical mass or people | Training Programs in deployment areas. Training focused on changing the mindsets of a critical mass in the organization to facilitate change. | "When LM was being adopted there were special Lean training courses for all the plant to explain that there are improvement methodologies, like Lean, that have better results than other improvement initiatives, and we invested in Training courses to change people's mindsets." (Plant M., P1). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 3. Deployment of LM adoption to the whole plant (Continued)** | | |
| **Training** | | |
| Practice oriented, focused on simpler and easily applied tools | Training Programs in deployment areas. More practical training, methodology applied to LM (*on-the-job training*), visual training (*Model Factory*), focused on simple tools that can be applied easily. | "A Model Factory was set up during the training, here on the shop floor, using a hands-on game and everyone came through here so they could see what Lean was all about and see what the benefits were… It's an extremely visual game, you see, and we did it in the Lean discourse which is a bit like where you are surprised by how you can do something about the haphazardness of a process by applying Lean." (Plant M., P4). |
| **Communication** | | |
| Changes in the roles of top and middle management (greater accountability, transparency and contact) | Change in management behavior: communication, transparency and contact with shop floor, fewer delays in information flow and continuous management support along with greater accountability to workers. Importance of the management support as key factor for success in worker engagement and involvement. | "We gradually changed the mentality from the top downwards, but we couldn't go on to the next stage without having done it first for all the steps beforehand for the first plant level down to the following levels… and what we saw was that the role of the people in charge, well it's obviously something fundamental… At the beginning the personnel in the plant responded to the initiative in a lot of different ways… it really depended a lot on how they were led from above, it depends a lot on the quality and on how they've had it focused for them by the chain of command, that's basic." (Plant M., P5). |
| Top-down persuasion | Lean objectives presented by Management, top-down mindset change, involvement of all management levels. | "Another idea that was clear for us was that Lean is not a bottom up process, but top down. We worked hard on being the drivers of the need, I mean, transmitting to the rest of the organization that we were serious about it and that we were going forward with it, that it brings results and that the rest of the organization has to be involved in Lean." (Plant M., P3). |
| Content focused on need for change and benefits of Lean | Meetings focusing on the need for Lean adoption and its benefits not only for the company but putting special stress on direct benefits for the worker. | "The people, they think that Lean is just like everything else, that it's just another training course we're giving them, and that's it… So, if the people don't think that Lean is useful, then there's no reason for them… we upped the communication a lot, and we explained how Lean was useful and that Lean has some effects on them, too." (Plant M., P2). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 3. Deployment of LM adoption to the whole plant (Continued)** | | |
| **Recognition** | | |
| Non monetary (consideration/study and implementation of workers' proposals by management) | Workers' opinions and proposals taken into account, valuing of proposals to motivate workers, implementation of proposals and, if they are not applicable, expla-nation of the reasons why. | "Now the management takes the workers' suggestions into account and implements them… there's been a complete change in the way we behave… and that's the way you get people hooked, we're going to listen to their suggestions and implement them. That's good for getting new ideas, and that's the second phase of getting people on board." (Plant M., P1). |
| **Job design** | | |
| Physical changes caused by applying accessible and easily-understood Lean tools that are useful and provide the worker with immediate positive results (VSM, 5S, Visual Management) | Initial use of tools that are accessible to workers and easily understood, such as 5S, VSM and visual management to improve the work environment, and ergo-nomics, which have direct bene-fits for the worker.<br><br>Goal: people see that they have positive direct results that affect them (easier day-to-day work, better ergonomics) and their work environment. | "Lean won't succeed if people don't really see that it really does give results. Workers have got to see that right from the start. The people saw how the first tools (VSM, 5S and Visual Management) were helping them, making their day-to-day work easier… That's how you really get people hooked, when they really see it working. We got people on board because of facts, because of results." (Plant M., P3). |
| Work standardization | Importance of standardizing the work station as one of the mainstays of Lean, through standardizing work procedures step-by-step in order to reduce variability. Standardization by the workers themselves: structured method and increased feeling of ownership. | "One of the fundamental tools at the beginning was standardizing work, as it's what allows you to get the work process in order and get rid of more wastage." (Lean Manager, P2). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 3. Deployment of LM adoption to the whole plant (Continued)** | | |
| **Work organization** | | |
| Specific department created to take charge of Lean (with a Lean Manager) | Creating a Lean department means resources tied up with the lean initiative *full time*, working as a success factor.<br><br>Creation of a Lean department on the corporate level and at each of the plants, provision of specific resources for the Lean initiative aimed at structuring implementation and monitoring advances in implementation.<br><br>Setting the Lean targets with the work teams and the other levels of the organization. Help and direct support given to Team Leaders. | "You can't make Lean work without the right resources. In the past, some of us managers in the plant had been making changes of this type more or less part-time… and we spent some of our time on it, too; but it's obvious, an initiative like Lean is only possible if you've got resources absolutely fully dedicated to it." "Creating a Lean department was one of Lean's success stories, it's a really powerful thing to have people exclusively devoted to it, working and organizing the whole change to Lean." (Plant M., P5).<br>"The Lean managers at all the plants played a major role in..., for me it's one of the factors that most drove the change." (Plant M., P2). |
| Forming of work teams (with a Team Leader) | Emergence of the figure of Team Leader to lead the work teams. Importance of work teams with multifunctional support in the pilot areas for creating the beginnings of the work team. Team Leader chosen democratically by all the members of the work team. Is the driver of Lean methodology, High knowledge of what can be done within the work team. Specific prior training for working as Team Leader. | "When the work teams with multifunctional support had been formed in the pilot areas, then the figure of the Team Leader was officially defined in the Labor Agreement. That's the person who sets out and drives forward all the Lean methodology in a natural work group." (Lean Manager, P4). |
| Training of multifunctional teams | Creation of multifunctional teams with personnel from different company departments to achieve specific targets. | "In the Deployment Phase we created multifunctional teams that worked towards some specific objectives. We got the teams from different departments to systematically try to encourage the sharing of ideas and opinions in these teams." (Plant M., P5). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| **Main/Explanatory success factors** | **Key concepts** | **Quotes** |
|---|---|---|
| **Phase 4. LM implementation, cultural change (continued)** | | |
| **Training** | | |
| Emphasis on Lean Training /Total Training total | Continuous effort put into the importance of Lean Training to keep moving towards cultural change (high percentage of all training given, strategic character of Lean). | "Currently 70 % of personnel training is on Lean, that is, 44 hours of training per year out of the total." (Plant M., P1).<br>"We've made a huge effort in training… altogether, out of all the training a person receives, some 70-80% is aimed at Lean." (Plant M., P2). |
| Continuous training in new Lean practices/tools | Continuous training in more complex practices and tools. Emphasis on training focusing on applied methodology (*on-the-job training*). | "We've got training fully deployed and coordinated with the Lean Academy on the group level, and we've got full training programs deployed and they're updated annually… we give training on new tools and there's a package for this program." (Plant M., P4). |
| Updating of Lean Training | Visual training refresher (*Model Factory*). | "We've currently got plans for all the operators to go back – and it's easy to say *all* the operators –, to go back through the Model Factory again to have a refresher course on the whole practical side of Lean Training." (Lean Manager, P4). |
| Focused on improving competence and skill levels | Emphasis on training to improve level of skills and competences in order to achieve a greater level of worker versatility. On-the-Job-Training.<br>Goal: to achieve a greater level of internal and inter-plant flexibility. | "We've developed a major training program, it really took a huge effort, and with the Skill and Competences tool we're continually regularizing all the operators' skills and competences. There's a whole training package to get them up to scratch every year and what we're aiming for is to make the operators as versatile as possible…, this year it's been over 50 hours /operator." (Plant M., P4). |
| **Communication** | | |
| Daily communication focused on key indicators for production performance (Structured SQCDP Methodology and Process Confirming) | Daily communication with the goal of achieving daily feedback on work shop indicators (*Safety, Quality, Cost, Delivery, People*).<br>Target: to achieve fluid communication, higher coordination levels and internal integration, visual management of the plant, communication structured by level, direct worker participation at SQCDP (Security, Quality, Cost, Delivery and People) meetings and Process Confirming, improvement suggestion system | "The fact that we're getting people together in an organized way every day, and following a series of structured indicators with them, all the people who work together on a specific plant level I mean, everyone on their own particular level and everyone at their own particular time, means everything's been really, really well coordinated. It's incredible how much it helps cultural change, how to do things in a different way." (Lean Manager, P3).<br>"With this SQCDP methodology and PC, the workers can feel that they it's them that are making all the improvements first thing in the morning and they report any problems and within an hour and a half the Manager knows all about them, and that's great for them, it's really important. Their immediate problems are dealt with immediately." (Corporate Lean M.). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| | **Phase 4. LM implementation, cultural change (continued)** | |
| **Recognition** | | |
| Strictly structured non monetary (individual and collective) | Acts of recognition, on both the collective and individual levels. Efforts aimed at achieving a structured model to give it greater significance and boost recognition.<br>Fundamental role in achieving motivation, engagement and the participation of people in the Lean initiative. Primacy over economic incentive. | "We discovered that recognition motivates people, there's no doubt about it, it's an essential tool… you can't implement lean unless you've got all your human resources aligned (…). We're currently working on ways of acknowledging people publicly, both individually and collectively. And we've been working on making it have a greater effect, making it more powerful, structuring it, that's the way forward. Make it stand out more, more apparent and, obviously, linking it to the whole Lean roll-out and implementation (…) We've realized that in today's world, recognition is a priority over economic issues." (Plant M., P3). |
| Monetary, linked to Lean | Economic incentives agreed with social representation structured by labor agreement, linked to the achievement of lean targets. | "We've got the whole economic incentive thing organized, it's in the Labor Agreement, no less. It's all agreed with the social representatives. Basically we've got the incentive system linked to achieving some specific targets, where the role Lean is playing is the engine behind these targets being achieved, they're linked to Lean." (Plant M., P3). |
| **Job design** | | |
| Improvement-oriented Standardization of Work | More complex SOI (*Standard Operations Instruction*) with the goal of achieving a higher level of maturity in job standardization. | "In the implementation phase we're working hard on SOI (Standard Operations Instruction)…, shall we say we're trying to reach a very high maturity level where the operation is perfectly defined: tools, times, the method, with a graphic process, etc." (Plant M., P4). |
| **Work organization** | | |
| Self-managed work teams | Mature, self-managing work teams. On average 90% of work-force works in self-managed work. | "These days, the work teams have got past the initial stages and now they're mature, independent and they work as they should (…) During the first phases, us department heads, the ones involved, would go, and I would go to meetings with the work teams, we were there, and we really got down to the nitty-gritty, but not these days any more…" (Plant M., P3). |
| Larger number of multifunctional work teams | Greater number of multifunctional teams and greater ability to solve problems. On average, 26.5% of workers are included in multifunctional teams. | "As for the multifunctional teams, many of them are really brutally strong now. For example, the multifunctional group that deals with the maintenance of a machine that was really giving us a headache, they're running that machine now, they own it, they're engineering it, in charge of the process, quality, maintenance..., and that's an example of Lean culture and how through LM methodology the team manages the whole process environment." (Plant M., P4). |

**Table 3.1 (Continued)**

Main and Explanatory Success Factors of Human Resource Management in LM Adoption and Implementation

| Main/Explanatory success factors | Key concepts | Quotes |
|---|---|---|
| **Phase 4. LM implementation, cultural change (continued)** | | |
| **Work organization** | | |
| Job rotation | Greater worker versatility due to training effort focused on improving levels of competences and skills. Greater level of task rotation both on the plant and inter-plant levels. On average, 23.33% of employees rotate between tasks. | "The operators are now a lot more versatile…, but even inside the group's plants, depending on the plants' workloads, we're working on flexibility." (Lean Manager, P4).<br>"Now there's a degree of flexibility in our workers thanks to the versatility we've achieved. That's what lets us play with our capability. We've got enough flexibility to be able to adapt to any variations we have." (Plant M., P3). |
| Cross-audit of Lean implementation results | Audits by Lean Managers and Lean Experts on the plant level of other plants in the group. External Lean Assessment. Goal: to obtain a less subjective external vision and more suggestions for improvement. | "We now get people coming here from other plants, and we go there so there are new opinions, new ideas … more than just the "per se" internal valuations, there are recommendations that can provide opportunities for improvement." (Lean Expert, P5). |

