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TOWARDS A THEORY FOR LEAN IMPLEMENTATION IN SUPPLY NETWORKS

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Abstract

This paper aims to investigate the supply network (SN) characteristics affecting the extension of lean programmes to SN and the interactions between lean practices and these characteristics to understand how to create more favorable conditions for lean extension programmes. A multiple case study methodology is implemented to analyze different lean programmes in SNs and different contextual conditions in which they are implemented. Three different SNs have been analyzed to provide insights on the whole value stream of the Andalusian aeronautics SN. This study finds that there is a recursive influence between SN characteristics and lean practices, and explains how this interaction takes place. The choice of lean practices to adopt, their aim and implementation mode are influenced by the state of SN characteristics companies face at the beginning of the programme and the SN distance (i.e. number of SN echelons) between lean knowledge owners and recipients. This study explains also how lean practices can modify the state of SN characteristics and suggests managers a sequence of phases and sets of actions to use depending on the initial state of SN characteristics.

Keywords: Lean Management, Supply Network Characteristics, Aeronautics

Paper type: Research paper

1. INTRODUCTION

Originating from the Toyota Production System as a method to systematically reduce waste and maximize value in manufacturing processes, lean is now being adopted also in non-production areas. Womack and Jones (1996b) and Liker (2004)'s books contributed to expand the scope of lean beyond manufacturing by distilling the essence of lean into principles applicable to any organization. Womack and Jones (1996a)'s article represents a further step in lean evolution. Here the authors claimed that lean principles should be applied beyond firms' boundaries to maximize value to customers. Companies in SNs should cooperate and use lean practices to improve the value streams involved in supplying goods or services to final customers. Existing research seems to agree that expanding the scope of lean programmes to SNs requires the involved organizations to implement lean within each company and at the interfaces across-companies (Kannan and Tan, 2005; Hsu et al., 2009; Danese et al., 2012; Chavez et al., 2015). In other words, each SN member should adopt lean internally to become a so-called "lean company" (Womack and Jones, 1996a), and the network of lean companies should be connected using lean at their interfaces. One of the most common cases of extension of the scope of lean programmes is a lean company which decides to diffuse lean to its upstream SN (Wee and Wu, 2009). However, Choi et al. (2001) provided a vivid description of how the individual firm's efforts to manage SNs are often unsuccessful due to the dynamic and complex nature of SNs. In addition, Nahapiet and Ghoshal (1998) observed that each company is "embedded" in its SN as its decisions can change the characteristics of the network but are simultaneously influenced by these characteristics. Viewed through the contingency theory lens, this phenomenon happens since companies should adapt their strategy to maintain fit with their changing context (Donaldson, 2001). From the literature it is known that certain characteristics of SNs such as the relationships among counterparts (e.g., Simpson and Power, 2005; Moyano-Fuentes et al., 2012), the SN structure (e.g., Hines, 1994), and the level of adoption of lean within the individual companies (e.g., Womack and Jones, 1996b) can affect the possibility to extend lean to SNs. However, as Taylor (2006) notes, most of previous contributions concentrate on outlining long term benefits of lean in a SN, while they don't adequately investigate the pre-requisites and actions to favor the extension of lean to SNs. Recent research on embeddedness in SNs (Kim, 2014) indicates the mutual influence between the firm and its SN as an interesting and relatively unexplored research area. The embeddedness concept and the contingency paradigm seem to admit that SN characteristics can influence the implementation of lean practices within the companies and at their interfaces and simultaneously such lean practices can change the network characteristics creating new conditions that can influence the adoption of further lean practices. However, from the literature it is not clear how this interaction takes place. This paper intends to investigate the mutual influence between lean practices and SN characteristics during the programme for the extension of lean to the upstream network of a lean company with a leading position in its SN. The aim is to provide managers with a theoretically robust and empirically grounded interpretation framework which can increase their understanding of the dynamic relations between SN characteristics and lean practices and supports their decision making during the implementation of lean practices across SNs.

The paper is organized as follows. The literature review discusses the practices commonly implemented to extend lean programmes to SNs and identifies the SN characteristics which can influence this extension. The methodology section motivates the choice of the multiple-case study method and case selection. After the cases description, we will conclude with the analysis and discussion, conclusions and implications for future research.

2. THEORETICAL BACKGROUND

2.1. Extending lean programmes to SNs

Inspired by the seminal works of Lamming (1993) and Womack and Jones (1996a), many companies, after having launched lean implementation programmes to eliminate internal waste, concentrate on improving extended value streams, which requires the involvement of SN counterparts. From the literature it emerges that extending the scope of lean programmes to SNs requires the implementation of practices coherent with lean principles both within the individual companies and at their interfaces.

As Shah and Ward (2007) stated, lean can be defined as an integrated socio-technical system that aims at eliminating waste by reducing internal and external variability along the supply network. Therefore, the extension of lean programmes should include practices that involve suppliers in finding and reducing problems that affect internal and external processes (Jones and Womack, 2002; Taylor, 2006; Bortolotti et al., 2015a; Bortolotti et al., 2015b; Chavez et al., 2015). As the main aim of the extension of lean programmes is to minimize variability in the SN, all the SN actors should streamline and align their internal production systems, and connect them by ensuring that suppliers deliver just-in-time (Shah and Ward, 2007). However, to be able to obtain the full adoption of lean in the SN, it is important that SN actors are committed, share the same lean knowledge, and their production systems are synchronized (Dyer and Nobeoka, 2000; Simpson and Power, 2005; Agnan and Nilsson 2008; Chavez et al., 2015). Past studies describe practices used to transfer lean knowledge, increase commitment and align production systems, that can be either implemented in a one-way mode (i.e. from customer to supplier) or in a bi-directional mode (i.e. from customer to supplier and vice-versa) depending respectively on the unbalance (on-way) or balance (bi-directional) of knowledge, commitment and alignment of customers and suppliers.

Based on these premises, we classified practices for extending the scope of lean programmes to SNs into four groups: supplier involvement, knowledge transfer, lean programme commitment and lean programme alignment. Table 1 reports the practices considered, their definition and scope (i.e. internal vs. interface).

2.1.1. Supplier involvement

The first group of practices is related to the involvement of suppliers in identifying and reducing waste in the internal systems and at their interface.

Jones and Womack (2002) describe the extended value stream mapping (EVSM) as a practice that involves SN counterparts in joint improvement initiatives addressing a wide range of processes, from materials management to design. The main goal of EVSM is to identify waste along the SN and find possible solutions to reduce it (Wee and Wu, 2009). Simons and Taylor (2007) argue that SN actors should map material and information flows within and between plants and assess the related performance targeting the final customer requirements. Other scholars focus on the design process and describe supplier-customer new product development (NPD) teams as a relevant interface practice that exploits both customer and supplier expertise to reduce errors, speed up time-to-market as well as satisfy final customer needs (Arkader, 2001; Ehret and Cooke, 2010). External expertise can be also useful to make lean tools more effective in solving problems affecting internal production processes. In particular, supplier-customer lean problem-solving teams are often created to reorganize process flows within a plant (Simpson and Power, 2005; Taylor, 2006). Supplier involvement is also crucial to introduce a pull system at the customer-supplier interface (Bortolotti et al., 2015b; Chavez et al., 2015). According to this practice, customers receive small lots of materials at regular and short intervals following the pace of the end-user demand, thus increasing operational performance of the entire SN (Danese et al., 2012).

2.1.2. Lean knowledge transfer

This set of practices refers to the transfer of knowledge on lean between actors in SNs.

