

LEAN SIX SIGMA PHILOSOPHY IMPROVES COLLABORATION TO GET MORE INTEGRATED SUPPLY CHAINS

FILOSOFIA LEAN SEIS SIGMA MELHORA A COLABORAÇÃO PARA OBTER UMA CADEIA DE SUPRIMENTOS MAIS INTEGRADA

LA FILOSOFÍA LEAN SEIS SIGMA MEJORA LA COLABORACIÓN PARA OBTENER UNA CADENA DE SUMINISTRO MÁS INTEGRADA

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ABSTRACT

The purpose of the case study is to investigate whether a combined Lean Six Sigma philosophy can help to improve collaboration to get more integrated supply chains. The method used was Literature review, multiple case study, face-to-face interviews and observations on-site in seven large swedish companies. It has been indicated that by implementing Lean Six Sigma Philosophy companies could improve business environment and improve collaboration to get integrated supply chains. The paper provides guidance to organizations regarding the applicability and properties of quality philosophies and concepts in logistics.

Keywords: Lean Six Sigma; Supply chain; Collaboration; Supply chain integration.

RESUMO

O objetivo deste estudo de caso é investigar se uma filosofia combinada de Lean e Six Sigma pode ajudar a melhorar a colaboração para obter cadeias de suprimentos mais integradas. O método utilizado foi a revisão de literatura, estudo de caso múltiplo, entrevistas presenciais e observações no local em sete grandes empresas suecas. Foi indicado que, ao implementar a filosofia Lean Six Sigma, as empresas poderiam melhorar o ambiente de negócios e a colaboração para obter cadeias de suprimentos integradas. O documento fornece orientação às organizações sobre a aplicabilidade e propriedades das filosofias e conceitos de qualidade em logística.

Palavras-chave: Lean Seis Sigma; Cadeia de suprimentos; Colaboração; Integração na cadeia de suprimentos.

RESUMEM

El propósito del estudio de caso es investigar si una filosofía combinada de Lean Six Sigma puede ayudar a mejorar la colaboración para cadenas de suministro más integradas. El método utilizado fue la revisión de la literatura, el estudio de casos múltiples, las entrevistas cara a cara y las observaciones in situ en siete grandes empresas suecas. Se indicó que, al implementar la filosofía Lean Six Sigma, las empresas podrían mejorar el entorno empresarial y la colaboración para lograr cadenas de suministro integradas. El documento proporciona orientación a las organizaciones sobre la aplicabilidad y las propiedades de las filosofías y los conceptos de calidad en logística.

Palabras clave: Lean Six Sigma; Cadena de suministros; Colaboración; Integración de la cadena de suministro.

1 INTRODUCTION

The present is characterized by a complex business environment (ANDERSSON, 2008; PARDILLO; GÓMEZ, 2013), where the customers are extremely demanding (ANAYA TEJERO; POLANCO MARTÍN, 2007; HILLETOTH, 2012; JAFARI *et al.*, 2016). The market are more competitive (HILLETOTH, 2012; JAFARI *et al.*, 2016), and there is an increasing demand for adapting to diverse customer requirements (KUO *et al.*, 2016; TACHIZAWA; THOMSEN, 2007; ZHANG; TSENG, 2009).

The firms realize that one cannot go all on its own (BAGCHI *et al.*, 2005). Individual businesses no longer compete as solely autonomous entities, but rather as supply chains (CARVALHO *et al.*, 2011; CHRISTOPHER, 2000; GLIGOR, 2014; LAMBERT; COOPER, 2000; MANGAN *et al.*, 2008; MIN; ZHOU, 2002; PARDILLO; GÓMEZ, 2013; RAGHU KUMAR *et al.*, 2016; AGUILAR, 2009). Firms should integrate both its suppliers and customers to gain competitive advantage (NARASIMHAN; KIM, 2002; SWINK *et al.*, 2007; VACHON; KLASSEN, 2006; VAN DER VAART; VAN DONK, 2008; VICKERY *et al.*, 2003). Today, firms view supply chain management as a strategic tool to increase their competitive advantage (QRUNFLEH; TARAFDAR, 2013). The ultimate success of the single business will depend on the management's ability to integrate the company's intricate network of business relationships (CHRISTOPHER, 1998; LAMBERT; COOPER, 2000). That is why companies focus attention on their Supply Chain (SC) (LIU *et al.*, 2013; LIU *et al.*, 2016; SIMCHI-LEVI *et al.*, 2008).