**Figure 3.1**

Model of Main and Explanatory Success Factors for HRM during the first and second phase of LM Adoption

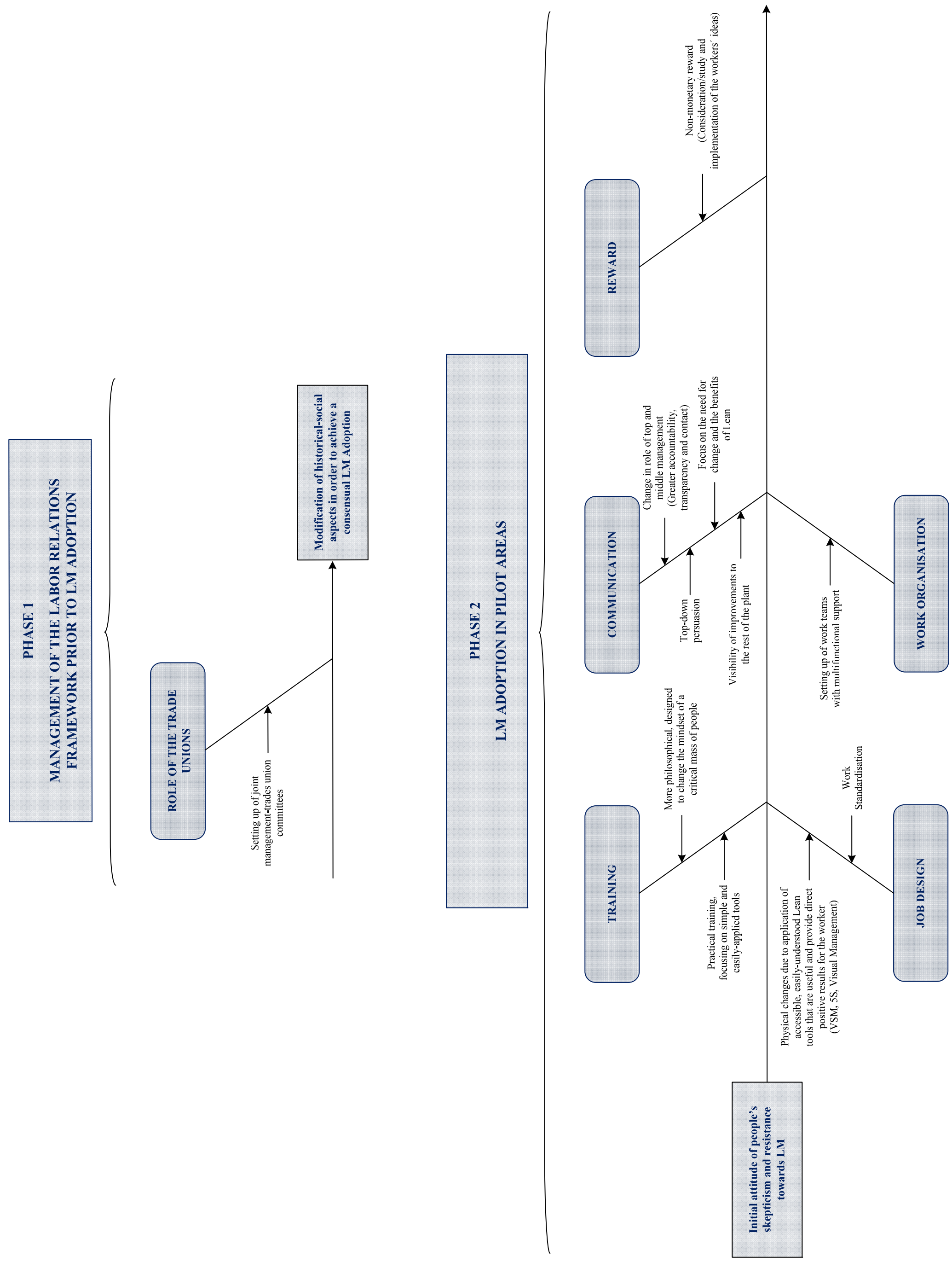


**Figure 3.2**

Model of Main and Explanatory Success Factors for HRM during the third phase of LM Adoption

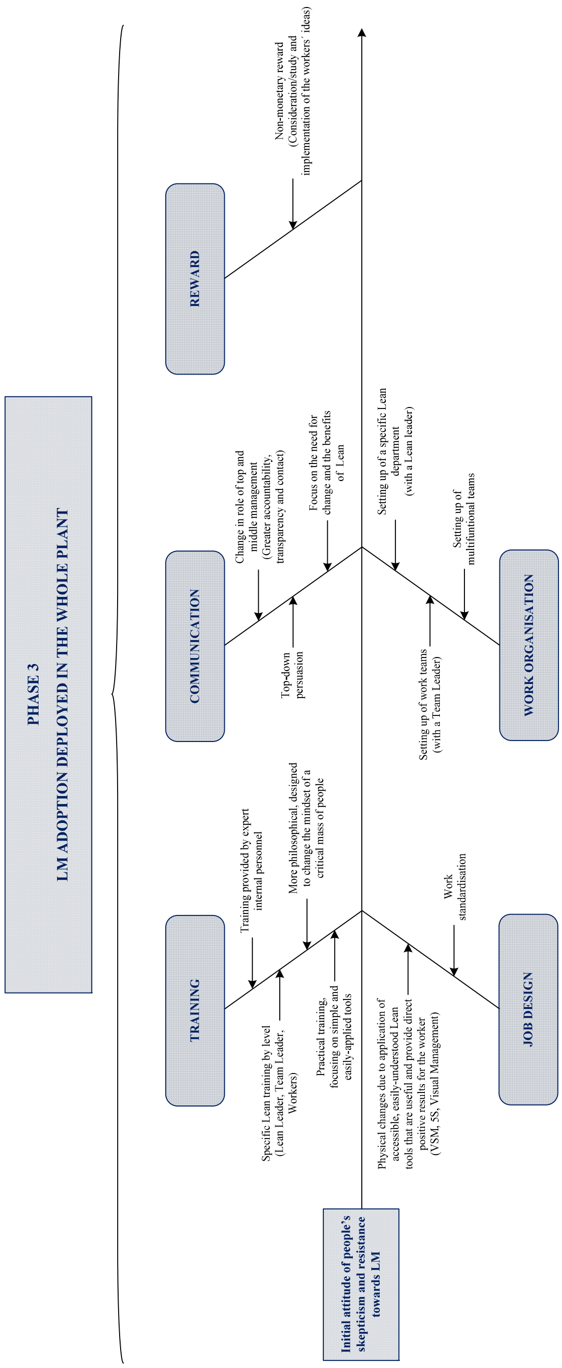
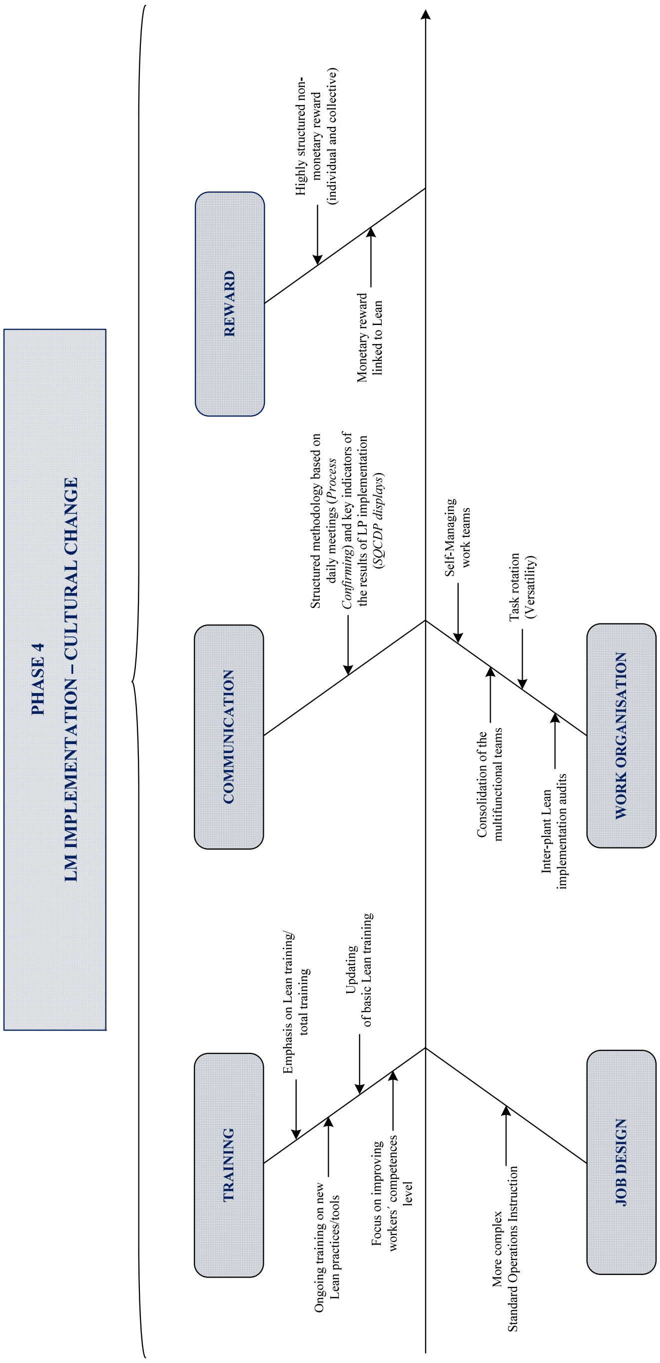


**Figure 3.3**

Model of Main and Explanatory Success Factors for HRM during the fourth phase: LM Implementation



### 3.5. Discussion and Conclusion

Our study contributes to connecting the fields of Operations Management and HR management that have traditionally been studied separately, but which, as Boudreau et al. (2003) point out, have important interaction features. Specifically, this study contributes to earlier research on the influence that HR management has on worker adaptation during the transition process to LM, by identifying a series of main factors that depend on the phase, whether it is the LM adoption or implementation phase. The explanatory elements that lead to success are established for each main factor. Our theoretical model enables the interrelationships between the main factors and the explanatory success factors to be understood graphically, and the most relevant HR management aspects to be identified for each phase. The four phases identified complement other authors' proposals that point to the sequential implementation of LM (e.g., Turesky and Connell, 2010; Pedersen and Huniche, 2011).

**Phase 1: Management of the labor relations framework prior to LM adoption**. The main factor in this stage is the creation of joint committees between management and social representation. This finding complements prior research on the role that the trade unions play in LM (Kochan et al., 1997; Shah and Ward, 2003) and are in line with Kim and Bae (2005), who state that a company's level of unionization is a crucial factor in its successful adoption of LM. In the same vein, Forrester (1995) highlights the demands that the LM system makes of the new labor relations. The innovation required and the less wasteful means of production necessitate the commitment of workers, so managers should create a trusting relationship with trade unions based on open communication.

**Phase 2: LM adoption in pilot areas**. Targeting resources to one area and the visibility of improvements achieved provide an example for other areas and facilitate the roll out of the LM initiative to the rest of the plant in line with what the gradual implementation of events focus proposes (Wilson, 2009). We identified an initial attitude of resistance to LM during this stage which, although mitigated to a certain extent by union negotiations, was managed by five main factors.

(1) *Training*. A first explanatory success factor was training focused on changing people's mindsets, in order to gradually reduce resistance to LM. Brown and Mitchell (1991) specifically earmarked training as a critical variable that scales down the issues for an optimal transition to LM. But although this kind of training is considered to be crucial for achieving success in Lean (Niepce and Molleman, 1996; Sawhney et al., 2010), little analysis has been done of it. A second explanatory success factor was practical training in the use of basic tools, which reinforces the idea that applied training improves learning about the first Lean tools (Barton and Delbridge, 2001; Stewart et al., 2010).