Lean training support is a practice commonly adopted by lean companies to transfer their knowledge to suppliers that start their lean transformation. It often takes the form of basic training courses and implies an intense teaching effort for the customer (Simpson and Power, 2005). As observed by Dyer and Nobeoka (2000), the success of Toyota largely depends on its effectiveness at facilitating inter-firm transfers of explicit and tacit knowledge. While explicit knowledge refers to easily codifiable information and could be transferred during basic training courses, tacit knowledge involves know-how that is complex to codify and difficult to transfer with the basic training support, thus more effectively addressable through guided tour of the customer's plant (i.e., open-door policy). Transfer of lean knowledge can occur not only when there are differences in lean competences between partners, but also when companies show similar expertise. In this case the transfer can be bi-directional. For example, Bruun and Mefford (2004) maintain that the creation of a shared database facilitates mutual learning about lean successful experiences of SN partners.

2.1.3. Lean programme commitment

The extension of lean programmes to SNs often starts from a lean company that has to stimulate non-lean counterparts to implement lean. Dyer and Nobeoka (2000) describe how Toyota monitors suppliers' progress in their lean implementation and rewards partners who make exceptional contributions to the network by giving them additional business. Lean customers can also punish suppliers to deter opportunistic and adverse behaviors by reducing or even making them lose business (Simpson and Power, 2005). In any case, providing regular acknowledgements of lean progress to suppliers helps them to feel motivated and continue the lean transformation (Dyer and

Nobeoka, 2000). Extending lean programmes to SNs does not require commitment exclusively from suppliers. Incentive schemes based on risk and benefit sharing mechanisms are widely employed when both customers and suppliers are experienced lean companies (Cox et al., 2007). Simons and Taylor (2007) suggest that these kinds of incentives help prevent opportunistic behaviors and create trust among the counterparts.

2.1.4. Lean programme alignment

When suppliers are in the early stages of lean adoption, more experienced customers usually ask them to regularly share their results in terms of level of practices implemented and performance achieved (Dyer and Nobeoka, 2000). As claimed by Taylor (2006), feedbacks on lean results lead experienced lean customers to control that their suppliers achieve the expected results. Cost transparency (Lamming, 1993; Romano and Formentini, 2012) is a further way to align the efforts of SN actors. Unlike feedback on lean implementation progress within individual companies, cost transparency implies that customers and suppliers share information on internal processes, costs and others KPIs to receive external suggestions for process improvements (Perez et al., 2010). Agndal and Nilsson (2008) claim that this practice is not only an “effective tool” for eliminating waste but it also leads to an increased trust, commitment and alignment between SN members.

Group of lean practices	Lean practice	Definition	Source	Scope
Supplier involvement	Extended value stream mapping	Tool used to (1) identify waste (2), find possible solutions, (3) raise awareness among suppliers on importance and feasibility of extending lean programmes to supply networks.	Jones and Womack (2002); Taylor (2006); Simons and Taylor (2007); Wee and Wu (2009); Perez et al. (2010)	Internal and interface
	Supplier-customer NPD team	Early involvement of suppliers in new product design process. The aim is to satisfy the final customer by exploiting both partners' expertise.	Arkader (2001); Ehret and Cooke (2010); Moyano-Fuentes et al. (2012); Chavez et al. (2015)	Interface
	Supplier-customer lean problem-solving team	Inter-organizational team with the responsibility and authority to indentify and implement process improvements by exploiting both partners' expertise.	Dyer and Nobeoka (2000); Simpson and Power (2005); Taylor (2006); Perez et al. (2010); Bortolotti et al. (2015a); Bortolotti et al. (2015b); Chavez et al. (2015)	Internal and interface
	Pull system (JIT deliveries by suppliers)	Bundle of practices (i.e., small lot sizes, frequent deliveries, vendor-kanban, milk run) to ensure that suppliers deliver the right quantity at the right time in the right place.	Arkader (2001); Shah and Ward (2007); Danese et al. (2012); Bortolotti et al. (2015a); Bortolotti et al. (2015b)	Interface
Lean knowledge transfer	Lean training support	Transfer of explicit lean knowledge to the suppliers so as to make them able to adopt lean within their company and in the supply network.	Dyer and Nobeoka (2000); Arkader (2001); Simpson and Power (2005); Shah and Ward (2007); Bortolotti et al. (2015a); Bortolotti et al. (2015b); Chavez et al. (2015)	Internal and interface
	Open doors policy	Practice that allows a partner who is not familiar with lean to visit the plant of a partner who applies lean. Open doors policy can be useful to (1) raise awareness of the junior partner and (2) to transfer lean knowledge on how to use specific practices.	Dyer and Nobeoka (2000); Arkader (2001); Simpson and Power (2005)	Internal
	Shared lean knowledge database	Shared database on best practices/procedures and hints for successful lean program implementation. It facilitates information and experience sharing and mutual learning about lean programs along the supply network.	Jones and Womack (2002); Bruun and Metford (2004); Simpson and Power (2005)	Internal and interface
Lean programme commitment	Acknowledgement of progress in lean programmes	Incentives and punishments given by the customer to the supplier depending on the progress of lean implementation programmes in supply networks.	Dyer and Nobeoka (2000); Simpson and Power (2005); Shah and Ward (2007)	Internal
	Risks and benefits sharing	Coordination mechanisms for risks and benefit sharing among counterparts involved in lean programmes in supply networks. The aim is to increase trust and commitment and to avoid opportunistic behaviours.	Lamming (1996); Arkader (2001); Cox et al. (2007); Simons and Taylor (2007); Perez et al. (2010)	Interface
Lean programme alignment	Feedback on lean results	Information transfer from the junior partner to the senior one on performance improvements achieved during lean programme implementation in supply networks.	Dyer and Nobeoka (2000); Simpson and Power (2005); Arkader (2001); Perez et al. (2010)	Internal
	Cost transparency	Sharing of proprietary information on internal processes and costs so as to allow counterparts in supply networks to align their processes and operational performance.	Lamming (1996); Taylor (2006); Perez et al. (2010)	Internal and interface

Table 1: Practices for extending the scope of lean programmes to supply networks.

2.2. SN characteristics and lean programme extension to SNs

Contingency theory proposes that not every method can be applied in any environment (Donaldson, 2001). As companies are embedded in their SNs, they are influenced by the characteristics of their networks, especially when the practices adopted actively involve actors of the same network (Flynn et al., 2010; Kim, 2014). Social network theory explains that an action can be successful when actors are well connected, while the same action can fail in the presence of “structural holes” in the network, namely when companies don’t communicate effectively and are not committed to the same objective (Polidoro et al., 2011). Basically, the success of an action depends on its fit with the context. This means that the effectiveness of lean practices may depend on the favourable or unfavourable contingent situation that companies face (Chavez et al., 2015). According to the literature certain characteristics of SNs can either facilitate or complicate the extension of lean programmes to SNs. This section discusses the most significant ones and classifies them in three groups: SN relationships, structure and leanness (see table 2).

2.2.1. SN relationships

SN relationships can be described in terms of type of inter-organizational arrangements and span of collaboration. As concerns the type, literature distinguishes between two polar cases: traditional/arm’s length customer-supplier relation and collaboration. As concerns the span, the two extremes are collaboration on a narrow set vs. a wide number of inter-firm activities.

According to Spekman et al. (1998), long-term time horizon, mutual and frequent exchange of information, and high trust and commitment between counterparts are essential characteristics that differentiate collaborations from more traditional customer-supplier relations. Lean literature provides ample empirical evidence supporting the relevance of collaborative inter-organizational relationships in facilitating the diffusion of lean across SNs (Moyano-Fuentes et al., 2012). Panizzolo et al. (2012) suggest that companies involved in extending lean programmes to their SNs should formalize long-term contracts to guarantee JIT deliveries and improve performance. As regards information exchange, Cagliano et al. (2004) demonstrate that firms implementing lean practices beyond their boundaries are characterized by frequent and intense interactions with their SN partners compared to non-lean companies. Scholars agree that high levels of trust and commitment facilitate the extension of lean programmes in SNs (Simpson and Power, 2005; Taylor, 2006; Cox et al., 2007). Simpson and Power (2005) argue that the commitment of SN partners in sharing resources is necessary to favor lean implementation. Conversely, Taylor (2006) observes that mistrust discourages investments on joint programmes for continuous improvement. As concerns the span of collaboration, literature recognizes that collaboration on a wide number of inter-firm activities favors lean implementation in SNs (Arkader, 2001). For instance, removing inter-firm boundaries between partners' production systems eases material and information flows, facilitating internal and inter-firm pull systems (Moyano-Fuentes et al., 2012).