Supply chains play a key role in the 21th century's business (PARDILLO; GÓMEZ, 2013) growing the tendency to research the subject in last years (ONNO OMTA; HOENEN, 2012); and because of their increasing vulnerability (CHRISTOPHER *et al.*, 2003; SVENSSON, 2002) it is more important to collaborate and be integrated (ANDERSSON; HAMMERSBERG, 2007). For a supply chain to succeed as a unit of competition must be agile and having an effective integration of its members (SHARIFI *et al.*, 2006). There are many articles about supply chain management related to integration (FABBE-COSTES; JAHRE, 2008), and many researchers discuss the need of integrated relationships emphasizing the systematic approach of integration of the supply chain (FLYNN *et al.*, 2010).

Supply Chain Integration (SCI) despite being a topic widely discussed in the literature, it is recognized as very difficult to achieve in practice (BAGCHI *et al.*, 2005; PARDILLO; GÓMEZ,

2013; TRKMAN; GROZNIK, 2006). In research as well as in practice, it is often believed that integration of the supply chain has a positive effect on performance (BAGCHI *et al.*, 2005; FABBE-COSTES; JAHRE, 2008; FROHLICH; WESTBROOK, 2001; KACHE; SEURING, 2014; NARASIMHAN; DAS, 2001; OLHAGER; SELLDIN, 2003; ROSENZWEIG *et al.*, 2003; SUN; NI, 2012; SWAIM *et al.*, 2016; SWINK *et al.*, 2007; TAN, 2002; VACHON; KLASSEN, 2006; VAN DER VAART; VAN DONK, 2008). Kache and Seuring affirm that further research is required to fully understand the reciprocity between SCI and performance (KACHE; SEURING, 2014). Even if integration is an everyday keyword in logistics and Supply Chain Management (SCM), as Power support “the formula for integration, however, is not a simple one” (POWER, 2005).

Lean Six Sigma philosophy (LSS) appears as a management methodology that firms can employ to achieve substantial improvement in supply chain performance (ANDERSSON, 2009). It is an approach of development because it give solution to many problems that the companies confront today (SNEE, 2010), and it creates extra value to organizations (TSIRONIS; PSYCHOGIOS, 2016).

Exist researches showing that LSS can generates profits into the business and improve customer relationships (FELIZZOLA JIMÉNEZ; LUNA AMAYA, 2014; TLAPA *et al.*, 2016), and that it is very effective in making the supply chain processes robust, flexible, agile and less risky (ANDERSSON, 2009; ANDERSSON *et al.*, 2014). Today many large Swedish international companies use a combination of LSS i.e. SKF, Volvo, Electrolux, Kinnarp, Alfa Laval, Ericsson group, etc. Some of them have experienced several success stories with regard to the joint use of LSS (ANDERSSON *et al.*, 2014). Nevertheless, the questions remain how to working with suppliers and involve entire supply chain. Andersson and Hammersberg (2007), affirm that future research in LSS should address integration of the entire supply chain.

Building on previous literature review and the study cases of the current problem situation at SC, the paper proposes the application of combination of Lean and Six Sigma to improve collaboration and get an integrated supply chain. In order to answer the need of having better SCI appears the research question:

RQ 1. “Can Lean Six Sigma philosophy help to improve collaboration to get more integrated supply chains?”

Face-to-face interviews and observations on-site in seven large companies, which have LSS, has been used and investigated with the goal of answering the research question.

The paper is structured in four more sections. Section 2 presents a theoretical framework with the conceptual development of LSS, collaboration and SCI. In Section 3, it is explained the case selection, unit of analysis, data collection method, analysis, and validity and reliability. Section 4 argues the results and discussion from the interviews in place and by observations in the companies. The paper closes with Section 5, which shows the conclusions of the research, and suggests possibilities for future researches.