(2) *Communication*. Communication has been widely recognized as a vital component of LM (Womack et al., 1990; Spear and Bowen, 1999). The first explanatory success factor was the change in the role of managers, with increased contact with blue-collar workers and feedback. The literature notes the importance of managers' changing roles and functions within the context of just-in-time and other tools oriented towards LM adoption (e.g., Power and Sohal, 2000). Consequently, the role of managers in a Lean environment is to work closer with workers and to provide them with support (Worley and Doolen, 2006; Beauvallet and Houy, 2010; Turesky and Connell, 2010). Top-down communication processes focusing on the need for change and the benefits of Lean were a second success factor for overcoming initial resistance and driving up commitment, as noted in other studies (Womack and Jones, 1996; Lucey et al., 2005; Worley and Doolen, 2006; Gagnon et al., 2008). Effective "top-down" communication processes can actively work to eliminate barriers between individuals and departments (Power and Sohal, 2000). Finally, the visibility of improvements in the pilot area was a crucial factor for recognizing effort and served as an example to other areas. Communicating Lean successes throughout the organization is critical for providing employees with a better understanding of the benefits of Lean and creates a positive perception of the initiative (Scherrer-Rathje et al., 2009; Turesky and Connell, 2010).

(3) *Rewards*. Rewards at this stage were non-monetary and linked to recognizing workers' ideas by implementing feasible proposals. This issue was a key feature in achieving greater trust in managers, overcoming the inertia of the past and aligning workers with the Lean initiative, and boosting motivation (MacDuffie, 1995; Worley and Doolen, 2006). In the same way, Boudreau et al. (2003) note that putting mechanisms in place for recognizing people´s success in a non-monetary way may contribute substantially to improving the performance of some Lean manufacturing plants.

(4) *Job design*. One first success factor was the physical changes that came from implementing basic Lean tools, such as VSM, 5S and Visual Management. The objective of these tools is to improve the work station and its ergonomics, which is of benefit to the workers and contributes to their adapting better to the Lean initiative. These findings are similar to those found by Abdulmalek et al. (2006), who state that there are easily applied tools that can be an excellent starting-point for identifying sources of waste, and by Antony (2011), for whom these tools help to organize the work place, motivating employees to forge ahead with implementing Lean. A second explanatory success factor was work standardization. Literature highlights the role of standardization as a key tool for coordinating work in LM (e.g., Parker, 2003; Olivella et al., 2008). Standardization enables workers to become familiar with techniques that they should implement in different situations and facilitates task rotation (Niepce and Molleman, 1996; Olivella et al., 2008).

(5) *Work organization*. The explanatory success factor here was the setting up of small work teams with multifunctional support. The literature states that the first work teams in LM adoption must receive support if they are to be successful (e.g., Åhlström, 1998). The creation of these teams is absolutely essential for getting workers to adapt to working in a Lean environment and developing the principles of participative management and delegation of responsibilities. These teams are responsible for quality, continuous improvement and problem solving (Parker, 2003).

**Phase 3: LM adoption deployed to the rest of the plant**. Initial resistance towards Lean was also detected during this stage. It was possible to keep this attitude under control by negotiating with trade unions and through workers seeing the improvements in the pilot area. Various factors also contributed to success:

(1) *Training*. One of the first differentiating explanatory success factors was the use of internal expert personnel to provide training. Skilled workers are likely to adapt to changes because they use their knowledge and experience to facilitate the process of new technology adoption (Lee et al., 2011). The use of internal expert personnel for training helped to speed up the Lean adaptation process. Another factor was the provision of specific Lean training by level, distinguishing between training focused on lean leaders and team leaders and that for workers, so that each member would know what role s/he had to play in the lean environment. As Turesky and Connell (2010) note, in an LM context there does not just have to be training and development for team members, but also for managers and team leaders in order to create an environment conducive to deciding, solving, listening, encouraging, teaching, and coaching. In this respect, Ritzman and Safizadeh (1999) indicate that as workers become more involved in teams, so team leaders become necessary and require some specific training.

(2) *Communication*. The key difference compared to the preceding phase was the leadership of the whole chain of command to achieve worker participation and the roll out of LM to the whole plant, findings in line with Groebner and Merz (1994) and Forza (1996).

(3) *Rewards* and (4) *Job design*. The same explanatory success factors were found as in the preceding phase.

(5) *Work organization*. One explanatory success factor was the creation of a Lean Department with full-time personnel devoted to LM (*Lean Manager, Lean Leaders, Lean Experts and Change Agents)*. Another factor was the setting up of work teams with a team leader in charge of standardization and improving processes (Forrester, 1995; Delbridge et al.,

2000). The last factor was the creation of multifunctional teams with goals for improvement, which supports prior empirical evidence (e.g., Forza, 1996; Åhlström, 1998).

**Phase 4: LM implementation**. The five main factors are found, although with different explanatory success factors.

(1) *Training*. Several success factors were found. First, the major importance of Lean training within the total amount invested in training. Second, ongoing training in the use of new Lean tools and practices in order to move forward in the culture change and upgrade employees´ skills and knowledge. Upgrading people's competences is important for them to be in a better position to adapt to change, produce high-quality products, and improve a firm´s competitiveness through product and/or process innovation (Birdi et al., 2008). Third, training focused on updating basic Lean tools and techniques in order to keep workers engaged with LM. Lastly, training focused on improving workers' competence levels in order to increase their versatility. MacDuffie (1995) pointed out that flexible production (i.e., LM) gives employees much more than a key role in the production system, and requires more problem-solving skills. Developing these skills requires multi-skill training. Ritzman and Safizadeh (1999) found that multi-skilled and versatile workers help handle the high product customization and changing customer requirements that characterize some types of manufacturing plants, such as those analyzed in this paper.

(2) *Communication*. Structured methodology based on daily meetings (*Process Confirming*) and key indicators of the results of LM implementation (*SQCDP displays*) were developed. These findings support the importance that the literature gives to transparency of information and feedback for Lean objectives to be achieved (Mehta and Shah, 2005; Worley and Doolen, 2006; Turesky and Connell, 2010).

(3) *Rewards*. Monetary incentives and non-monetary recognition are used. Whereas during the LM adoption phases managers only recognize workers' achievements, monetary incentives are added during the implementation phase. Our findings complement the findings of Karlsson and Åhlström (1996), who believe that a monetary incentive system acts as an

inhibitor at the beginning, but over time facilitates the implementation process. LM-linked compensation can reward multi-skilling and teamwork and increase worker participation and commitment (Olivella et al., 2008).

(4) *Job design*. One explanatory success factor is the implementation of the *Standard Operations Instruction* (SOI), which reduces internal variability.

(5) *Work organization*. One of the explanatory success factors was the increased number of self-managing teams. Within the LM environment, autonomous teams enhance the firm´s performance by motivating their members, reducing labor costs by requiring less supervision, improving the range of skills required for carrying out a range of tasks, and providing the opportunity for members to learn from each other (Birdi et al., 2008). Consolidation of the multifunctional teams was also seen to be a second explanatory success factor. Approximately 27% of the personnel at all the plants analyzed belonged to teams of this type. Forza (1996) and Martínez-Sánchez and Pérez-Pérez (2001) found that progress in LM implementation consolidates multifunctional teams. A third explanatory success factor was the increased task rotation between workers resulting from versatility-oriented training and the high degree of standardization. The idea that LM-oriented firms actively promote the development of versatile workers has been widely stated in the literature (e.g., MacDuffie, 1995; Forza, 1996; Pil and MacDuffie, 1996; Power and Sohal, 1997, 2000; Angelis et al., 2011). Finally, one factor that has not been analyzed in the literature to any great extent is the setting up of teams to carry out inter-plant lean audits (Lean Assessment). The aim is to obtain an external and less subjective view of a plant's work structure and suggestions for improvements.

### 3.6. Implications for Management and Future Lines of Research

Our findings can serve as guidelines for companies wishing to adopt LM and can help managers responsible for the LM implementation process, draw up aligned and time-sequenced action plans for achieving and sustaining the results of LM transition. It should be highlighted that the factors that we have identified should not be considered in isolation but as a system, where each factor interacts with the others in each phase.

Our paper has some limitations. The study is qualitative and exploratory and was conducted in a specific industrial sector, so the generalisation of the results is limited. Future studies could validate the proposed models in other industrial and geographical contexts using logic replication. Future studies could also examine whether the proposed models could be applied to other levels of the aerospace supply chain. In other respects, although the study identifies the relationships between the explanatory success factors and their main factors, it does not enable their strength or intensity to be measured. We therefore propose further research to measure the intensity of the relationships. In addition, it would be interesting to combine qualitative and quantitative methodologies in order to avoid the above-mentioned generalisation issues.

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# THE ADOPTION OF LEAN SUPPLY CHAIN MANAGEMENT: A CONTINGENT AND NETWORK APPROACH IV

## 4.1. Introduction

Companies in a variety of industries have made advances in their levels of Lean Management (LM) implementation in recent decades. In many cases this has enabled them to improve their results and step up their competitiveness. However, other companies have not achieved the results that they had anticipated. According to some authors (Rivera et al., 2007), it is not enough to deploy some LM principles and practices in isolation to make a company competitive. Shah and Ward (2007) maintain that to achieve all the potential benefits that LM may offer companies must adopt it not only internally, but also externally, extending Lean principles and practices throughout the supply network.

In other respects, the current competitive environment clearly demonstrates the need for flexibility in the supply chain. What is meant by flexibility is the company's responsiveness to customers' demands changes, with efficient and minimum cost changes in their requirements for raw materials, parts and products in terms of volume, variety and delivery date (Duclos et al., 2003). To be precise, what is required is a Lean focus to be given to supply chain management to combat the need for reductions in the coordination costs that come from the growing demand for flexibility. This strategy was detected by Lamming (1993), who stated that the supply chain needed to be redesigned for the responsibility for value creation to be shared.

However, Lean Supply Chain Management (LSCM) has become an increasingly challenging process due to the contingent factors and the increased complexity, length, and globalization of supply chains (Mollenkopf et al., 2010). These structural features of supply chains mean that building a Lean supply chain entails a series of challenges on the practical level (Taylor, 2006).

Despite the importance of managing these challenges, the literature on LSCM has focused on its guiding principles and theoretical practices (Lamming, 1993), the role played by Information and Communication Technologies (Bruun and Mefford, 2004), the outcomes of its implementation (Simpson and Power, 2005) and how to integrate Lean and Agile (Stratton and Warburton, 2003). There are, however, few articles that consider the role of industry-related contingent factors in the successful adoption of LSCM.

A number of studies note failed transitions to LSCM brought about by a wide range of contextual factors. The most important of these include the power relationships in the supply chain, inter-organizational barriers, demand characteristics and the supply chain structure itself (Arkader, 2001; Taylor, 2006; Cox et al., 2007).

Apart from this, what little research has been done has focused on analyzing advanced stages of the LSCM implementation process (Taylor, 2006) and has marginalized the strategic decision pre-adoption evaluation and the adoption phase itself. As such, it is crucial to identify the factors that play a key role depending on the context before and during the adoption process. Lack of knowledge of these factors could slow down the adoption process and, in the final analysis, could affect the success of the transformation (Cox et al., 2007).

Similarly, the literature on implementing Lean throughout the supply chain has focused on the automotive sector (Moyano-Fuentes and Sacristán-Díaz, 2012) and, specifically, on the assembler–first-tier supplier dyadic relationship. Yet there has been recent interest in exploring the applicability of LSCM to other industries (Pérez et al., 2010), including the aerospace sector (Ehret and Cooke, 2010). This is why research focusing on the whole of an industry's supply network is important, distinguishing between adoptions in the various supply networks that it is made up of, as the competitive priorities and contingent factors might vary from supply network to supply network.

For these reasons, the main research question of this study is: *Why and how do industry-associated contingent factors affect the success of LSCM adoption throughout the entire supply network?*

Using this focus as our starting-point we also seek to achieve the following complementary objectives:

- To identify the industry-associated contingent factors that act as facilitators or inhibitors for LSCM adoption depending on how the supply chain being evaluated is configured.
- To determine how different supply networks within the entire supply network address the various contingent factors that they are confronted with.
- To propose an interpretive model with the aim of explaining LSCM adoption.

This study is divided into six sections including this introduction. The second section analyzes the background to the research, and identifies a set of critical LSCM elements. The methodology used is then described. The fourth section shows the changes that are necessary before LSCM can be adopted. The following section presents a discussion of the findings and, finally, we set out the conclusions, the implications for management and the challenges that will have to be addressed by future research.

## 4.2. Background

### 4.2.1. Lean Management and Lean Supply Chain Management

LM has developed significantly since it was first disseminated (Womack et al., 1990). It has evolved from being a production system focused primarily on minimizing the waste and variability produced on the factory floor level to one that concentrates on these main objectives from both an internal and an external approach (Hines et al., 2004; Shah and Ward, 2007).