2.2.2. SN structure

Also the SN structure can affect the extension of lean programmes beyond the single company. Since resources to develop collaborative relations are limited, the supplier base needs to be restricted to a few key suppliers (Shah and Ward, 2007). Hines (1994) and Nishiguchi (1994) describe the "keiretsu" as the SN structure that best fits with lean. Keiretsu is characterized by a reduced number of suppliers and the establishment of single- or dual-sourcing policies for each item supplied. It is crucial that companies select suppliers according to multidimensional criteria. Arkader (2001) maintains that if customers focus on price only the extension of lean practices beyond the individual company will be difficult to achieve. Indeed, suppliers' technical competencies are needed to create valuable products for the final customer, to manage the design process on an inter-firm basis, and to implement an inter-firm pull system (Panizzolo, 1998; Danese et al., 2012; Bortolotti et al., 2015b). The extension of lean programmes is facilitated by a low distance between facilities as it is extremely difficult to apply lean across global SNs (Womack and

Jones, 1996b). In fact, lean requires low inventories and frequent deliveries that are difficult to fulfill when the distance between customer and supplier's plants is high. In this case, higher inventory is necessary because of longer transit times, thus inhibiting JIT deliveries (Danese et al., 2012).

2.2.3. SN leanness

The term "leanness" identifies the level of lean implementation within companies involved in lean programmes across SNs. Literature provides different definitions of which practices a company should adopt to be considered lean. However, most of these publications refer to practices that are part of four bundles of practices; Just-In-Time, Total Quality Management, Human Resource Management and Total Productive Maintenance (Shah and Ward, 2003). Therefore, it seems generally accepted that a company that implements these bundles can be labelled as "lean company". Danese et al. (2012) argue that the successful implementation of lean at the interfaces across companies requires that the involved counterparts master internal lean practices; otherwise, a number of problems are likely to occur. Indeed, the use of internal lean practices leads companies to a cultural change (Harrison and Storey, 1996) and the establishment of values and behaviors consistent with lean principles (Womack and Jones, 1996b). Given that pursuing the elimination of all sources of waste implies reducing internal and external variability (Shaw and Ward, 2007), companies implementing lean practices internally are likely to broaden the scope of their lean systems towards other SN members, thus creating the conditions for the introduction of interface lean practices.

Table 2 summarizes the discussion above and identifies, for each group of SN characteristics, a set of associated characteristics together with their definition. The "state" of these characteristics can either facilitate or hinder the extension of programmes to the SNs. Using Fisher (1997)'s terminology, we label with "match" the state that facilitates the extension of lean programmes, and with "mismatch" the opposite state.

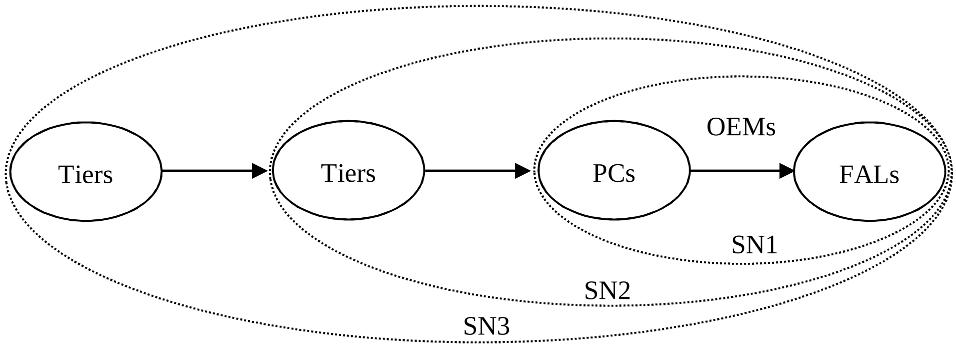
Group of supply network char.	Supply network characteristic	Definition	Mismatch	Match	Source
Supply network relationships	Time horizon	Duration of the relationship between counterparts involved in the lean programme.	Short-term	Long-term	Lamming (1993); Hines (1994); Lamming, (1996); Womack and Jones (1996a); Arkader (2001); Humphreys et al. (2001); Simpson and Power (2005); Taylor (2006); Cox et al. (2007); Shah and Ward (2007); Simons and Taylor (2007); Mollenkopf et al. (2010); Perez et al. (2010); Moyano-Fuentes et al. (2012); Panizzolo et al. (2012)
	Information exchange	Intensity and frequency of information exchanged between counterparts involved in the lean programme.	Low/narrow	High/ wide	Lamming (1993); Lamming (1996); Womack and Jones (1996a); Arkader (2001); Humphreys et al. (2001); Cagliano et al. (2004); Simpson and Power (2005); Taylor (2006); Shah and Ward (2007); Simons and Taylor (2007); Cox et al. (2007); Mollenkopf et al. (2010); Perez et al. (2010); Moyano-Fuentes et al. (2012); Panizzolo et al. (2012)
	Commitment and trust	Level commitment and trust between counterparts involved in the lean programme.	Low	High	Lamming (1993); Lamming (1996); Womack and Jones (1996a); Arkader (2001); Humphreys et al. (2001); Simpson and Power (2005); Taylor (2006); Cox et al. (2007); Shah and Ward (2007); Simons and Taylor (2007); Mollenkopf et al. (2010); Perez et al. (2010); Moyano-Fuentes et al. (2012)
	Span of collaboration	Number of inter-firm activities in which supply network counterparts involved in the lean programme collaborate.	Narrow	Wide	Lamming (1993); Hines (1994); Panizzolo (1998); Arkader (2001); Humphreys et al. (2001); Cagliano et al. (2004); Taylor (2006); Cox et al. (2007); Simons and Taylor (2007); Shah and Ward (2007); Mollenkopf et al. (2010); Perez et al. (2010); Danese et al. (2012); Moyano-Fuentes et al. (2012); Panizzolo et al. (2012)
Supply network structure	Supplier base	Number of suppliers in the upstrem tiers of the supply network.	Large	Small	Lamming (1993); Hines (1994); Arkader (2001); Cagliano et al. (2004); Taylor (2006); Shah and Ward (2007); Panizzolo et al. (2012)
	Suppliers per item	Number of suppliers for each part/assembly/sub-assembly.	Multi	Single/ dual	Lamming (1993); Hines (1994); Arkader (2001); Cagliano et al. (2004); Shah and Ward (2007)
	Supplier selection and evaluation	Criteria customer usesto select and evaluate suppliers.	price	Multi criteria	Lamming (1993); Hines (1994); Arkader (2001); Cagliano et al. (2004); Taylor (2006); Shah and Ward (2007); Panizzolo et al. (2012)
	Supplier localization	Geographical distance between plants of counterparts involved in the lean programme.	High	Low	Hines (1994); Cagliano et al. (2004);Taylor (2006); Shah and Ward (2007); Mollenkopf et al. (2010); Panizzolo et al. (2012)
Supply network leanness	Supplier leanness	Level of implementation of lean practices within each counterpart involved in the lean programme.	Low	High	Cox et al. (2007); Shah and Ward (2007); Danese et al. (2012); Moyano-Fuentes et al. (2012)

Table 2: Supply network characteristics and their impact on programmes to extend lean to the supply network.