2 LITERATURE REVIEW

2.1 LEAN SIX SIGMA PHILOSOPHY

Lean (L) and Six Sigma (SS) have a strong focus on processes, project work and improvement work, and they can be applied in manufacturing and service sectors, (ANDERSSON *et al.*, 2006; KLEFSJÖ *et al.*, 2001; MAGNUSSON *et al.*, 2003). There is not any contradiction between the objectives in Lean and Six Sigma (DAHLGAARD; DAHLGAARD-PARK, 2006). Both can be appropriate approaches for organisations in order to make important progress, often this improvement extend to include suppliers and other stakeholders. Lean addresses process flow and waste, whereas Six Sigma addresses variation and design (ANDERSSON; HAMMERSBERG, 2007).

Lean thinking is fundamentally customer value driven (ANDERSSON *et al.*, 2014). It includes ideas of continuous improvements, flattened organization structures, teamwork, elimination of waste, efficient use of resources and cooperative supply chain management (GREEN, 2000; RAGHU KUMAR *et al.*, 2016). L methodology provides a set of standard solutions to common problems and optimizes processes across the entire value chain (DE KONING *et al.*, 2008; TSIRONIS; PSYCHOGIOS, 2016). Evidence suggests that lean methods and tools have helped organizations, from various sectors, to improve their operations and processes (BELEKOUKIAS *et al.*, 2014; CHAN *et al.*, 2009; FORRESTER *et al.*, 2010; VILLARREAL *et al.*, 2016).

SS is a methodology that improves business processes based on understanding, controlling variation and reduces cost of poor quality (BENDELL, 2006; CHANG-TSEH, 2007; DE MAST, 2006; HARRY, 1998 ; KANJI, 2008; TSIRONIS; PSYCHOGIOS, 2016). The SS methodology has become one of the most significant strategies for improving processes and products (TLAPA *et al.*, 2016), and suggests that there is a direct correlation between the defects appearing in products and customer satisfaction (TSIRONIS; PSYCHOGIOS, 2016). It can be applied in many different context and processes (ANDERSSON *et al.*, 2014) but a central aspect is committed leadership in all levels (ANDERSSON *et al.*, 2014; HENDERSON; EVANS, 2000; SÖRQVIST, 2004). SS based its success on the use of statistical methods for identifying defects and improving processes and at the same time responding to the voices of customers (FAZZARI; LEVITT, 2008; SHARMA; CHETIYA, 2009; TSIRONIS; PSYCHOGIOS, 2016). Recently many large organizations as well as in small and medium enterprises (SMEs) are using SS strategy (KUMAR; ANTONY, 2008; TLAPA *et al.*, 2016).

L aims on cycle time and waste elimination whereas SS seeks to eliminate defects and reduce variation (LUBOWE AND BLITZ, 2008). Lean cannot bring a process under statistical control, while SS alone cannot dramatically improve the speed of the production process and reduce invested capital (CARREIRA, 2005; TSIRONIS; PSYCHOGIOS, 2016). Therefore, a combination between the two methods is required (ARNHEITER; MALEYEFF, 2005; TSIRONIS; PSYCHOGIOS, 2016), and it may result on the reduction of process variation and elimination of waste (ANTONY *et al.*, 2003; FURTERER; ELSHENNAWY, 2005; JING, 2009; TSIRONIS; PSYCHOGIOS, 2016).

The joint-use of L and SS has appeared in the academic literature (ANDERSSON *et al.*, 2006; ANDERSSON *et al.*, 2014; GEORGE; WILSON, 2004; MARTICHENKO, 2004). LSS concept emerged as a balanced approach that incorporates principles and concepts from both concepts, attempting to create a synergy between their functionalities (ARNHEITER; MALEYEFF, 2005; FERGUSON, 2007; TSIRONIS; PSYCHOGIOS, 2016). George (2002) claims that *“Lean Six Sigma helps companies flourish in a new world where customers expect no defects and fast delivery at the minimal cost”*. LSS targets to maximize shareholder value by achieving fast improvements in customer satisfaction, quality cost and speed of the process (HILL *et al.*, 2011; SUNHILDE; SIMONA, 2007; TSIRONIS; PSYCHOGIOS, 2016).

These two vital strategies have been effectively integrated, enabling companies to meet and exceed customer expectations in a changing and competitive global environment (BYRNE *et al.*, 2007; GEORGE, 2002; GEORGE *et al.*, 2004). By implementing this methodology, companies could improve business environment and therefore performance (TSIRONIS; PSYCHOGIOS, 2016). LSS include methods and values, which support collaboration (ANDERSSON *et al.*, 2006).