Although many companies are successfully advancing in the LM implementation and are improving their results and competitiveness, others have not achieved the results that they had anticipated, and failed transitions are common (Turesky and Connell, 2010). A range of studies emphasize in this respect that one of the main critical factors for achieving success and obtaining all the potential benefits of LM and, ultimately, gaining a competitive advantage is managing external relationships and the variability caused by these relationships (e.g., Panizzolo, 1998; Shah and Ward, 2007; Moyano-Fuentes et al., 2012).

However, extending Lean principles and practices to supply chain management -what has come to be known as LSCM (Lamming, 1993; Womack and Jones, 1996)- has become an increasingly challenging and complex process (Taylor, 2006; Cox et al., 2007; Pérez et al., 2010). In fact, a variety of factors, such as increasingly complex, long and globalized supply chains (Mollenkopf et al., 2010) and inter-organizational and contingent factors (Arkader, 2001) give rise to a large number of challenges on the practical level.

This has led to researchers showing greater interest in analyzing Lean deployment across the supply chain, not only in the automotive industry, but in other industries, too (Moyano-Fuentes and Sacristán-Díaz, 2012). Research has thus identified the causes and consequences of extending Lean principles and practices throughout the supply chain (Fynes and Ainamo, 1998; Taylor, 2006; Cox et al., 2007; Taylor and Pettit, 2009; Pérez et al., 2010). This is due to the crucial role that specific contingent factors in any particular industry play in the transition to LSCM (Crute et al., 2003; Cox et al., 2007).

The literature has focused on the guiding principles and management practices (Lamming, 1993, 1996; Womack and Jones, 1996; Sako and Helper, 1998; Rivera et al., 2007), the role played by the Information and Communication Technologies (Bruun and Mefford, 2004; Ward and Zhou, 2006; Adamides et al., 2008), the results of implementation for both customers and suppliers (Hines, 1996; Wu, 2003; Simpson and Power, 2005; Wee and Wu, 2009; So and Sun, 2010) and how to incorporate Lean/Agile strategies into supply chain management (Mason-Jones et al., 2000; Prince and Kay, 2003; Stratton and Warburton, 2003; Narasimhan et al., 2006; Aronsson et al., 2011).

Despite the importance that research on LSCM has for reaching all the potential benefits of LM and its strategic importance, a number of gaps have been detected. Firstly, only a few papers have considered the role of contingent factors in the strategy's success (Arkader, 2001; Taylor, 2006; Cox et al., 2007; Simons and Taylor, 2007; Pérez et al., 2010). We therefore consider that a more detailed look should be taken of the factors that could inhibit or even undermine transformation to LSCM.

Secondly, the available empirical evidence has focused on analyzing dyadic relationships instead of using a holistic approach that evaluates the relationship network that might be found in the supply chain as a whole. Only a few research articles have used this network approach (Taylor, 2006; Cox et al., 2007; Simons and Taylor, 2007; Pérez et al., 2010). We consider that this network approach is vital for gaining an integrated understanding of this phenomenon and the factors that might play a key role given the multiple supply networks that could exist in an industry.

Thirdly, research has redoubled its efforts into analyzing the advanced stages of the LSCM transformation process, and has paid little attention to either a pre-diagnosis or the adoption process itself. Only a few studies focus on the phase prior to adoption have been identified (Taylor, 2006; Pérez et al., 2010). However, these studies are focused on a pre-diagnosis of the applicability of LSCM (Taylor, 2006) and evaluate the characteristics and performance of an entire supply network to establish the extent to which it is operating under an LSCM approach (Pérez et al., 2010). They thus find a number of potential barriers and prerequisites for LSCM adoption and propose theoretical recommendations with the aim of moving forward in the transition process towards LSCM.

In this study we therefore seek to use a network and contingent approach to investigate LSCM in greater detail, and to evaluate empirically both the phase prior to the adoption phase and the development of the adoption phase itself in an industry that has made recent advances in this strategic transformation.

#### 4.2.2. Interpretive Framework of Reference

The literature review has enabled us to identify a series of critical elements and characteristics associated with LSCM (Table 4.1). We shall later analyze empirically how these can act as initial facilitating and inhibiting factors depending on how the supply networks that exist in the aerospace sector are configured.

**Table 4.1**
Critical elements and characteristics of LSCM

| | |
|---|---|
| *Supply Chain Structure* | Small supply base |
| | Low vertical integration |
| | Supply of complex products (systems and subsystems) |
| | Number of suppliers by part/assembly/sub-assembly: Single or dual supply |
| *Selection and Evaluation of Suppliers* | Multidimensional criteria focusing on supplier’ skills and added value and on the background to the relationship |
| *Supplier-Customer Relationship Pattern* | Cooperation relationships based on trust and mutual commitment, frequent contact |
| | Time horizon: long-term |
| *Communication and Information-Sharing* | Frequent. Feedback on results |
| *Involvement in Design and Engineering activities* | Frequent involvement from an early phase in the new product design and development process. High level of shared risk and benefits |
| *Attitude towards Quality* | Strict process and evaluation systems |
| | Problem solving: working together towards shared solutions, frequent feedback |
| *Delivery Practices* | Just-in-Time (JIT) |

Sources: Lamming (1996); Hines (1996); MacDuffie and Helper (1997); Arkader (2001); Simpson and Power (2005); Shah and Ward (2007).

#### 4.2.3. Lean Management and Lean Supply Chain Management in the Aerospace Sector

The world aerospace sector has been subject to growing global competition over the last decade. Whilst in the past competition was mainly based on differentiation and technological aspects, a number of competitive priorities have currently come to the fore that have turned into an enabling factor for competing in the industry. These include, especially, improved delivery reliability and delivery times (James-Moore and Gibbons, 1997; Smith and Tranfield, 2005).

Companies began to embrace LM with a view to achieving these objectives and, in many cases, this led to them achieving better results (Smith and Tranfield, 2005). However, an inability to respond to unforeseen changes in demand and huge delays in delivery are still frequent occurrences and may be due to a late adoption of LM in the industry (Crute et al., 2003).

This has sparked research interest in the transition to LM in the industry. However, research is still scarce and has mainly focused on assessing the applicability of LM. Several authors find that difficulties in the LM transition process are more related to general organizational aspects than specific factors in the industry. In this line, Crute et al. (2003) find difficulties related to the context of the production plant and the role of management. Meanwhile, Bamber and Dale (2000) find issues related to the role of people and redundancy programs. However, other authors, such as Browning and Heath (2009), find that a range of contingent factors, such as novelty, complexity and instability impact on the LM–production costs reduction relationship and can even cause a potential rise in costs.

Despite contradictory results, there is consensus regarding LM's appropriateness in this industrial sector, characterized by highly differentiated and complex products, low production volumes, low repeatability, and significant sources of variability (James-Moore and Gibbons, 1997; Bamber and Dale, 2000; Crute et al., 2003; Smith and Tranfield, 2005). Nevertheless, the challenges to its implementation are real and complex for many companies in this sector

(Crute et al., 2003). This is why it is crucial to consider and evaluate the initial situation and the context of the company before adopting LM (Murman et al., 2002).

We emphasize that LM adoption in this industry should focus on efficient value creation throughout the whole of the company and its stakeholders. This focus is crucial due to the importance that new product design and development, supply chain integration and product life cycle management have. Nevertheless, research into LSCM in the industry has been limited to only a handful of studies (O'Neill and Sackett, 1994; Michaels, 1999; Smith and Trandfield, 2005; Ehret and Cooke, 2010). O'Neill and Sackett (1994) focus on cooperation mechanisms, such as the development of strategic alliances, in theoretical terms. Michaels (1999) found that the legacy of past practices and cultural and behavioral attributes were a curb on progress being made in LM implementation both in a tier 1 and in its suppliers. Smith and Trandfield (2005) evaluate strategic changes in the supply chain configuration, mainly in the tier 1s, finding that these are changing from "mere outsourcers" into suppliers with the skill to innovate in high added value processes. Similarly, Ehret and Cooke (2010) identify generic trends in supply chain restructuring from the point-of-view of the OEM, and explore the extent to which the LSCM focus adapts to industry trends in terms of outsourcing, finding that technological abilities and knowledge play a key role.

However, a weakness that is common to all these studies is that they analyze dyadic relationships exclusively instead of adopting a global supply network focus for the whole industrial sector. Moreover, they are mainly focused on structural changes.

## 4.3. Research Methodology

### 4.3.1. Research Design

LSCM adoption in a number of industrial sectors, such as the aerospace, is an emerging research question and so the use of the case study as a qualitative research method is especially appropriate.

The research developed here is exploratory as available empirical evidence regarding LSCM strategy adoption throughout an entire supply network is very limited, and non-existent in the aerospace sector. In this respect, a number of authors (e.g., Meredith, 1998; Yin, 2003) state that case study method is especially applicable in exploratory research where the phenomenon under study is not well understood and where what is required is a deep understanding of the factors that might have some influence on a relatively new reality.

What needs to be highlighted especially about case studies is their applicability for analyzing longitudinal change processes (Eisenhardt, 1989) where they provide a holistic overview of the phenomenon (McCutcheon and Meredith, 1993; Gummesson, 2000). Moreover, Yin (2003) states that compared to other research methods case studies are very suitable for responding to “how” and “why” questions.

For all these reasons we consider the case study to be an appropriate method as it provides the depth required for exploring the study’s main research question: *Why and how do industry-associated contingent factors affect the success of LSCM adoption throughout the industry’s global supply network?*

A multiple case study has been used as it enables a complex research phenomenon to be explored and described in a way that increases understanding of this and build theory (Meredith, 1998). It also prevents observer bias (Handfield and Melnyk, 1998), facilitates triangulation and improves generalization of the findings (Voss et al., 2002), thus reinforcing both the internal and external validity of the study (Eisenhardt, 1989). It therefore affords the research greater robustness (Herriot and Firestone, 1983).

#### 4.3.2. Selection of Case Studies and Unit of Analysis

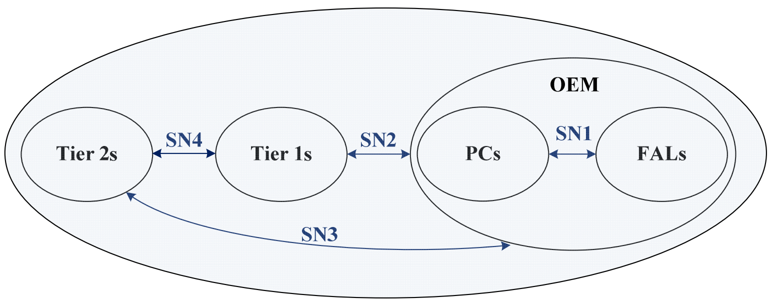
The choice of case studies and the unit of analysis for the case study method was a major decision in order to ensure the validity of the findings (Yin, 2003).

We used a theoretical sampling model (Eisenhardt, 1989). The conditions used were designed to select organizations belonging to different supply networks included in the whole supply network that would offer an "optimal opportunity to learn" (Stake, 1995). The resulting case studies could therefore offer significant findings that might help to provide an answer to the research question. Our strategy was based on literal replication (Yin, 2003), using cases that were rich in information and distributed to achieve maximum variation (Stuart et al., 2002).

This is the reason why we selected plants operating at different levels of the entire aerospace supply network, to be precise: *Final Assembly Lines* (FAL), *Prime Contractors* (PC), and *Tier 1* and *Tier 2 suppliers*. The plants also differ both in size and with respect to the goods that they manufacture and/or assemble and the services that they offer.

The unit of analysis is the "supply network", with the aim of developing comprehensive knowledge of the whole supply network. Specifically, the supply networks that were analyzed were those formed by vertical dyadic relationships between different levels of the aerospace supply network. Figure 4.1 shows the supply networks analyzed in the context of the aerospace sector as a whole.

**Figure 4.1**
Entire aerospace sector supply network




Each of these supply networks includes the following relationships:

*SN1:* dyadic relationships between the aircraft final assembly lines and the prime contractors. The FAL are responsible for the final assembly of the aircraft and its sale to the end-customer, while the contractor plants belong to the OEMs (*Original Equipment*

*Manufacturers*) responsible for the manufacture and assembly of large aerostructures, subsystems and systems primarily supplied to the FAL.