3. RESEARCH METHODOLOGY

Literature review permitted to build a conceptual framework on practices for expanding the scope of lean programmes to SNs (table 1) and states of SN characteristics that can either facilitate or obstruct the extension of lean programmes beyond the single firm's boundaries (table 2). From the literature it emerges that interactions between SN characteristics and lean practices can exist, however, literature is incomplete and doesn't give a feasible answer to how these interactions take place. Therefore, we adopt a theory building approach to answer the research question and to create a set of theoretical propositions (Eisenhardt and Graebner, 2007). The multiple-case study method is used to analyze lean programmes applied to different SNs and characterized by different contextual conditions. A theoretical sampling approach guided the selection of case studies analyzed (Eisenhardt, 1989). We selected the Andalusian aeronautics industry, where a group of companies decided to extend their lean programmes to the entire industry, facing very different initial states of SN characteristics. We divided the members of the Andalusian aeronautics industry into SNs and searched for similar cases in terms of initial states of SN characteristics to provide evidence of literal replication and polar types of SNs in order to observe contrasting patterns in the data for theoretical replication (Voss et al., 2002; Eisenhardt and Graebner, 2007). At the end of the selection process, we chose three SNs, where members operating in supply network 1 (SN1) found a favorable initial situation for the creation of a network of connected lean companies, while actors of supply networks 2 (SN2) and 3 (SN3) faced unfavorable conditions.

The selected SNs encompass "nested" portions of the entire Andalusian aeronautics industry (figure 1). SN1 regards the relationships between the Original Equipment Manufacturers (OEMs), namely the Final Assembly Lines (FALs) and the Prime Contractors (PCs). Since tier-1 companies can deliver to both PCs and FALs, SN2 consists of OEMs and tier-1 companies. Similarly, since tier-2 companies can deliver to tier-1 companies and OEMs, SN3 concerns the relationship between tier-2 companies and SN2.



Note: FALs: Final Assembly Lines, PCs: Prime Contractors, OEMs: Original Equipment Manufacturers

Figure 1: The SNs analyzed

The database of Fundación Hélice (a member of the European Aviation Clusters Partnership, funded by the European Commission with the aim to promote the development Industrial Clusters in the Aerospace industry) was used as a basis to identify companies in the three SNs. In line with the research aim, we selected plants that implemented practices for extending the scope of lean outside their company boundaries. In total, fifteen plants have been analyzed (see table 3).

	Members of the SNs - main item produced; principal customers
SN1	FAL1 and FAL2 - final assembly of aircrafts; end-customers PC1, PC2 and PC3 - manufacture and assembly of large aerostructures, subsystems, and systems
SN2	Actors in the SN1 T1-1, T1-2, T1-3, T1-4, T1-5, T1-6 and T1-7 - build-to-print subsystems and systems
SN3	Actors in SN2 T2-1, T2-2 and T2-3 - low value items

Table 3: Members of the supply networks analyzed and their characteristics

In order to increase the reliability of the research we developed a case study protocol, where data collection instruments, procedures and general rules for carrying out the case studies were formalized (Yin, 1994). It also includes the list of issues analyzed through case studies, developed on results of the literature review and improved through discussion with managers involved in the study. The protocol covers:

- state of SN characteristics at the beginning of the programme;
- lean practices adopted, their implementation mode and SN characteristics addressed; other actions activated, if any, and their objectives;
- state of SN characteristics after the adoption of such practices/actions activated.

The prime sources of data were semi-structured interviews. In the period between July 2010 and March 2011 thirty-three top/middle managers and executives belonging to the three SNs were interviewed. Two researchers conducted, recorded and transcribed the interviews, ranged from 60 to 160 minutes. In each plant, managers also guided the researchers on a plant-tour allowing direct observations.

To ensure research reliability, data was triangulated considering primary and secondary information (McCutcheon and Meredith, 1993). In addition to interviews and direct observations (primary sources), companies' documents, reports, web resources, and published interviews were analyzed (secondary sources).

Data analysis involved two steps: within-case analysis, and cross-case analysis. Data were broken down in the within-case analysis and evaluated according to the SN characteristics (table 2) and lean practices (table 1) emerged from the literature review. The within-case analysis made it possible to compare and contrast practices implemented in the three SNs, their aims and implementation modes, other actions activated as well as SN characteristics' situation at the beginning of lean programmes. This was a preliminary step to discuss the cross-case issues where the foundation for the theoretical arguments derived from data interpretation.

Based on the approach presented by Strauss and Corbin (1990), axial and selective coding techniques were used to group issues identified during within-case analysis, summarize them into themes, and make connections among categories to explain the phenomenon of interest.

4. CASE STUDIES

4.1. SN1: relationships between aircraft final assembly lines and prime contractors

When the extension of lean programmes to SN1 started, the counterparts involved found a favorable condition. The number of prime contractors was already small and they had long-term collaborations with buyers based on single/dual sourcing schemes. Though OEMs were lean, companies didn't adopt any particular interface practice to connect material flows.

However, the counterparts were aware of the importance of interacting in product/process innovation and supplier selection processes.

The initial steps in extending lean programmes beyond the single firm's boundaries consisted in the adoption of a series of practices aiming at enhancing knowledge sharing across the counterparts. A "bidirectional" joint lean training program was launched where each counterpart transferred its expertise to the others. The creation of a shared lean knowledge database with standardized procedures for the use of lean practices/tools/techniques was another practice that facilitated bidirectional lean knowledge transfer. This database also included information on the sequence in which these actions had to be implemented as emerged from the individual plant or dyad trial and error experience. This meant that if a plant or a dyad pioneered the adoption of a lean practice, the rest of the plants had access to the knowledge created during the adoption process. This way knowledge on adoption and progress of lean programmes was made visible to all the partners in SN1. In order to implement cost transparency, information on KPIs were established and shared. Later, inter-organizational teams were created responsible for EVSM programmes. These programmes aimed at the identification of waste at the inter-organizational level and the implementation of continuous material flows also by using supplier kanban systems. Joint multifunctional teams were adopted beyond the EVSM programmes and there was a transfer of personnel across companies with two aims: improve and homogenize the level of internal lean implementation and adapt internal lean standards upstream to the needs of the demand downstream. For instance, joint lean assessment teams were particularly efficacious in obtaining feedback on opportunities for improvement and in "standardizing the standards" across different partners in the SN1.

4.2. SN2: relationships between OEMs and tier-1 companies

The actors involved in SN2 faced an unfavorable initial scenario. The OEMs managed a high number of suppliers according to a multi-sourcing scheme. Although relations between the counterparts were long lasting, the level of collaboration was low. Supplier participation in decision-making processes was scarce, as well as the level of commitment and trust. Tier-1 companies produced "build-to-print" items, independently designed by the OEMs. Since suppliers weren't involved in decision making, information exchanges were limited and unidirectional (from customer to supplier). Furthermore, there wasn't any attempt of inter-firm integration as tier-1 companies totally lacked internal lean adoption.

As a preliminary step toward the creation of a network of connected lean companies, OEMs leveraged on their bargaining power to simplify the structure of the upstream network by forcing mergers and demanding turn-key subsystems. In order to support tier-1 companies in the design, OEMs established inter-firm NPD teams and introduced a risk and benefit sharing mechanism. The implementation of such interface lean practices broadened the horizon of relationships between counterparts and resulted in improved inter-firm collaborations. Moreover, other initiatives were used to push for internal lean implementation in tier-1 organizations. In order to make suppliers aware of the benefits of lean, OEMs organized tours of their facilities and training sessions on the most relevant lean aspects. Moreover, OEMs informed suppliers about their lean introduction experience, such as the lean practices implemented and their adoption sequence. After theoretical training, pilot projects on VSM were carried on by inter-firm dyadic teams, where each team involved personnel from OEMs and one supplier. Later, a number of KPIs was established and shared between SN2 members, providing continues feedback on improvements in lean implementation. OEMs had also begun to acknowledge suppliers' progress in lean implementation by providing better supply contracts. These actions resulted in more collaborative relations between OEMs and tier-1 companies with two-way communication and increased level of commitment and trust.