2.2 COLLABORATION

Developing a supply chain's performance requires focus on the interaction of processes not the optimization of isolated processes (STEVENS; JOHNSON, 2016). To the overall performance of the chain, it is crucial the collaboration among supply chain partners (NURUL KARIMAH *et al.*, 2016). It could help companies to find the supply chain solutions that can improve their capabilities and competitiveness (GOLD *et al.*, 2010; NURUL KARIMAH *et al.*, 2016). Collaboration is the confluence of all parties in the supply chain acting in unison towards common objectives (BAKER *et al.*, 2007).

Andersson and Hammersberg (2007) consider that the best solution for the performance of the supply chain would be to collaborate with all companies, but it is quite complicated. That is why the starting point is to look at decisions of key suppliers or customers to collaborate. Once collaboration begins with key supply chain members, it eventually becomes routine and the focus can turn to new relationships (MENTZER, 2001).

The new forms of collaborations are a response to global competition and the strategic need of supply chains to combine resources to be competitive (BAK, 2007). Collaboration is included in many definitions of supply chain (ANDERSSON; HAMMERSBERG, 2007), and appears as one of the principles that characterize supply chain resilience (CHRISTOPHER; PECK, 2004). The practice of collaboration is also the core tenet in developing flexible supply chains (BAKER *et al.*, 2007). It is often not possible to collaborate with every company in the supply chain, even if all the companies are important. Collaborations offer many value-added capabilities to the supply chain (BAK, 2007); but developing and maintaining collaboration requires considerable time and effort (ANDERSSON; HAMMERSBERG, 2007). Supply chain collaboration is effective only if the collaboration tools are integrated and used jointly by supply chain partners (BAK, 2007).

The goal is to integrate and coordinate all activities and processes across the supply chain through enhanced collaboration and information exchange (LUMMUS ; VOKURKA, 1999). Effective collaboration also encompasses planning, development, coordination, organization, integration and control, process across the supply chain. Managers across the supply chain must take interest in each others' success and work together to make the entire supply chain competitive. Today business continuity planning often remains a one-firm focused activity; very few companies have a true understanding of the composition of the network beyond the first tier, and yet it is often at those more distant tiers where risk to business continuity originates (CHRISTOPHER; TOWILL, 2000; ERICSSON, 2003; LUMMU; VOKURKA, 1999). The collaboration is required to get the integration of the supply chain.

2.3 SUPPLY CHAIN INTEGRATION

Existing literature promotes the significance of integration within the firm (FRANKEL; MOLLENKOPF, 2015; SWAIM *et al.*, 2016; SWINK; SCHOENHERR, 2015). However, some authors consider that there is no universally accepted definition of SCI (SUN; NI, 2012), and it is recognized that there is a conceptual vagueness about it and more knowledge is needed (FABBE-COSTES; JAHRE, 2008). The scope of integration may include upstream, downstream, and extended integration (FABBE-COSTES; JAHRE, 2008; FROHLICH; WESTBROOK, 2001; ROSENZWEIG *et al.*, 2003; SWINK *et al.*, 2007).

According to Fabbe-Costes and Jahre (2008), SCI is a multidimensional concept with a complex nature. Through the integration of the whole supply chain, is being created customer value (SUN; NI, 2012). The challenge of the Supply Chain Management is to integrate operations across multiple enterprises that are engaged by the same proposition of value (RIVEROS; SILVA, 2004; BOWERSOX *et al.*, 2002; VOIGT, 2011). Integrating the supply chain refers as much to the need for strategic and operational integration within and across the business (STEVENS; JOHNSON, 2016; SWINK *et al.*, 2007) as it does to relational integration with customers and suppliers (BENTON; MALONI, 2005; STEVENS; JOHNSON, 2016).

Supply chain integration is a strategic, which attempts to minimize the operating costs and thereby enhancing values for the customers and shareholders, by linking all participating players throughout the system (KWON; SUH, 2005). Steven and Johnson (2016) consider that SCI is the alignment, linkage and coordination of people, processes, information and strategies

across the supply chain between all points of contact and influence to facilitate the efficient and effective flows of material, money, information, and knowledge in response to customer needs.