*SN2:* dyadic relationships between the OEM and Tier 1 suppliers. In this case we consider the relationships between the OEM (FAL and PC) and the Tier 1s. The Tier 1s are the organizations that have recently been increasing their product and process innovation skills and supply high added value subsystems and systems directly to the OEMs.

*SN3:* dyadic relationships between the OEMs and Tier 2 suppliers. The Tier 2s are the organizations that have recently moved up from supplying low added value parts directly to the OEMs to supplying them directly to the Tier 1 as a result of LSCM strategy in the new aerospace programs. They still maintain direct relationships with the OEMs despite this, mainly in the old aerospace programs, although these types of direct relationships are tending to disappear even in these types of programs.

*SN4*: dyadic relationships between Tier 1 and Tier 2 suppliers. These types of relationships are new and have emerged post-LSCM adoption, as previously the Tier 1s did not manage their own purchases and, subsequently, their own supply chains.

There are other reasons that have determined the choice of the supply network as the unit of analysis. On the one hand, Lean principles and practices spreading throughout the whole supply network is frequently produced through the vertical buyer-supplier type dyadic relationships when these trading partners are located in different supply networks. As LSCM is also often adopted progressively, there might be substantial differences between the various supply networks. Similarly, the various networks could be subject to different competitive priorities and a number of contingent factors of their own.

Data collection was done at different production plants in the entire Andalusian aerospace sector supply network. This industrial sector was chosen as it has begun to adopt LSCM only recently and is still at an initial stage. The supply network structure transition is also in process, which might enable us to obtain relevant findings regarding the role that it plays. This also facilitates analysis of how a network is built and evolves in uncertain circumstances and under contextual conditions. Similarly, as LSCM adoption only began a few years prior to the data collection process, the way that the initial conditions evolved can be observed over a significant period of time.

We used the company database provided by *Fundación Hélice* as the basis for identifying the set of companies that make up the aerospace sector population. This database was filtered with the condition that companies in different supply networks had commenced LM adoption on an internal level at least one year previously and/or were part of an LSCM initiative.

As a result, fifteen plants belonging to four different supply networks were established as case studies. This is consistent with research in a network context. According to Seuring (2008), as data collection in this context includes multiple companies it should be done through the various levels. The case studies are, specifically: two final assembly lines, three prime contractors[4], seven Tier 1 and three Tier 2 supplier plants. Sampling continued until the theoretical saturation point was reached, which is when any increase in learning is minimal (Eisenhardt, 1989).

#### 4.3.3. Data Collection

A protocol was designed before the field work began that contained the data collection instruments, procedures and general rules for carrying out the case studies. This protocol was updated and improved with every visit (de Weerd-Nederhof, 2001).

A tentative script was designed for the in-depth semi-structured interview based on a literature review on LM and LSCM and on their applicability to the aerospace sector. A preliminary version of the script was pretested by two renowned researchers in Operations Management and two experts in the aerospace sector with proven experience. Finally, a pilot study was carried out at two production plants belonging to the OEM and its supplier base, respectively. As a result of this process new questions were included and some changes were made to the wording to eliminate any problems with interpretation during the interviews.

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[4] The Final Assembly Lines (FAL) and the Prime Contractors (PC) are members of the *European Aeronautic Defence and Space Company* (EADS) consortium.

Both primary and secondary information sources were used to triangulate data. This helped to ensure construct validity of the research (Easterby-Smith et al., 2002; Yin, 2003). The in-depth semi-structured interviews, surveys, direct observations during visits to the plant facilities and, in some cases, statements made by top management were used as the primary information sources. As secondary sources we used company documents, reports, including annual reports, websites, published interviews and similar sources.

The same *pretest* process was used for the survey used to triangulate information as for the preliminary version of the interview script. It was therefore ensured that the definitions of the questionnaire items made sense and were correctly understood.

Construct validity was ensured by interviewing various executives in all cases (from two to three key informants). Thirty-three top managers and executives were interviewed in all. The interviews were always carried out in the presence of two researchers which enabled explanatory field notes to be taken independently, and allowed us to clarify some ambiguous issues and identify interesting aspects during the data collection process. This helped to limit observer bias (Eisenhardt, 1989).

The data was collected from July 2010 to March 2011. Each in-depth semi-structured interview lasted from 60 to 160 minutes. Each visit to the plant facilities lasted 60 minutes on average. All the interviews were recorded and transcribed immediately afterwards. A database was constructed with the interview transcriptions, questionnaires, documents and explanatory field notes.

#### 4.3.4. Data Analysis

A range of measures were adopted to guarantee the validity of the data analysis and interpretation process and thus ensure the chain of evidence (Barratt et al., 2011). The analysis was done on a case-by-case basis and, subsequently, a cross-case analysis was done (Miles and Huberman, 1994).

The within-case analysis helped us to begin the progressive task of making sense of the huge amount of data collected and interpreting them (Eisenhardt, 1989). We firstly evaluated the reference framework that had come from the literature review in each of the supply networks identified. This enabled us to deduce how these critical elements of LSCM can act as initial facilitators or inhibitors depending on the supply network being analyzed. We then identified the LSCM practices adopted, both those found in the prior literature and those that were not, that were aimed at overcoming the inhibiting factors and enhancing the facilitators that had been detected.

The cross-case analysis of the various supply networks enabled us to identify common patterns. For this we used the technique of selecting pairs of cases and comparing the similarities and differences between them. We then compared all the cases together. The authors did this independently and as a result several categories were identified that corroborated some of those in the literature. These categories were named as key determinants and were compared across the cases.

The coding process comprised several steps and was based on the paradigm proposed by Strauss and Corbin (1998). Firstly, in the open coding phase, data were coded, analyzed and conceptualized. The basis for this was, but was not limited to, the interpretative framework of reference. The concepts with the same meaning were then grouped into tentative initial conceptual sub-categories and categories. Secondly, these sub-categories and categories were inter-connected during axial coding (e.g., specific techniques-subcategories- in LSCM practices -category-). In the selective coding phase, we identified the central category: the adoption of LSCM across the entire supply network. The categories and subcategories were refined and interconnected with the aim of building a theoretical LSCM framework. The results of the open, axial and selective coding were constantly compared.

The authors of the paper analyzed the data independently in order to ensure the consistency of the findings and later held several joint meetings to compare the results. Some aspects needed to be confirmed by the interviewees after the interview had taken place, which helped to control the construct validity of the research.

**Table 4.2**
Summary of methodology used

| | |
|---|---|
| **Research Question** | – Why and how do industry-associated contingent factors affect the success of LSCM adoption throughout the entire supply network? |
| **Research design** | – Qualitative methodology. Multi-case study. Exploratory. |
| **Case selection** | |
| • Unit of analysis | – Supply network: vertical buyer-supplier dyadic relationships. Objective: to achieve a full understanding of the phenomenon under study through the entire supply network. |
| • Cases | – Theoretical sampling (literal replication). 15 production plants operating at four different levels/tiers of the aerospace supply network (four supply networks). Andalusia (Spain). Companies that had initiated LP adoption internally at least a year previously and had taken part in an LSCM initiative. |
| **Data collection** | |
| • Protocol | – Design of data collection instruments, procedures and general rules.<br>– Pre-test of instruments and two pilot studies (prime contractor and supplier). |
| • Information sources | – Primary: in-depth semi-structured interviews, surveys, direct observation and, in some cases, statements from top management.<br>– Secondary: company documentation, reports, annual reports, websites, published interviews and similar sources. |
| • Key Informants | – All Cases: Plant manager and plant Lean leader.<br>– Other cases: Operations manager, corporate Lean leader and plant Lean expert.<br>– Total number: 33 managers. |
| • Period | – July, 2010 – March, 2011. |
| **Data Analysis** | – Within and Cross-Case. Open, axial and selective coding. Atlas.ti software. |

### 4.4. Changes Prior to LSCM Adoption Process

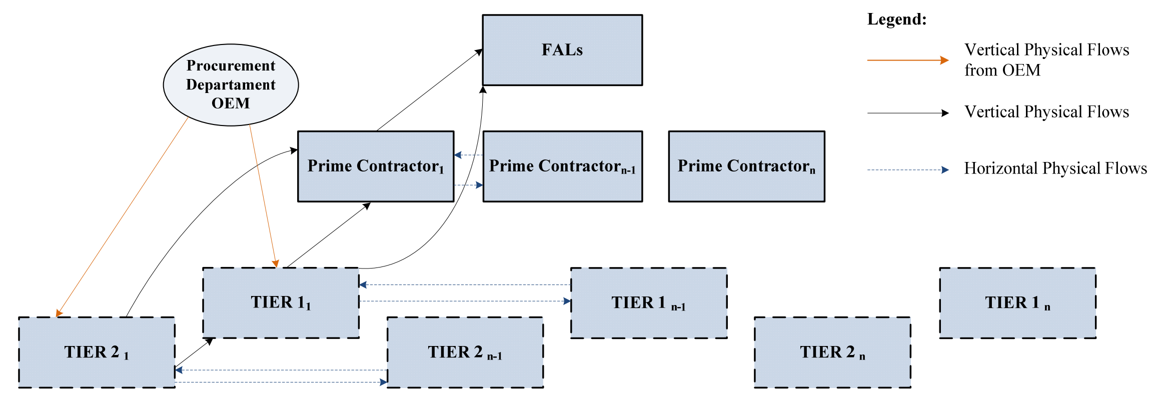
Using the above-described methodology we were able to deduce the changes that needed to be made for LSCM to be adopted in the aerospace sector and set them down on a timeline. At the same time it was possible to observe how the problems encountered were managed for LSCM to be successfully adopted.

#### 4.4.1. Whole Supply Network Restructuring Process in the Aerospace Sector

LSCM strategy adoption was prompted by the introduction of recently developed aerospace programs (e.g., defense and civil aircrafts: A380, A400M, A350, B787, Falcon 7x, Embraer ERJ190, Bombardier CRJ700) which required a substantial change in the aerospace sector supply network. In fact, this restructuring is still in process and has still not stabilized. There are currently two outsourcing strategies existing side-by-side in the supply network, one for the “old programs” and the other for the LSCM adoption-linked “new programs”. However, we have observed that all the programs are progressively changing to LSCM.

Figures 4.2 and 4.3 show the supply network structure and flows for the “old” programs and the newly developed programs, respectively, that enable us to analyze the restructuring of the supply network and the effect that this has had on the supply networks identified for analysis.

**Figure 4.2**
“Old” programs supply network structure and flows




In this Figure, the physical flow of raw material/elemental parts/tools from the OEM to its supplier base should be highlighted. In other words, the OEM is “supplier of its supply base” and is responsible for managing supplier base’s purchases. This is the cause of “spaghetti chart”-type physical flows, with dual supply and delivery relationships (double *lead times*). The difference between first tier (*Tier 1s*) and second tier suppliers (*Tier 2s*) is blurred, as they are "*build-to-print*" manufacturers and do not have the skill to innovate either in complex product or process. Furthermore, once the supplier base has carried out the internal manufacturing/assembly operations, they supply parts/subsystems directly to the OEMs, which are responsible for assembling the aerospace subsystems and systems, and the aircraft.