4.3. SN3: relationships between SN2 and tier-2 companies

An unfavorable mix of SN conditions was found in SN3. A large number of tier-2 companies supplied low-value items to tier-1 and OEMs. Scarce and mainly mono-directional information sharing and short-term multi-sourcing scheme with low commitment and trust characterized relationships among these counterparts. Tier-1 and OEMs did not collaborate with tier-2 companies neither in technological, nor in any form of inter-firm operative integration. Finally, tier-2 companies did not lever on any lean practice.

Firstly, to contrast this unfavorable situation, the SN was reconfigured. OEMs and tier-1 companies forced tier-2 companies to reduce their number through mergers and to increase their ability to supply turn-key subsystems. Tier-1 companies had not enough lean experience to implement countermeasures to face this unfavorable initial context. Unlike OEMs, tier-1 companies were at the beginning of their lean programme, thus their expertise was not sufficient to involve tier-2 companies in lean initiatives. For this reason, after the SN reconfiguration, all the lean initiatives came from OEMs, which tried to replicate the approach successfully used with tier-1 companies. OEMs adopted open-doors policy and lean training support to strengthen the collaboration with tier-2 companies and to convince them on the importance of lean. Unlike what happened with tier-1 companies, these practices failed to achieve the expected results. Tier-2 companies found that lean training support was too theoretical and their visits to the OEMs' facilities were useless due to the large difference between production systems. To break down the initial resistance to lean adoption, OEMs decided to "go to the gemba" of tier-2 companies to support them in starting basic and practical lean programmes. They created inter-organizational problem-solving teams to conduct VSM programmes at tier-2 facilities to increase awareness, understanding, acceptance and implementation of lean. Starting from these initiatives, tier-2 companies began to give frequent feedbacks on their lean journey. Customers in turn rewarded their suppliers' improvement by increasing the time horizon of the supply contract.

5. ANALYSIS AND DISCUSSION

Table 4 and figures 2, 3 and 4 synthesize the within case analysis. Table 4 classifies the match/mismatch state of SN characteristics found at the beginning of the lean extension programmes. Figures 2, 3 and 4 show the flow of actions of the three different lean programmes. These figures depict the changes of SN characteristics during the lean programmes, the key actions and their implementation mode (i.e. interface vs. internal actions, bidirectional vs. one-way), their aim and results.

Group of supply network characteristics	**Supply network characteristic**	**Supply network 1**	**Supply network 2**	**Supply network 3**
Supply network relationships	Time horizon	Match *Long-term*	Match *Long-term*	Mismatch *Short-term*
	Information exchange	Match *High/wide*	Mismatch *Low/narrow*	Mismatch *Low/narrow*
	Commitment and trust	Match *High*	Mismatch *Low*	Mismatch *Low*
	Span of collaboration	Mismatch *Narrow*	Mismatch *Narrow*	Mismatch *Narrow*
Supply network structure	Supplier base	Match *Small*	Mismatch *Large*	Mismatch *Large*
	Suppliers per item	Match *Single/dual sourcing*	Mismatch *Multi sourcing*	Mismatch *Multi sourcing*
	Complexity of item supplied to the firm	Match *High*	Mismatch *Low*	Mismatch *Low*
	Supplier selection and evaluation	Match *Multidimensional criteria*	Match *Multidimensional criteria*	Match *Multidimensional criteria*
	Supplier localization	Match *Low distance*	Match *Low distance*	Match *Low distance*
Supply network leanness	Level of customers' leanness	Match *High*	Match *High*	Mismatch *Low*
	Level of suppliers' leanness	Match *High*	Mismatch *Low*	Mismatch *Low*

Table 4: Positioning of the investigated supply networks according to the interpretation framework

Supply Network 1

State 1 — **STRUCTURE**: match | **RELATIONSHIPS**: match, *span of collaboration* | **LEANNESS**: match

Action 1	**Implementation mode**
Lean training support	Internal and Interface - Bidirectional
Shared lean knowledge database	Internal and Interface - Bidirectional
Cost transparency	Internal and Interface - Bidirectional
Open door policy	Internal - Bidirectional

Aim of the action:
Span of collaboration
Information exchange
Levels of customers' and suppliers' leanness

Result: successful

State 2 — **STRUCTURE**: Match | **RELATIONSHIPS**: Improved match, *Improved span of collaboration* | **LEANNESS**: Improved match

Action 2	**Implementation mode**
Supplier-Customer lean problem solving team	Internal and Interface - Bidirectional
Extended Value Stream Mapping	Internal and Interface - Bidirectional
Pull system	Interface - Bidirectional

Aim of the action:
Span of collaboration
Information exchange
Levels of customers' and suppliers' leanness

Result: successful

State 3 — **STRUCTURE**: Match | **RELATIONSHIPS**: Improved match, Span of collaboration from mismatch to match | **LEANNESS**: Improved match

Note: mismatch status of SN characteristics are in italics

Figure 2: SN1 decision tree.

Supply Network 2

State 1

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Mismatch	*Mismatch*	Customers' leanness *Suppliers' leanness*

Action 1 **Implementation mode**

Customer pressure	Interface - Oneway

Aim of the action: Supplier base; Suppliers per item

Result: successful

State 2

	STRUCTURE	RELATIONSHIPS	LEANNESS
	From mismatch to match	*Mismatch*	Customers' leanness *Suppliers' leanness*

Action 2 **Implementation mode**

Customer pressure	Interface - Oneway
Supplier-Customer NPD team	Interface - Oneway
Risk and benefits sharing	Interface - Oneway

Aim of the action: Span of collaboration; Information exchange; Commitment and trust; Time horizon

Result: successful

State 3

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Match	From mismatch to match *Improved span of collaboration*	Customers' leanness *Suppliers' leanness*

Action 3 **Implementation mode**

Customer pressure	Internal - Oneway
Open door policy	Internal - Oneway
Lean training support	Internal - Oneway
Acknowledge of progress in lean programmes	Internal - Oneway
Feedback on lean results	Internal - Oneway

Aim of the action: Span of collaboration; Information exchange; Commitment and trust; Level of suppliers' leanness

Result: successful

State 4

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Match	Improved match *Improved span of collaboration*	From mismatch to match

Note: mismatch status of SN characteristics are in italics

Figure 3: SN2 decision tree.

Supply Network 3

State 1

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Mismatch	*Mismatch*	*Mismatch*

Action 1 **Implementation mode**

Customer pressure	Interface - Oneway

Aim of the action: Supplier base; Suppliers per item

Result: successful

State 2

	STRUCTURE	RELATIONSHIPS	LEANNESS
	From mismatch to match	*Mismatch*	*Mismatch*

Action 2 **Implementation mode**

Customer pressure	Internal - Oneway
Open door policy	Internal - Oneway
Lean training support	Internal - Oneway
Acknowledge of progress in lean programmes	Internal - Oneway
Feedback on lean results	Internal - Oneway

Aim of the action: Information exchange; Commitment and trust; Level of suppliers' leanness

Result: unsuccessful

State 3

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Match	*Mismatch*	*Mismatch*

Action 3 **Implementation mode**

Customer pressure	Internal - Oneway
Supplier-Customer lean problem solving team	Internal - Oneway
Acknowledge of progress in lean programmes	Internal - Oneway
Feedback on lean results	Internal - Oneway

Aim of the action: Span of collaboration; Information exchange; Commitment and trust; Time horizon; Level of suppliers' leanness

Result: successful

State 4

	STRUCTURE	RELATIONSHIPS	LEANNESS
	Match	From mismatch to match *Improved span of collaboration*	*Improved suppliers' leanness*

Note: mismatch status of SN characteristics are in italics

Figure 4: SN3 decision tree.