SCI is characterized by joined up thinking, working, and decision making, underpinned by principles of flow, simplicity, and the minimization of waste (STEVENS; JOHNSON, 2016). Therefore, its scope includes governance knowledge, organization structure, systems, relationship management, business strategy, process design, and performance management (STEVENS; JOHNSON, 2016).

The degree of integration in the supply chain often influences both cost and efficiency in a positive way. Furthermore, the outcomes of integration in improvement between companies are often improved logistics objectives in the supply chain (LENNY KOH *et al.*, 2006). Bagchi *et al.* (2005) have also shown that supply chain integration effects operational performance such as cost, efficiency, on time delivery, and rate of return. The supply chain business relationship between companies is growing, or should be growing, ever closer through just-in-time contracts, which are focused in L philosophy (GEORGE *et al.*, 1999).

3 RESEARCH METHOD

The research is driven by the knowledge and experience in the theory and practice. Using literature review, multi-disciplinary and cross-functional approaches such as case studies is a good solution for logistics research, which deals with practical oriented problems (JAFARI *et al.*, 2016; NÄSLUND, 2002).

3.1 CASE SELECTION

The research follows the cases study methodology (YIN, 2009); that it is increasingly becoming accepted in this exploratory studies (EISENHARDT, 1989A; JAFARI *et al.*, 2016; YIN, 2014). The case study method enables researchers to develop a better insight into a complex and relatively unexplored phenomenon (ELLRAM, 1996), that are difficult to identified with other methods (FLYVBJERG, 2006). At the same time, it helps to detect the appropriate explanation to be analyzed (YIN, 2014). Having multiple cases, the findings are likely to be more robust than having only a single case (YIN, 2014); and this is used in the research.

A multiple case-study approach can also provide more in-depth evidence in understanding complex relationships related to operations and supply chain management (ELLRAM, 1996; TSIRONIS; PSYCHOGIOS, 2016), which are associated with the concept of LSS (TSIRONIS; PSYCHOGIOS, 2016). In addition, an empirically valid theory can be supported mainly by multiple case-studies (EISENHARDT; GRAEBNER, 2007), that can explore and explain better social phenomena that cannot be identified easily through other methods (EISENHARDT, 1989A; EISENHARDT, 1989B).

This multiple-case study has been performed, by means of qualitative methods of data collection, such as observations, face-to-face interviews and document analysis. Multiple-case selection was used as seven large companies have been investigated, large here meaning over 500 employees.

To select the companies have been used purposeful sampling and convenience sampling (PATTON, 2005). All the companies (except Dell) were chosen from a SS association. They were selected based on their participation in a network, and it was then assumed that they understood and applied SS. The selection of companies was also made with the following criteria: the companies must have used the principles in L and SS for at least two years and run more than ten SS projects. Hence, all companies have been using a combined LSS approach. Six of them had used a typical L approach before, and all of them used only TQM some years ago. The participating companies were Ericsson AB (Borås), Volvo Engine (Skövde), Volvo Cars (Göteborg), Alfa-Laval (Lund), Dell (Stockholm), Parker Hannifin (Trollhättan), and SKF (Göteborg); all of them are referred by numbers in the article. Covering different sectors has been also taken into consideration.

3.2 UNIT OF ANALYSIS

Interviews are performed with industrial engineers, middle managers, operators, Six Sigma Champions, Black-Belts, and Lean coordinators. The intention is to cover different professions with different perspectives, but due to the credibility at company 3, and accessibility at company 5, only one person from these companies has been interviewed, see table 1. Face-to face interviews were performed with different personal sympathies and professions.

Table 1 – The interviewed companies and interviewees

Company	Interviewee Position
Company 1 (C1)	Lean coordinator Six Sigma Master Black Belt Six Sigma Black Belt
Company 2 (C2)	Lean coordinator Six Sigma Master Black Belt Middle Manager
Company 3 (C3)	Six Sigma Black Belt
Company 4 (C4)	Six Sigma Master Black Belt Middle Manager
Company 5 (C5)	Procurement manager
Company 6 (C6)	Lean coordinator Six Sigma Black Belt Middle Manager
Company 7 (C7)	Lean coordinator Six Sigma Master Black Belt Middle Manager

Source: Elaborated by the authors, 2019.