**Figure 4.3**

Newly-developed programs supply network structure and flows

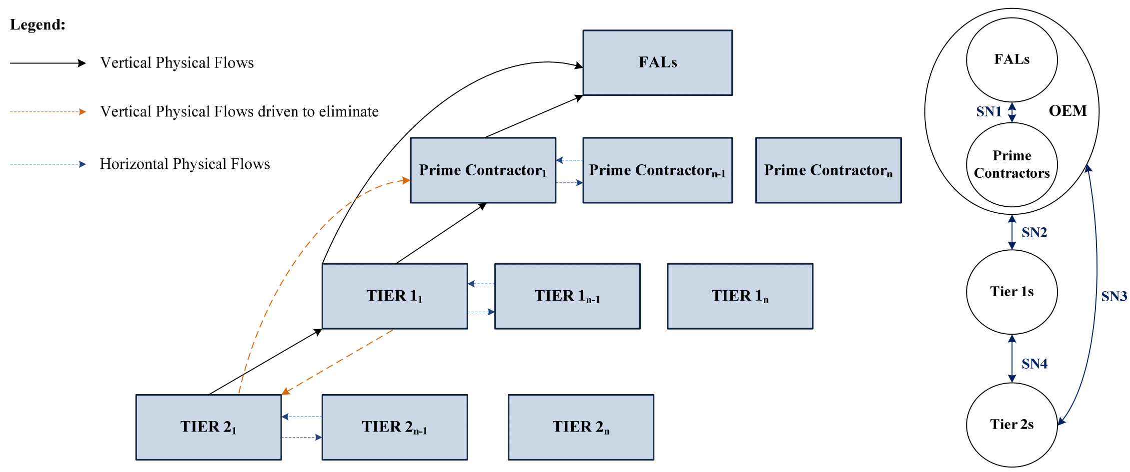



Figure 4.3 shows the structure of the supply network after being restructured in keeping with LSCM principles in order to attend to the newly-developed programs. The physical flows from the OEM to its supplier base have thus disappeared and the supply base is responsible for its own supply chain (physical flows still exist in the Tier 1-Tier 2 relationships, however, but are destined to die out). On the other hand, cooperation relationships have arisen, mainly with the Tier 1s that have progressively acquired the skills to innovate in complex product and process. "Build-to-print" has therefore completely disappeared in the "new" aerospace programs and Tier 1s are involved in product design and development from the initial project phase. They are also characterized by the supply of complex systems and subsystems. Meanwhile, there is a clear distinction between Tier 1s and 2s. Tier 2s are therefore

progressively trimming back their relationships with the OEM and setting up new relationships, mainly with Tier 1s. Despite this, the product and process innovation skills that the Tier 2s have remain limited.

#### 4.4.2. Problem Management during the Supply Network Restructuring Process

The first supply network to adopt LM in the aerospace network was SN1. The main factor that triggered this was mostly the end-customers' (states and airlines) bargaining power, demanding improved key performance indicators basically linked to delivery times and reliability, and cost reductions. The first step in LSCM strategy adoption was restructuring the OEM's supply network due to supplier atomization, the complexity of prior relationships and supply variability.

Subsequently, and practically at the same time, the OEM adopted LM on the internal level. Meanwhile, the OEM continued to require greater ability in product integration with greater added value, and innovation in processes, mainly from suppliers that were capable of becoming Tier 1s. This required an increase in size of these suppliers through mergers, acquisitions, etc.

Simultaneously the OEM continued to move forward in LM implementation. However, a number of problems were encountered linked to the variability that came from the supplier base due, mainly, to the reliability of deliveries and delivery times. Along with problems resulting from the complex conversion of suppliers into Tier 1s, i.e., their acquiring greater product and process innovation skills, this led the OEM to focus its Lean strategy on managing said external variability. The OEM thus upped its requirements regarding its suppliers adopting LM, mainly those that had already become or were becoming Tier 1s.

The OEM then adopted a number of LSCM practices by creating an LSCM department responsible for managing Lean with its supplier base, mainly with the Tier 1s. However, as it was aware of the impact that the Tier 2s had on the supply network's overall performance and their role in the success of an LSCM initiative, the OEM subsequently also included these suppliers in Lean initiatives. This was due to two reasons. Firstly, these new Tier 2 suppliers were still supplying the OEM with low added value parts directly, which was the cause of great variability in supply, meaning that they had to be taken on board in LSCM initiatives with the main objective of them adopting LM internally. Secondly, the new Tier 1s were immersed in pilot projects to establish and manage this Tier 2 supplier level.

And this, combined with the coexistence of two different supply strategies (old and new aerospace programs), meant that there were a large number of challenges for network management.

### 4.5. Results

#### 4.5.1. Management of Critical Factors during the LSCM Adoption Process

The literature review enabled us to identify a series of critical factors in LSCM adoption. The presence of these factors was evaluated empirically in each of the supply networks analyzed and classified as either facilitating or inhibiting factors. They were then linked to the LSCM practices adopted on the supply network level and to the key determinants managed with the aim of both eliminating the inhibiting factors and enhancing the facilitating factors (See Table 4.3).

**Table 4.3**

LSCM practices adopted and key determinants managed depending on inhibiting/facilitating factors evaluated

| **LSCM critical factors** | | **SN1** | **SN2** | **SN3** | **SN4** |
|---|---|---|---|---|---|
| *Supply Chain Structure* | Small supply base | + | – (10) | – (10) | – (10) |
| | Low vertical integration | + | – (10) | – (10) | – (10) |
| | Supply of complex products (systems and subsystems) | + | – (10) | – (10) | – (10) |
| | Number of suppliers by part/assembly/sub-assembly: Single or dual supply | + | – (10) | – (10) | – (10) |
| *Selection and Evaluation of Suppliers* | Multidimensional criteria focusing on suppliers' skills and added value and on the background to the relationship | + | + (12, 11) | + (12, 11) | – |
| *Supplier-Customer Relationship Pattern* | Cooperative relationships based on trust and mutual commitment, frequent contact | + | – (1, 5, 2, 3, 4, 6) | – (3, 6) | – |
| | Time horizon: long-term | + | + (9, 12) | + (12) | – |
| *Communication and Information-Sharing* | Frequent. Feedback on results | + (5, 2, 8, 3, 4) | – (1, 2, 8, 3) | – (8, 3) | – (8) |
| *Involvement in Design and Engineering activities* | Frequent involvement from an early phase in new product design and development process. High levels of shared risk and benefits | + | – (9, 4) | – | – |
| *Attitude towards Quality* | Strict process and evaluation systems | + | + | + | + |
| | Problem solving: working together to find joint solutions, frequent feedback | + (5, 2, 8, 3, 4) | – (8, 3, 4) | – (8, 3) | – |
| *Delivery Practices* | Just-in-Time (JIT) | – (11, 3, 7) | – | – | – |

Legend: Facilitator "+"; Inhibitor "–"

LSCM practices: 1) Open doors policy; 2) Lean knowledge transfer; 3) Value Stream Mapping; 4) Supplier-customer multifunctional teams; 5) Lean training; 6) Acknowledgement of progress in LM; 7) Pull system; 8) Feedback on Lean results; 9) Shared-risk associations.

Key determinants: 10) Customer pressure to achieve greater ability for product integration: product and process innovation skills; 11) Level of LM implementation; 12) Degree of product and added value integration.

The following describes the process of how the critical factors were managed and how a range of LSCM practices were adopted in each of the supply networks identified. Quotes that support these statements are also given.

**SN1: dyadic relationships between the aircraft final assembly lines and the prime contractors.** As can be seen in the Table, all the initial factors were consistent with the LSCM critical factors before it was adopted, and showed themselves to be facilitators of LSCM adoption, except for the JIT delivery factor.

A series of practices were adopted to enhance the communication and information sharing factor. Firstly, joint LM training was adopted. Subsequently LM knowledge transfer was enhanced through Lean managers and the adoption of a number of tools, such as a common database with LM practices/tools/techniques and standard operations instructions. Also included was information on the sequence in which these had to be adopted and on the success and inhibitor factors found. This meant that if a plant pioneered the adoption of an LM practice, for example, the rest of the plants had access to the knowledge surrounding its adoption process. Each plant could also update its knowledge on adoption and progress, and was visible throughout the supply network. Simultaneously, key performance indicators were established on progress in LM. VSM (*Value Stream Mapping*) processes were subsequently put in place using multifunctional teams throughout the supply network with the aim of eliminating any waste, improving the integration and overall optimization of inter-organizational processes.

> *"We've got global VSMs of the programs that we share, and we're linked to Lean activity in other plants and other centers in the OEM system... and we're debating about how we do the VSM of the shared-processes … what I mean is, we can be connected because we, because all the centers that is, have implemented Lean… we work together in an integrated way." (Plant Manager, PC2).*

Joint multifunctional teams were adopted along with these practices and there was even a transfer of personnel with two basic aims in mind: improved level of LM implementation and demand flexibility. The adoption of cross-audit of LM implementation level throughout the supply network should be highlighted within this practice, that is, assessment by Lean management teams with the aim of obtaining feedback on opportunities for improvement. Together this all improved problem solving and finding joint solutions in this supply network.

Finally, the development of a pull system should be noted. Inter-organization kanbans were adopted with a view to achieving and reducing inventory levels. This was made possible by one of the key determinants identified, the high internal level of LM implementation in the two tiers of this supply network, and the development of joint VSMs for a continuous flow. This has all led to progressively overcoming the initial JIT delivery-related inhibiting factor.

> *"We've all got connected VSMs now with the same aim of reducing inventory, with kanbans between one plant and another ... if some operation we're doing here we pass it on to there or an operation here, let's say on the inter-center level, to optimize the common process, the global process... I mean, all the centers have implemented Lean to some extent or other… we're integrated and work together now." (Plant Manager, PC3).*

**SN2: dyadic relations between the OEM and Tier 1 suppliers.** Firstly we highlight the initial factors that facilitated LSCM adoption. On the one hand, the long-term relationship time horizon between the two parties. Supplier selection and evaluation is also linked to the historical background to the relationship and criteria other than cost, mainly connected with quality and its certification.

In other respects, the inhibiting factors related to the supply chain structure should be highlighted. There were very high numbers of base suppliers supplying the OEM. There was also a very high level of vertical integration, with the OEM being responsible for the whole design process and even the management of supplier base's purchases. Suppliers were also "build-to-print" manufacturers and did have low product and process innovation skills. Along with the small size of the suppliers and the widespread atomization, this meant that parts were supplied by an extremely high number of suppliers instead of single or dual system/subsystem supply. Consequently, this supply chain structure involved a high level of complexity on relationship management, physical flows, and high supply variability, which was a major barrier to adopting the LSCM strategy.

*"What we had before, it was just unworkable, we gave our suppliers the raw materials, we managed them … Not anymore, there's been a change in the trend, it makes it easier..." (Plant Manager, FAL-1).*

*"In the old program, they weren't only outsourcing the part to you, they also gave you all the means so you could manufacture it and, well, of course, in that sense it's not Lean at all … It was all very complicated… So that's a great handicap for implementing Lean… what I mean is, there were non-linear relationships between the buyer and the supplier, a spaghetti chart, and that's just not flexible, it's not agile, it makes it all hard." (Plant Manager, T1-3).*

Consequently, the first measure that the OEM adopted was to restructure its supply network through greater pressure on demands regarding the ability for product integration and suppliers managing their own purchases/supply chains (*turnkey projects*). The customer thus increased his requirements so as to obtain suppliers that were larger in size through mergers, acquisitions, consortiums, etc.

*"We pushed them, from the top … to get them to merge and form big Tier 1 suppliers working directly with us." (Plant Manager, PC3).*

The first LSCM practice adopted in this respect was the creation of multifunctional Tier 1–OEM teams for the design and development of high added value systems and subsystems from an early stage. This was done with high shared-risk and long-term relationships, and increased relationship time horizons compared to earlier contracts. However, we found that these teams were formed with the Tier 1s that manufactured the highest added value parts/sub-systems.

The OEM simultaneously upped its requirements for improved key performance indicators through LM adoption.

*"As we've improved our KPIs we're much more demanding, we've been demanding a lot more… we're more demanding of the suppliers… it was a way of urging them on and getting them to adopt LM." (Plant Manager, PC1).*

> *"Our customer is a pull factor, a facilitator, that's obvious… we adopted Lean because our prime contractor pulling us along has been running quite a few years longer than us and it's something that we implemented because on the one hand we were convinced it works, and because of the needs imposed by the customer." (Plant Manager, T1-5).*

It should be noted that the OEM also adopted an open doors policy with a view to developing relationships with a greater degree of cooperation and contact and improved communication. These relationships have therefore been strengthened as the Tier 1s analyzed were already suppliers to the OEM. The aim of this practice was, firstly, to convince the suppliers of the benefits of adopting LM and of its strategic importance (persuasion to adopt LM). The OEM arranged a number of meetings to provide information about progress made in LM implementation in its plants. This process was built up as time went on with the aim of improving contact and continuing learning on LM (e.g., the OEM invited its suppliers to help define and develop its internal VSMs).

The OEM subsequently rolled out training initiatives on the most relevant aspects of LM adoption (this type of initial training was developed with support from public administrations and clusters) with the intention of convincing suppliers of the need to adopt LM. We also discovered that in the future the OEM plans to promote supplier integration through joint training programs.