5.1. The recursive effect between SN characteristics and lean practices

Table 4 shows that the three SNs faced two dichotomous initial contexts. While SN1 found a favorable mix of SN characteristics, SN2 and SN3 had to handle far more unfavorable situations. Figures 2, 3 and 4 reveal that the SN characteristics influenced the practices activated, as SN1 adopted a different set of actions compared to SN2 and SN3, given the favorable initial context. SN1 managers took advantage of the favorable structure, relationships and leanness across their network to implement practices that SN2 and SN3 actors weren't able to, such as shared lean knowledge database, cost transparency and pull system.

"Sharing information about our production costs with our tier-2 suppliers? No, not now. They are too many and we don't trust them yet. We do it only with OEMs" (Plant manager – PC1).

On the opposite, SN2 and SN3 experienced a radical reconfiguration of their structure to create a keiretsu-like SN configuration. SN1 didn't introduce this action as they were already well structured. In addition, the mismatch status of relationships and leanness in SN2 and SN3 led managers to launch practices that SN1 didn't use as they had already good relationships and high levels of leanness, such as acknowledgement of progress in lean programmes and feedback on lean results.

"Our customers are a pull factor, a facilitator...We adopted Lean in our plants driven by them, who experienced lean few years longer than us...We are awarded from them for every improvement that we are able to obtain and sustain" (Plant manager - Tier1-5).

The last examples show that SN actors carefully selected those practices that were likely to change the state of SN characteristics toward favorable conditions. The acknowledgement of progress in lean programmes and feedback on lean results permitted to foster relationships in SN2 and SN3, and improve the level of leanness in tier-1 and tier-2 suppliers' plants. This evidence corroborates the existence of a recursive effect between SN characteristics and lean practices: SN characteristics influence practice selection, but also that the match/mismatch state is not frozen, as lean practices can modify it; for example, the pull system adopted in SN1 increased the span of collaboration and improved the already good relationships across the network.

"…The implementation of the pull system permitted to have almost no inventory between one plant and another. We are fully integrated now, and we collaborate even better!" (Plant manager – PC2)

This result is in line with the contingency theory as SNs adopted different approaches to maintain congruence between strategy and external contexts (Sousa and Voss, 2008; Chavez et al., 2015) and confirms also what social network theory suggests; companies are embedded in their SNs, hence any action depends on the SN characteristics, but also that any action can modify these characteristics by altering social relations, interactions and flows among actors or "nodes" (Uzzi, 1997; Borgatti and Li, 2009, Kim, 2014). However, Kim (2014) maintains that it is not clear how the mutual influence between practices and SN characteristics takes place. Our cases clarify the dynamics of the recursive effect: lean practices are selected by considering the state of SN characteristics (i.e. match vs. mismatch, using the interpretation framework this paper proposes) and with the aim to improve match conditions or to transform mismatch conditions into match ones so as to eliminate obstacles in the extension of lean programmes to SNs.

Based on the empirical evidence, we propose that:

PROPOSITION 1: there is a recursive influence between SN characteristics and practices adopted to extend the scope of lean programmes to SNs as the result of the embeddedness of the actors in their SNs.

> *COROLLARY 1.1: the state of SN characteristics can be represented in terms of match and mismatch conditions and influences the choice of the practices to adopt.*
>
> *COROLLARY 1.2: the lean practices adopted can modify the state of SN characteristics.*

Using the lens of social network theory we can grasp a deeper understanding of how the recursive effect operates. The prevalence of “matching” conditions found in SN1 characterizes it as a “dense” network, namely one without structural “holes”, where the actors are closely connected, mutually committed and have intense communications (Polidoro et al., 2011). SN density facilitated the implementation of practices that require intense information exchanges from multiple sources, and these practices in turn, made the SN even “denser” by reinforcing the already excellent information exchange. As network theories explain, when the ties in a network are extremely strong, the nodes of the network tend to behave similarly, as an effect of isomorphism over time (Choi et al., 2001). This phenomenon happened in SN1, as the increased density led the actors to be homogeneous internally. This alignment facilitated the creation of a network of interconnected lean companies through the introduction of pull systems.

“We were able to implement a pull system with our customers only because we were connected with a central lean database shared with other plants and other centers in the SN...and because our lean programs were connected, our internal systems were coherent and we all speak the same lean language…” (Plant manager – PC2)

In contrast, SN2 and SN3 can be described as “sparse” in terms of structure and relationships. In both cases structural holes were present, there weren’t strong and direct contacts among actors, commitment and trust were very low as well as the level of leanness. Therefore, actors in SN2 and SN3 activated specific actions to modify the structure and strengthen SN relationships with the aim at closing the structural holes and increasing the density of the networks, as a first step toward the complete extension of the lean to SNs.

“We’ve tried to rationalize our supply base because we can’t handle so many suppliers…After that now we are able to collaborate with our suppliers.” (SN3: Plant manager – Tier1-1).

Based on these evidences, we propose that:

PROPOSITION 2: the creation of a network of interconnected lean companies requires a dense SN.

> *COROLLARY 2.1: structural holes in the SN prevent the creation of a network of interconnected lean companies, thus reducing structural holes is a pre-requisite for the extension of lean programmes to the SN.*
>
> *COROLLARY 2.2: members of denser SNs tend to behave similarly, as an effect of isomorphism over time, and their internal lean systems tend to be homogeneous. This facilitates the implementation of lean practices at interfaces.*

5.2. Supply network characteristics and lean programme strategies

Propositions 1 and 2 refer to the relationship between SN characteristics and the choice of lean practices to adopt. However, the analysis of figures 2, 3 and 4 reveals that SN characteristics influence also the number of lean practices to adopt, their aim and implementation mode. This means that the same lean practice can be adopted in different ways, in combination with different practices depending on the initial situation.

Table 5 reports the different lean strategies in terms of practices successfully implemented together with the matching or mismatching SN characteristics that companies intended to address. It is worth noting that we introduced customer pressure as a further action, even though it is not a specific lean action, as it had an important role in SN2 and SN3.

		Supplier involvement				Knowledge transfer			Commitment		Alignment		Customer Pressure
		EVSM	NPD	Problem solving team	Pull system	Lean training support	Open door policy	Shared database	Acknowl. of Progress	Risks and benefits sharing	Feed-back on lean results	Cost transparency	
Supply network relationships	Time horizon		SN 2						**SN3**	SN2	**SN3**		
	Information exchange	SN 1	**SN 2**	SN1/**3**		SN 1/**2**	SN 1/**2**	SN1		**SN2**	**SN2**	SN 1	
	Commitment and trust		**SN 2**	**SN3**			**SN 2**		**SN2**	**SN2**			
	Span of collaboration	**SN 1**	**SN 2**	**SN1/3**	**SN 1**	**SN 1/2**		**SN1**		**SN2**		**SN 1**	
Supply network structure	Supplier base												**SN 2/3**
	Suppliers per item												**SN 2/3**
	Supplier selection and evaluation												
	Supplier localization												
Supply network leanness	Customer leanness	SN 1				SN 1	SN 1	SN1					
	Supplier leanness	SN 1		SN1/**3**		SN 1/**2**	SN 1/**2**	SN1	**SN2**				

Bald indicates mismatches in the table.

Table 5: Successful actions.