3.3 DATA COLLECTION METHOD

The findings were supported empirically by on-site interviews and by observations in five of the companies. The observation is used as a tool for collecting data, which enable the researcher to describe existing situations and to have a better understanding of the context and phenomenon under study (KAWULICH, 2005). On-site interviews and observations were also chosen to identify whether the companies had the same definition as the academy of a combined management philosophy. Different respondents were asked the same questions, notes were written down, and the interviews were tape-recorded. In four of the companies, the interviews started with a group interview, to create a relaxing atmosphere and opportunities for the authors to explain their viewpoint. All the companies agreed to participate in the study; the interview response rate was 100 %.

3.4 VALIDITY AND RELIABILITY

Efforts have been made to increase the validity and reliability of the results in the study. The interview key was formulated and adjusted during a period. The questions have been discussed with colleagues and persons from companies before testing. The questions have been first tested on one respondent and then adjusted. One pre-interview was made at one company that only use L and TQM philosophies (Tour Andersson, Annelund, Sweden). After

some adjustments the real interviews were made. All the interviews were recorded and written down. The respondents were contacted by phone and agreements on interviews and on-site observations were made. In five of the companies more than three persons were interviewed. The interviews were written down and sent to the respondents, and afterwards the companies had the opportunity to confirm or adjust the answers. The authors also attempted to select different respondents who support L and SS in the same company.

4 RESULTS AND DISCUSSIONS

This section is about the results and discussions from the interviews in place and by observations in the companies. It addresses the complementary use of LSS, and the degree and organization of collaboration in the supply chain.

4.1 LSS AND COLLABORATION

All the companies mention that risk outside the focal company is the most dangerous risk, and come up with solutions and prevention of problems or risk they must collaborate with suppliers and other stakeholders. For quantitative problems, SS is often most suitable. L should be recommended when the solution is of a qualitative nature; all the companies were in agreement regarding that point. However, they have integrated some tools and methods from both philosophies.

From the seven company interviews, it is possible to conclude: SS is the problem solving philosophy and L assists in governing the everyday work. It involves all employees and creates a standard platform in processes, workstations, and product assort, but it is not so often involved collaboration with suppliers. SS and its tools help solve the problems that are too advanced for L and its tools. Often the problem of the root cause is outside the company that also include suppliers in the project that improve collaboration outside the focus company. According to C7 LSS improve the barriers and it will be easier to understand each other if they have the same DMAIC (ANDERSSON; HAMMAERSBERG 2007)

The improvement projects in a SS are conducted over a wide range of areas and at different levels of complexity. SS and L philosophies can be applied in several areas, including

manufacturing and service industries (MAGNUSSON *et al.*, 2003). These arguments should make using LSS in the entire supply chain favorable.

The companies were asked questions regarding how they work with supply chain processes, e.g. how they collaborate and about their present relationship with suppliers and customers. The processes often go from the starting point to the end of the supply chain, and across the network of companies. Even if both SS and L have a strong focus on processes, the companies often work only with the process inside the focal company or at best persuade some suppliers to change their routines. In approximately one third of the SS projects, the root cause of variation was found outside the focal companies. To solve these causes, companies today often invite members from these companies to take part in some meetings, but people are seldom enrolled in the entire project.

C6 argues that today they have worked extensively with L and SS inside the focal organization. The next step will be collaboration with both suppliers and customers. Today the company's suppliers create problems for the company; therefore, it is important to include them in future work.

Six of the companies could show that if the projects expand outside a department, or even better, outside the company, the savings would increase. For example, C2 would like to collaborate more often, but it is easier to focus on improvement work within the focal company, because of the established legitimacy of improvement work.

Experiences from C7 show that there are key advantages by collaborating within the supply chain. For example, the company could not deliver the desired amount of the product, depending on its suppliers; thus, the suppliers in turn got deficient raw material. C7 then started a SS project together with the suppliers' sub-contractors to improve the raw material they supplied. These sub-contractors also deliver to C7's competitors. Furthermore, SS has given C7 a common language, which has built bridges between departments, factories, and between suppliers and customers. For instance, C7 has developed application solutions together with another supplier, which also uses SS, and has performed SS projects together with suppliers in their factory. Today there is even a demand to work with SS from three other suppliers.