> *"We implemented it because our customers who were beginning to implement Lean indicated we should, then they called a number of meetings at their place which we logically attended (…) And we've also attended courses and talks the customers have given on Lean…, there were some talks to explain what Lean was, where they told us how important it was, well, why we needed to implement Lean." (Engineering Manager, T1-6).*

The OEM next transferred knowledge on the LM adoption sequence and the success and inhibiting factors that could be encountered along the process (mainly through audits). In many cases the Tier 1s began to adopt LM by replicating the tools and practices adopted by the OEM. We also found that the OEM intends to continually augment Lean knowledge transfer.

*"We don't want them to do Lean on their own, we want them to have a replica of Lean models… we know that's where success lies, not in us but in the entire supply chain, and those who've got Lean …" (Plant Manager, PC2).*

*"We followed all the right steps in adopting LM. We began with 5S, visual management, before other tools, also because the customer is on top of us and wants so-and-so because of this, that and the other." (Plant Manager, T1-1). "They stress the things we can't do wrong, through their own experience in implementing a Lean system in their plants." (Plant Manager, T1-2).*

The OEM has also developed supplier development policies by sending out Lean support groups. In this way the OEM has led the development of a range of pilot VSM projects, involving its Tier 1s with a view to eliminating waste in the value flow. This has helped to begin to improve joint problem solving. The OEM is also planning to drive up the use of this practice in order to achieve greater inter-organizational process integration.

*"Now we go right into their facilities, and have VSMs in place right throughout the supply chain… we get the suppliers who are involved in it just like everyone else who's involved, because we depend, we really depend a lot on them." (Plant Manager, PC1).*

The existence of Tier 1-OEM multifunctional teams should also be highlighted. However we detected that this practice is still in its very early stage (embryonic stage) as we only came across it in the FALs and only then depending on the type of product supplied by the Tier 1. Finally, we found that the customers were just beginning to acknowledge the progress made by their suppliers in LM. This acknowledgement is basically connected with the suppliers' chances of getting new contracts. In fact, the Tier 1s value the customer's positive recognition of the progress that they have made in LM.

*"At a meeting in our plant they asked about the Lean measures we had documented and they congratulated us on that … In future I think it would be good for it to be valued because, after all, we made an effort and we got the result." (Plant Manager, T1-5).*

However, there is currently a hierarchy for new contracts that depends on the ability to supply (level of product integration and management of supply base) and costs. In spite of this, suppliers are beginning to be assessed according to their level of Lean implementation.

It needs to be underscored that joint adoption of these LSCM practices helped strengthen the cooperative relationships in this network, with increased contact and mutual commitment between the OEM and the Tier 1s.

The frequent feedback on LM results also needs to be highlighted, especially the results regarding improved delivery times, reliability of delivery and quality indicators.

> *"Now the OEM shares the KPIs indexes with the suppliers, delivery and quality indicators, for example, and so on. They now measure the reliability of the suppliers' deliveries, they make it public and share it with all the suppliers. There's been a distinct change in these 2 or 3 years and it's going to carry on" (Plant Manager, T1-2).*

The joint adoption of the above—mentioned LSCM practices (open-doors policy, LM knowledge transfer, VSM development and feedback on LM results) is improving the level of communication and information sharing within this network. The VSMs, the feedback on LM results and supplier-customer multifunctional teams are also improving joint problem solving.

With respect to the initial facilitating factors, the supplier selection and assessment criterion has been broadened to include the degree of product integration and added value, and the level of LM implementation has also been included. The time horizon of relationships with Tier 1s has also been lengthened compared to previous contracts, due to the ability for product integration and, above all, the shared-risk associations in high added value products.

**SN3: dyadic relationships between the OEM and the Tier 2 suppliers.** The factors evaluated with respect to the supply chain structure acted as inhibitors, as they were common to the entire supplier base. However, these suppliers, whose customers gradually became the Tier 1s, were characterized by the supply of low value products. The OEM began by increasing its demands regarding their ability to integrate simple subsystems instead of mere parts, and to manage their own supply chains through mergers, forming groups, etc., with the aim of getting the global supply network restructured and reducing the external variability that they originated.

> *"Here you have to be improving all the time and offering the customers more and more services and more management and everything … but, apart from that, we are becoming part of a group now so we can tie down our contracts." (Plant Manager, T2-2).*

We found the following initial facilitating factors for LSCM adoption in this network: a strict quality assessment systems process; time horizon of the relationship with suppliers and their selection and evaluation (regarding quality and certification).

In the Tier 2s that were analyzed we found that even though the OEM stated that both the initial open doors policy and training were deployed in the same way to all its suppliers, the welcome that they received was not the same in all cases.

> *"With the supplier atomization that we had previously, when, a few years back, you mentioned Lean to them, they just stood there gawping …, and when you tried to put your foot down a bit to get them to come to a Lean initiative, a VSM or something like that, well, they simply didn't bother." (Plant Manager, PC2).*

> *"When did it become evident that we had to improve? When they said in the audits that the shop floor standard was low, really low, and that the situation that existed might even put the production flow at risk, or they saw major failings … and every year we said the same thing, and all the action plans were there to be passed on to the customer, but not to be put into operation." (Plant Manager, T2-3).*

The first effective LSCM practice to involve the Tier 2s in a Lean initiative was a pilot VSM project to eliminate waste in the value flow. However, the real objective was to break down initial resistance to LM so that they would adopt it internally. Training in basic Lean tools also stands out as does the transfer of Lean knowledge in VSM deployment.

> *"We really started to make progress in Lean with the OEM's VSM project and it gave us this opportunity and, well, we were grateful and took it with both hands, great, … to do it with someone showing us the way and, well, great … at the talks we have about their project, they're to study the value flow. The two courses I've been on were standardization and 5S. But up to now the customer hadn't played a major role, only the current VSM project, which is the first initiative we're taking part in." (Production Manager, T2-2).*

We also found frequent feedback on the outcomes of LM implementation, especially regarding delivery times, delivery reliability and quality indicators, along with LM beginning to receive recognition.

> *"The customer is running a VSM initiative and one of the auditors… and when they assess the suppliers, one of the things in our favor is Lean implementation, it gets you points." (Plant Manager, T2-1).*

Deploying VSM and recognizing advances in LM have initially achieved increased cooperation and contact. These practices are also improving communication and information sharing levels and problem-solving in quality.

With respect to the initial facilitating factors, we find that the criteria for selecting and evaluating them have been extended (including a growing evaluation of the product integration skill and the level of LM implementation). The time horizon for relationships with some suppliers has also been increased compared to previous contracts due, mainly, to the integrated management that they are achieving. This has only been the case of Tier 2 suppliers that still have contracts with the OEM (old aerospace programs) and still might be given new contracts, but only in mature technologies and not the strategic technologies (parts and simple subsystems) in the new programs.

> *"We work for the OEM and for the Tier 1s, too. Before, when there was no integrated management, we didn't have a fixed contract with the OEM. The cadences/timings of the orders were shared among several suppliers. Today, and with every day that passes, we're getting greater control of the program, thanks to integrated management (…) We've been lucky enough to still be suppliers, but others have fallen by the wayside and they'll tell you right the opposite…". (Plant Manager, T2-1).*

> *"We work almost exclusively for the Tier 1s, 90% of what we do, and now the long-term relationships are mostly between the OEM and the Tier 1s, and they're very long-term, but between the Tier 1s and the Tier 2s they're certainly not." (Plant Manager, T2-3).*

**SN4: dyadic relationships between Tier 1 and the Tier 2 suppliers.** As previously commented, this supply network has just emerged as the Tier 1s did not manage their purchases. As a result, all the factors acted as inhibitors since new relationships had to be forged; except for the suppliers´ selection and evaluation factor (because in order to be a supplier in this industry is required to be certified). In spite of this, the Tier 1s state that this latter causes problems for creating a new supplier base as it leaves very little room for action in the supplier selection criteria, given that there are very few certified suppliers of some specific parts/subsystems. As a result, there is very little room for bargaining.

*"As far as selection criteria are concerned, the problem is they're certified…, and the problem is that for some things you've only got one or two certified suppliers." (Plant Manager, T1-2).*

Despite the complexity inherent in setting up a new supply network, we find a facilitating factor connected with the fact that most of the suppliers with which new relationships were created had had or still had relationships with the OEM.

*"Right now, the customer has no responsibility over our suppliers, we do. The thing is, a lot of these suppliers have had relationships with the customers at some time or other, and they're more conscientious, it's easier to demand more from them, as otherwise …" (Plant Manager, T1-6).*

The Tier 1s have been seen to be fully engaged in the process of establishing LSCM-oriented supply networks.

*"The change we've gone through with our suppliers, it's been dramatic because they simply didn't exist before. So we had to start from scratch … from naught to a hundred, just like that … with nearly everything to do… and it's a long race that's going to be run over a long time … and we're right in the thick of it." (Plant Manager, T1-5).*

The Tier 1s have been found to have used the same LSCM outsourcing strategy to create their new supply network as the OEM used with them as part of its global supply chain strategy. Firstly, with respect to rationalizing the supply base, an attempt was made to set up relationships with a small number of suppliers and to gain their loyalty. Secondly, performance standards and periodic reports were introduced to establish corrective actions. Finally, greater demands were made of the Tier 2s for supplying the products with greater integration and management of their own suppliers.

> *"We've tried to rationalize our suppliers right from the get-go because we just can't handle so many … the supplier base has been rationalized … at the start we had to take the step of rationalizing the supplier base … and now, to a certain extent, with integrated management we can guarantee a greater and more stable workload for our suppliers" (Plant Manager, T1-3).*

> *"We've chosen some working standards for our suppliers and some monthly metrics for defects, deliveries, and so on and we require a number of corrective actions… We set a supplier network in motion with our pilot scheme, where we audited them and certified them … and it's consolidated and been standardized and it's going to carry on." (Plant Manager, T1-1).*

> *"Almost everything we're contracting is managed by the supplier on their own, their own supplier chain, at least, and the end goal is to make the same demands of our suppliers as are be made of us." (Plant Manager, T1-4).*

As such the only LSCM practice identified was feedback on LM results. Despite this, the Tier 1s comment on a range of problems linked to the Tier 2s' lack of capabilities. It should be highlighted that the "spaghetti chart" -where raw materials/parts are supplied to some of their suppliers- continues to exist.

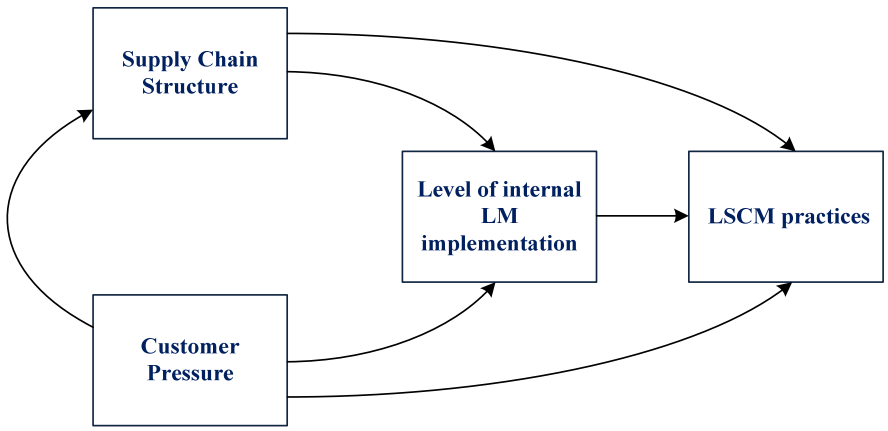
> "Our supply chain is still complex because generally-speaking, what you buy from a supplier is not a finished part, you still carry on supplying them with raw materials and elemental parts…, and that makes it complex (…) We're working with the supply chain to get a certain degree of reliability in deliveries, and in quality too, that goes without saying, but above all with respect to quantity, which is our biggest problem … We began where we saw the biggest failings were." (Plant Manager, T1-3).

> "Until a short time ago the raw material, the parts and what have you, were supplied to us by our main customer, a Tier 1, but now we're having to start buying them in ourselves. At the present time some 90% is supplied by the customer and the other 10% is what we purchase ourselves." (Plant Manager, T2-3).