Contrasting the set of actions implemented in SN1 and SN2 we can observe several differences (see figures 2 and 3 and table 5). While in SN1 managers implemented a large number of lean practices by focusing on few specific SN characteristics, SN2 actors had to launch several lean practices directed to a broader scope of SN characteristics (supplier base, suppliers per item, span of collaboration, information exchange, commitment and trust, time horizon and leanness), given the unfavorable initial situation. As already discussed, SN1 and SN2 actors implemented some peculiar practices, due to the different initial context. Some other practices instead were used in both SNs, such as lean training support and open-doors policy. In this case the different state of SN characteristics didn't influence the type of practices to adopt, but their aim and implementation mode. While in SN1 lean training support and open-doors policy aimed at strengthening the already collaborative relationships and were applied in a bi-directional way due to the leanness balance across the network, the imbalance of knowledge and degree of leanness in SN2 determined that the same practices have been used in a "one-way mode" (from customer to supplier) to create the conditions for collaboration, so as to increase the density of the network, and improve leanness. Another difference of lean practices implementation mode was related to the different aim of lean knowledge transfer. While in SN1 lean practices were used to share common standards to homogenize lean systems across the network, in SN2 OEMs transferred lean knowledge to tier-1 companies, but leave them free to learn how to implement lean, thus *de facto* postponing homogenization. In fact, the imposition of a common standard since the beginning would have meant the exclusion of tier-1 companies from the design of their internal lean systems, thus limiting their creativity and relegating them to a purely passive role.

"The two courses on standardization and 5S that our OEMs taught us were quite interesting. However, we really started to make progress when we tried to implement these concepts in our plant by ourselves. We made several errors, but we learned from them." (Production Manager, Tier1-2).

Contrasting SN2 and SN3 (figure 3 and 4, table 5), we can observe that SN3 actors found an unfavorable context characterized by a mix of SN characteristics very similar to that in SN2. Therefore, a set of actions similar to those activated in SN2 and targeted to the same SN characteristics were launched. However, open–door policy and training support, successfully implemented in SN2, failed in SN3. Given the constraints found in SN3, OEMs reshaped their strategy and tried to focus on few practices targeted to a large number of SN characteristics. They created lean problem-solving teams including both their and tier-2 companies' personnel. Instead of transferring theoretical knowledge and showing how lean works in the OEMs plants, as happened in SN2, these teams used common lean tools to address practical problems in tier-2 companies'. In this way they demonstrated that lean can work with beneficial effects also in tier-2 companies. Although these initiatives didn't lead to a complete cultural change as happened in SN2, they contributed to break the resistance to change and to increase collaboration in SN3.

"*Our customers played a major role during our VSM project. They helped us to find our source of waste and suggest us how to increase our efficiency. It was our first initiative we had with them, now we feel part of an extended family"* (Production Manager, Tier2-5).

We propose a set of propositions that provides deeper details on how the state of SN characteristics influences the choice of the practices to adopt, their aim and implementation mode:

PROPOSITION 3: The state of SN characteristics represented in terms of match and mismatch conditions influences the number, type and aim of lean practices.

> *COROLLARY 3.1: the prevalence of match conditions makes it possible to adopt a "surgical approach" in the lean programme, i.e. selection of a set of lean practices targeted to specific SN characteristics to facilitate the introduction of lean practices at interfaces across companies.*

> *COROLLARY 3.2: the prevalence of mismatch conditions determines either the adoption of a large set of lean practices ("undifferentiated approach") or a narrow set of lean practices targeted to a broad range of SN characteristics ("constrained approach") to increase network density and leanness of internal lean systems.*

PROPOSITION 4: The state of SN characteristics represented in terms of match and mismatch conditions influences the implementation mode of lean practices.

> *COROLLARY 4.1: when match conditions are prevalent and the degree of leanness across the network is balanced lean practices can be bi-directional and are implemented to increase homogeneity of internal lean systems across different companies in the SN.*

COROLLARY 4.2: when mismatch conditions are prevalent and the degree of leanness across the network is unbalanced lean practices are implemented one-way either to favor the creativity and autonomy of the recipients of lean knowledge even at the expense of homogenization of internal lean systems or to break the resistance of the recipients of lean knowledge even at the expense of creativity and autonomy.

5.3. The role of supply network distance

When considering corollaries 3.2 and 4.2 we noticed that the SN characteristics included in the interpretation framework were not sufficient to differentiate SN2 and SN3. From the cases it emerged that, though SN2 and SN3 initial contexts were similar, the programmes to extend lean to the two SNs differ for the practices successfully adopted. In particular, actions successfully activated in SN2, such as open doors policy and lean training support, didn't prove effective in SN3.

A detailed analysis revealed that the main problem affecting SN3 was the lean knowledge transfer. Contrasting SN2 and SN3, we observed a difference in the distance between the lean knowledge owner and the recipient of such knowledge. In both cases OEMs led the initiatives adopted by SN2 and SN3, but while in the first case OEMs were direct customers, in the second one, they were customers' customers. This "distance" between partners involved can be measured in terms of SN echelons and indeed had an impact on the successful implementation of certain practices. For instance, while in the SN2 tier-1 companies were able to "absorb" lean knowledge, tier-2 companies found the training from OEMs too theoretical and distant from their practical problems.

"We used the same material to train our tier-1 and tier-2 suppliers, but while tier-1 suppliers were able to translate the knowledge into practical actions, tier-2 suppliers remained at the surface with no clues to how to use what we told them" (Plant manager - PC1).

Similarly, study tours were fundamental for tier-1 companies to see practical solutions to their internal problems, while tier-2 companies found these tours useless due to the large “distance” between OEMs’ and their facilities. In other words, the low degree of identification of the “students” – tier-2 companies – to their “teachers” – OEMs – broke the learning relationship (MacDuffie and Helper, 1997), thus making the lean knowledge transfer ineffective. Borgatti and Li (2009) argue that actors that are at a short distance (i.e., that have a direct link) are able to receive information sooner than actors operating far away from the information owner. This is because actors incorporate information easier from similar environments in which they act, compared to a different one. Borgatti and Li (2009) called this phenomenon the "adaptation mechanism", by which actors adapt to their environments, and similar environments lead to similar adaptations. Moreover, social obligations and bargaining power are effective when there is a direct link between the source and the recipient, but less powerful when the distance between actors increases (Galaskiewicz, 2011). Therefore, network theories suggest that information should be transmitted through direct links, and the convergence toward a common practice follows a cascading effect as the actors of a SN receive information locally, from their SN neighbors (Choi et al., 2001).

Therefore, we argue that the “distance” between senior partners plays a role similar to the state of SN characteristics and contributes to clarify what stated in corollaries 3.2 and 4.2:

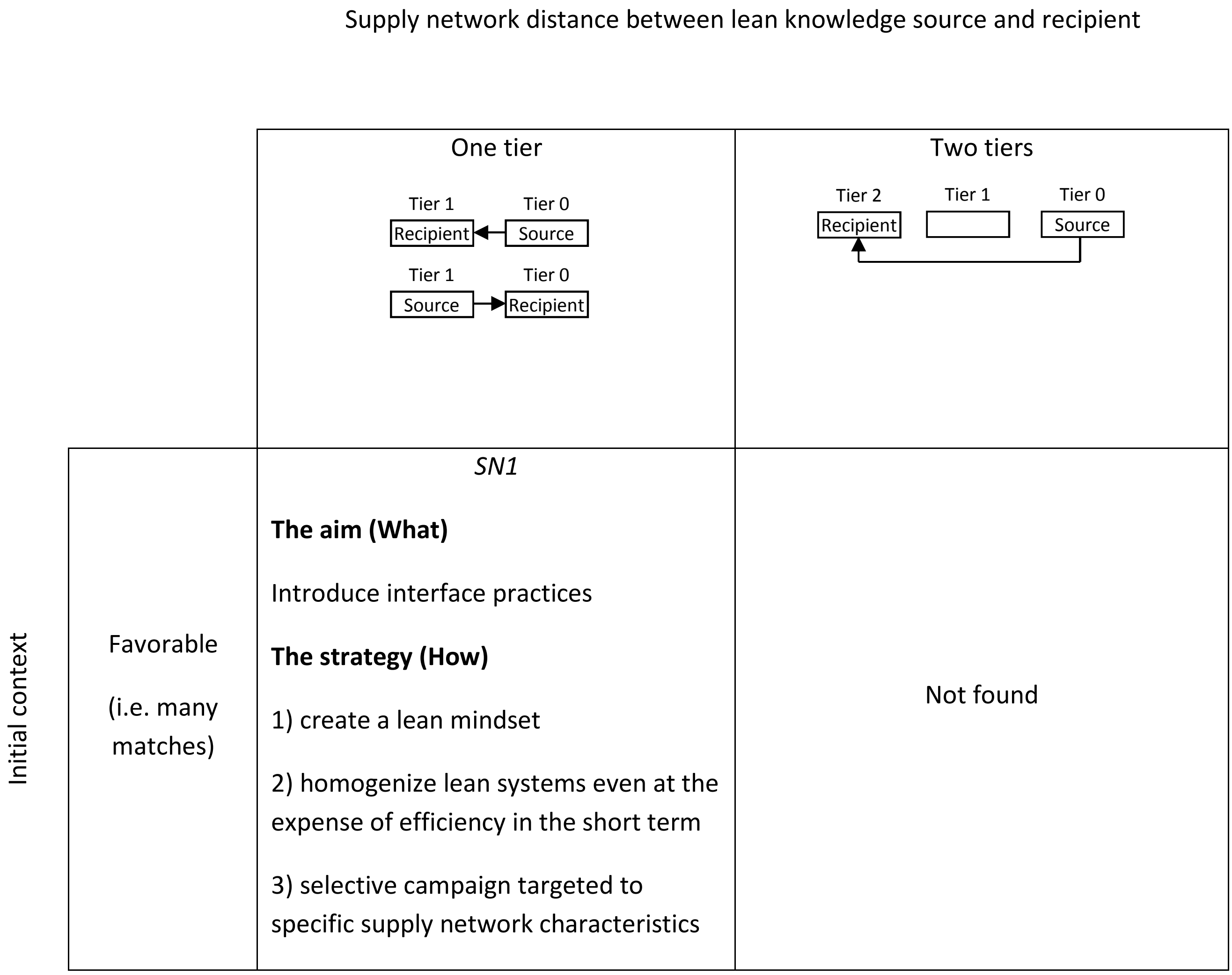
PROPOSITION 5: the SN distance (i.e. number of SN echelons) between the member who owns lean knowledge and the recipient influences the choice of practices to adopt, their aim and implementation mode.

5.4. Managerial implications

Figure 5 summarizes some lessons for managers involved in extending lean programmes to their SN. The differences found in the three SNs can be interpreted as a sequence of phases companies can follow to switch from a very unfavorable initial situation to a favorable one allowing the creation of a network of connected lean companies. Empirical evidences show that it is necessary to follow different and incremental actions to avoid failures in the lean extension process. In particular, two variables seem to influence the choice of practices to adopt, their aim and implementation mode; state of SN characteristics and SN distance. If a SN faces an unfavorable initial situation lean practices should initially aim at modifying the mismatching SN characteristics. After a preliminary reconfiguration of the SN, the choice of what SN characteristics to address and what practices to activate depends on the SN distance between the lean knowledge owner and the recipient. If this distance is large (SN3), managers face a very unfavorable situation that limits the number of initiatives that can be successfully activated ("constrained campaign"). Investing on a broad set of practices could be ineffective because the distance blunts the voice of the customer and hinders the recipients' capacity to absorb new external knowledge. It follows that actions should be driven by the need to show tangible and immediate results through lean implementation to convince the junior partner that lean can work. This way it is possible to break the resistance of distant recipients and favor an initial lean introduction, even if such an initiative limits the recipient's autonomy in the short term because it is carried out mainly by the lean knowledge owner.

On the contrary, when the lean knowledge owner and the recipient are close (SN2), it is possible to launch many practices addressing a broad scope of SN characteristics ("undifferentiated campaign") with the aim at introducing internal lean systems and increasing inter-firm collaboration to prepare the implementation of interface practices. This strategy is effective because lean knowledge owner and recipient operate in a similar context with similar competences, resulting in an accelerated learning process of the recipient due to its higher absorptive capacity. We found also that in this situation, lean knowledge owners must promote recipients' creativity to facilitate their autonomy in the long term, even if this choice can lengthen the duration of the overall programme.

When a SN faces a favorable initial situation, where the actors are already collaborating and have internal lean systems (SN1), it is possible to adopt a "selective campaign" by directing practices targeted to specific SN characteristics. Companies can benefit from the favorable context and follow a surgical strategy to create a common lean mindset and homogenize their internal lean systems. Also in this case we found a trade-off between effectiveness of the action and its duration. However, only when all the actors have the right mindset and homogenized lean systems it is possible to introduce interface practices and obtain the final goal: the creation of a network of connected lean companies.



Unfavorable (i.e. many mismatches)	*SN2* **The aim (What)** Introduce internal lean practices and increase collaboration to prepare the introduction of interface practices **The strategy (How)** 1) transfer lean knowledge to the junior partner 2) favour creativity and autonomy of the junior partner in internal lean introduction even at the expense of the homogenization in the short term 3) undifferentiated lean campaign targeted to a broad range of supply network characteristics	*SN3* **The aim (What)** Introduce internal lean practices and increase collaboration to prepare the introduction of interface practices **The strategy (How)** 1) convince the junior partner that lean can work and break its resistance to change 2) favour internal lean introduction even at the expense of the creativity and autonomy of the junior partner in the short term 3) constrained lean campaign targeted to a broad range of supply network characteristics

Figure 5: aim and strategy of the three supply networks

6. CONCLUSIONS

The aim of this paper is to study the mutual interactions between lean practices and SN characteristics in order to understand how to create favorable conditions for the extension of lean practices across SNs. Three SNs belonging to the Andalusian aeronautics industry were analyzed. This study provided several academic contributions. Our findings confirm that there is a mutual and recursive influence between SN characteristics and practices for extending the scope of lean programmes to the SN. We found that SN characteristics can either facilitate or complicate the adoption of lean practices, but also that the initial match/mismatch state of the SN characteristics is not frozen and companies can lever on lean practices to modify it toward more favorable conditions. Our findings are original not only because describe the interactions between network characteristics and lean practices, but also because show how this interaction takes place.

Another important contribution is the identification of the SN distance (i.e. number of SN echelons) between the lean knowledge owner and the recipient as a further variable that influences the lean extension programme. The empirical evidences indicate that the efficacy of actions decreases when the distance increases. Our findings, even showing that the distance worsens the effectiveness, suggest that it is possible to launch specific actions to transmit some preliminary information on lean.

This study provides also contributions that partially differ from the dominant views in the OM literature. The supply chain management literature explains that SNs must be managed as a whole to eliminate problems linked to the traditional approach of companies operating as an isolated entity (e.g., Slack et al., 2013). However, our findings are more in line with other studies (e.g., Romano, 2009; Kim, 2014) suggesting that SNs consist in groups of different subsystems, and each of them should be managed differently because they differ in terms of operational characteristics. Our findings differ also from the classical view of lean as a managerial approach that leads to a standardization of practices along a SN (Lamming, 1996). Our paper partially contradicts this view by showing that this is true in the long term, but not during the early stages of a lean programme, when a more creative approach is preferable.

It is important to reflect on potential limitations connected to the research and future research opportunities. A case study from a single sector may have limitations in terms of generalizability of the findings. We suggest testing our results in other sectors and/or with different methodologies. Moreover, our cases are characterized by customer dominance, future research could verify if our findings are valid also with other power configurations.

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