C1 has collaborated with their customers in a few cases. The customers could decide how they wanted the delivery of the goods; however, they were not interested in fast delivery, which implied a more expensive way of transportation. C1 often collaborates with the machinery suppliers in SS projects. When there is a fault after delivery it is difficult to diagnose is the location of the problem. For example, one project with a supplier resulted in a solution, which give rise to a better piece of equipment, and the savings were several hundred thousand Euros. C1 has now trained two Black Belts who work with the suppliers.

C4 has also developed a tool-kit for working with suppliers in their SS project. The last project with a supplier yielded a savings of 250 000 Euro.

C5 differ from the other investigated companies, in that they have integrated the suppliers. For example, C5 has employees at the suppliers' companies, as well as suppliers working in C5's factories. The collaboration also includes designing products and processes together with suppliers. Suppliers also participate in their training programme, which focuses on rapid flows and customer focus. Nevertheless, they have not integrated delivery to private customers; often there is a large transportation company responsible for this last step. In this last step, there are problems and potential for improvements, according to the authors.

After a few years of working with LSS the companies have improved considerably within the focal organization and have begun to realize that their suppliers create problems for the company. To be effective and efficient, the next step will be to collaborate with suppliers and customers to solve these problems together. The companies may invite staff members from these companies to take part in projects and in Six Sigma training courses, but only two companies have follow this practice.

SS organizations have standardized training courses, ranging from basic courses for White Belts to comprehensive courses for Black Belts (MAGNUSSON *et al.*, 2003). An improvement project is mandatory here; the authors' suggestion is to take a SS approach and have people participate from the entire value chain, and run the project together.

The above results have been summarized in the table 2, where can be appreciated that the results most important are 1, 2, 3, 5 and 8 showing that LSS enable collaboration. At the

same time the results 4 and 9 shows that companies most involve suppliers and other stakeholders in order to be more integrated.

Table 2 - Main results by case companies

	Results	Case Companies						
		1	2	3	4	5	6	7
1	LSS has strong focus on processes that enable collaboration between departments and companies	X	X	X	X	X	X	X
2	Working sometime with LSS in the process outside the focal company	X	X	X	X	X		X
3	Involving some suppliers in the routines of the focal company	X	X	X	X	X	X	X
4	Companies today often invite members from suppliers to take parts as a member in some improvement projects					X		X
5	By expanding LSS projects outside the company, the savings would increase.	X		X	X	X	X	X
6	LSS give a common language for working with suppliers and other stakeholders				X			X
7	LSS improve the barriers communication	X						X
8	Companies must collaborate with suppliers and stakeholders	X	X	X	X	X	X	X
9	Suppliers staff are permanently present in the focal company					X		

Source: Elaborated by the authors, 2019.

5 CONCLUSIONS

This research aimed to investigate if LSS can help to improve collaboration to get more integrated supply chains, and the answer is yes. The companies included in the study have integrated some tools and methods from both philosophies and all have aligned Lean and Six Sigma with great results in collaboration.

Working with LSS the companies have improved the processes in the focal organization, at the time that they have realize that their suppliers create problems for the company. These companies have create the strategy of inviting members from their suppliers to take part in some meetings, but people are seldom enrolled in the entire project

Lean is a systematic philosophy for identifying and eliminating elements not adding value to the process, and creating a stable ground as well as striving for perfection and a customer-driven pull of the process. By integrating Six Sigma's training system, tools, and the roadmaps for improvements, new products, and processes the company may have a competitive ground.

The next step for the companies is to involve the entire supply chain and take the value chain into consideration. If the companies intend to become more integrated they must involve both suppliers and customers more in their own processes and design products and processes together. Moreover, representatives from different parts of the supply chain may co-operate with each other in the Six Sigma approach to training, thus performing projects together and crossing over boundaries.

A critical point for a future research would be to develop a methodology that combine LSS and the existent models of integration in the supply chains, taking into account the enrollment of people in the entire project, to be applied into the companies. The developing of the combined methodology will allow measuring the quantitative parameters and indicators of efficiency and effectiveness.

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