#### 4.5.2. LSCM Adoption Model

After analyzing how the factors that were critical at the supply network level were managed, a cross-case analysis was done that enabled a series of key determinants explaining LSCM adoption to be identified. These are: a) Customer pressure, which is defined as the bargaining power that the customer exerts on its suppliers (Porter, 1980); b) a supply chain structure characterized by the following elements that are consistent with LSCM: a small supplier base, low vertical integration, supply of complex systems and subsystems, single or dual supply (Lamming, 1996; MacDuffie and Helper, 1997; Arkader, 2001); c) Internal LM level measured on the Shah and Ward (2003) scale. These determining factors should not be observed in isolation but are interrelated in the ways shown in the following LSCM adoption model.

**Figure 4.4**
LSCM adoption model




It can be observed in the model that customer pressure is related to: 1) The supply chain structure in keeping with LSCM characteristics, 2) The internal level of LM implementation, and 3) The adoption of LSCM practices.

The main customer pressure for LSCM adoption is connected firstly with restructuring the supply chain to facilitate the adoption of Lean throughout the supply chain. However, if the supply chain adheres to LSCM characteristics, customer pressure can focus on the internal level of LM implementation and/or the adoption of LSCM practices with this same aim.

This is due to the fact that the supply chain structure influences on the internal level of LM implementation. In other words, a structure that is not in keeping with these characteristics and/or intermediate states where this has not stabilized can act as a curb on LM implementation on the internal level.

The supply chain structure was also seen to influence on the adoption of LSCM practices. For example, an intermediate state in the transition towards an LSCM supply chain structure can result in resources being focused exclusively on the transformation and, consequently, does not allow and/or acts as a curb on the adoption of certain LSCM practices in the supply network. Also, if the aim is to achieve certain supply chain characteristics, such as the supply of systems and subsystems, the adopted LSCM practices can be focused on this aim.

With respect to customer pressure on the level of internal LM implementation, this plays a major pull role in achieving an effective LSCM strategy. The internal level of LM implementation influences on the adoption of LSCM practices, precisely, and therefore also the progress made in LSCM strategy. To put it another way, depending on the internal level of LM implementation, the adoption of LSCM practices will have to be adapted so as to implement the practices that are most suitable for achieving different objectives. Thus, if the internal level of LM implementation is zero or very low, the customer will require LSCM practices to be adopted that encourage suppliers to adopt or improve their internal levels of LM implementation. Whereas, to give another example, if the internal level of LM implementation is high, advanced LSCM practices can be adopted in order to achieve greater inter-organizational process integration between the LM systems.

Finally, customer pressure for the adoption of LSCM practices will define strategy throughout the supply chain. Depending on the importance of the key members, the customer can adopt one type of LSCM practice or another, not only with its suppliers situated on an immediate or direct level, but also other levels regarded as strategic that play a key role in LSCM strategy on the level of the network as a whole.

This generic LSCM adoption model needs to be adapted to the peculiarities of each of the supply networks analyzed but without losing sight of the aerospace sector's comprehensive supply network approach.

SN1. Dyadic relationships between the aircraft final assembly lines and the prime contractors. Firstly, external end-customer pressure was the factor that triggered LM adoption. With respect to the supply chain structure, this was consistent with LSCM characteristics, but this specific supply network had interrelationships with its supplier base. The impact of atomization, the complexity of the relationships with suppliers and the resulting variability of supply therefore meant that the first thing that had to be done was to restructure the initial supply chain. The OEM later adopted LM on the internal level, but, nevertheless, had to shore up its production/assembly flows with inventory *buffers* due to high supply variability (lead times, quality) in order to prevent stoppages that might delay LM adoption. The structure of the whole supply network therefore influences on the internal level of LM implementation. Despite this, the supply chain structure enabled advances to be made in both the internal level of LM implementation and the adoption of LSCM practices designed to improve the level of implementation.

SN2. Dyadic relationships between the OEM and Tier 1 suppliers. The supply chain structure was an inhibiting factor. Customer pressure therefore firstly focused on restructuring the supply chain in order to improve product and process innovation skills, and own supply chain management. Consequently the first LSCM practice adopted was oriented at creating multifunctional product design and development teams through long-term shared risk relationships. Customer power then turned to its suppliers adopting LM. For this the customer adopted a number of LSCM practices designed to drive up LM adoption by its suppliers and their internal levels of LM implementation. This and stabilizing this supply network's structure in line with LSCM characteristics enabled progress to be made in the internal level of LM implementation.

SN3: dyadic relationships between the OEM and Tier 2 suppliers. The supply chain structure showed itself to be an inhibiting factor for LSCM adoption. Firstly, customer pressure focused on supply chain restructuring seeking a greater ability for the integration of simple subsystems and own supply chain management. The goal was to restructure the entire aerospace supply network and reduce the external variability caused by the Tier 2s both in the OEM and the new Tier 1s. The OEM did not adopt any LSCM practice for this, however, unlike in the previous network (e.g., shared risk relationships). This can be explained by the type of product supplied, which is technologically mature, not strategic and with low added value, and also because this type of relationship is gradually dying out. Customer pressure subsequently focused on these suppliers adopting LM internally. Curiously, we find that despite a range of LSCM practices being adopted with the objective of achieving LM adoption, these were not readily accepted. As a result, the OEM involved the suppliers in VSM projects in order to overcome this initial resistance to LM and to encourage them to adopt LM internally. This initial resistance can be explained by the transition of these suppliers to a new level in the supply network.

SN4: dyadic relationships between the Tier 1 and Tier 2 suppliers. This supply chain has only emerged recently. Customer pressure focused on it being set up with LSCM characteristics. However, problems have been found related to the Tier 2s' lack of process and product innovation skills, and their low internal level of LM implementation. What is more, this supply chain continued operating with a spaghetti chart, where the Tier 1s often supplied raw materials/parts to their supplier base. As a result, customer pressure focused on demanding greater ability for integrating simple subsystems and own supply chain management. However, based on a network approach, the Tier 1s have been found to be almost simultaneously managing a triple strategic change: 1) Greater product and process innovation skills (SN2); 2) Improving the internal level of LM implementation (SN2); and 3) Establishing and managing the supplier base (SN4). This complexity has led to no LSCM practice being adopted except the "soft" practice of feedback on LM results. This can be explained by the proposed model since an intermediate state in the transition towards the LSCM supply chain structure has meant that resources are focused on this reconfiguration. It can also be explained by the relatively low customer's bargaining power urging the Tier 2s to move forward in the internal level of LM implementation.

#### 4.6. Conclusions, Implications for Management and Future Lines of Research

LSCM strategy adoption is a competitive priority in many industries as companies do not compete as entities, but as whole supply networks. However, LSCM adoption presents many challenges on the practical level as a result of increases in complexity, length and globalization, and contingent factors relating to different industries (Mollenkopf et al., 2010).

The aim of this study is to move forward in research on the LSCM adoption process. Both the changes required before the adoption process and the process itself are analyzed in this respect. We have used a network and contingent approach for this and analyzed four supply networks with vertical dyadic relationships, thus overcoming one of the weaknesses of prior research on supply chain management (Seuring, 2008).

Our findings show how four supply networks having to contend with different contingent factors have managed a range of key determinants -customer pressure, supply chain structure and internal level of LM implementation- and how they have adopted a range of LSCM practices in order to enhance the facilitating factors and overcome the inhibiting factors that were evaluated. Some of these LSCM practices add to and complement those proposed by other authors (Lamming, 1996; Simpson and Power, 2005; Shah and Ward, 2007; Wee and Wu, 2009). However, our findings show how these practices should be adapted to the facilitating and inhibiting factors found in each of the networks. An adoption model has also been proposed that enables us to discern the interrelationships that exist between the key determinants and the LSCM practices.

This adoption model considers each of the supply networks analyzed and demonstrates that supply chain structures not in keeping with LSCM characteristics, or intermediate states that make the transition process complex, affect the internal level of LM implementation and the adoption of LSCM practices. These findings are in line with Choi and Hong (2002) and Choi and Krause (2006), who state that reducing supplier base complexity can also increase risk and variability in the entire network in certain circumstances.

Our findings also show that customer pressure acts as a pull factor for LSCM adoption in three ways: restructuring the supply chain, internal level of LM implementation and adoption of LSCM practices. Dependence on the key company in the supply network is therefore one of the factors that conditions adoption. These findings agree with those of various authors (Cox et al., 2007; Sousa and Voss, 2008; Akbulut-Bailey et al., 2012). The OEM therefore initiated LSCM adoption with its key Tier 1 suppliers and, subsequently continued with its Tier 2 suppliers, which were gradually turning into supplier base of the Tier 1 suppliers. This finding is in line with Narasimhan et al. (2009) and relates to centralization or the degree to which the power authority for decision making is concentrated. Thus, due to its proximity to the customer, the level with the highest degree of centralization plays a crucial role in establishing a market strategy, the network structure and the adoption of management systems like LSCM. This corroborates the findings of Ehret and Cooke (2010), who propose that the supplier's knowledge and technological ability should be incorporated into LSCM theory. In other words, as the type of product supplied by the Tier 2s was technologically mature, not strategic, and with low added value, the OEM focused LSCM adoption on its Tier 1s in the first instance as they possessed greater technological capabilities.

With respect to the LSCM practices that were identified, this study adds to and complements proposals made by other authors (Lamming, 1993, 1996; Wu, 2003; Simpson and Power, 2005; Shah and Ward, 2007; Wee and Wu, 2009). However, theoretically it differs from their proposals as our findings show how to adopt these LSCM practices depending on the initial facilitating and inhibiting factors evaluated during the adoption process. Our findings therefore confirm that LSCM practices have a positive influence on the level of both suppliers' and customers' LM implementation in the long term, and improve the overall results of the Lean supply network (Simpson and Power, 2005; So and Sun, 2010).

Finally, we found that the focal company (OEM) has adopted LSCM not only with its Tier 1 suppliers, but also its Tier 2s, as it is aware of the impact that the supplier base has on the variability that arises throughout the entire supply network. These findings are therefore in line with those of various authors (Lamming, 1996; Womack and Jones, 1996) who emphasize that a successful LSCM strategy must adopt a network approach.

In the following we offer a number of implications that might be useful for managers responsible for managing the supply chain who are thinking about adopting an LSCM strategy. Table 4.3 could act as a guide for evaluating the initial factors found in the supply networks in the industry in which they operate. This evaluation is important for gaining prior knowledge of the factors that might turn out to be either facilitators or inhibitors. Subsequently, after evaluating and informing themselves of the situation that their supply networks are in, they can adapt the management of key determinants and the adoption of certain LSCM practices sequentially in order to enhance the facilitating factors and to overcome the inhibitors. The key determinants and the LSCM practices must be considered jointly for this.

Thus the first step in LSCM must be to restructure the supply chain in line with LSCM characteristics and, more specifically, from a network perspective, in order to obtain a structure that facilitates its adoption. For this bargaining power must be focused on restructuring and also adopting LSCM practices designed to achieve restructuring. Not having this type of supply chain structure affects the internal level of LM implementation in the companies that make up the supply networks. However, networks that do have an LSCM regulated structure will have built up momentum that facilitates LSCM adoption. In this way they can focus their bargaining power on driving up the internal level of LM implementation and/or the adoption of LSCM practices in order to make advances in LSCM strategy.

As far as study limitations are concerned, it must be noted that the study is qualitative and exploratory and has been conducted in a specific industrial sector, as a result of which generalization of the findings is limited. In spite of this, the initial inhibiting and facilitating factors that were empirically evaluated in each of the supply chains analyzed can be found in other industrial contexts apart from the aerospace sector. We therefore have no reason to believe that the key determinants identified and the LSCM practices adopted cannot be valid for overcoming inhibiting factors and enhancing facilitating factors in other contexts. However, although the proposed adoption model identifies the relationships between the key determinants and the LSCM practices, we have not been able to measure their intensity. Also, although a network approach has been used, we have only analyzed vertical dyadic relationships.

For these reasons, as future research we propose testing the proposed model in other industrial and geographical contexts, in keeping with a process of logical replication. Greater research is also proposed to measure the intensity of the relationships identified. This should combine qualitative and quantitative methods in order to overcome the above-mentioned issues with generalization and enable the concept to be further developed. Finally, it is necessary to emphasize that research into LSCM should adopt a network approach to enable the phenomenon to be understood holistically. It would therefore be interesting to move forward in the study of the set of dynamic relations throughout the whole network, i.e., the study not only of vertical dyadic relationships, but also of horizontal and triadic relationships.

#### 4.7. References

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