An ANP model to support decision-making in a Portuguese pharmaceutical supply chain

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Resumo

Para que as cadeias de abastecimento consigam competir no seu meio envolvente, as empresas que as constituem tiveram de adoptar novas maneiras de pensar, nomeadamente, considerando a gestão da cadeia de abastecimento como um pilar essencial para a sobrevivência no mercado. No contexto da gestão da cadeia de abastecimento, é fundamental entender de que modo é que os paradigmas de gestão *Lean* e Ágil aplicados às cadeias de abastecimento permitem alcançar uma gestão eficiente. A gestão da cadeia de abastecimento envolve ainda práticas de gestão e indicadores de desempenho, sendo importante que os seus gestores identifiquem os que permitem alcançar mais vantagens competitivas. A presente dissertação apresenta um modelo de apoio à tomada de decisão, baseado no *Analytic Network Process*, que tem como objectivo apoiar os gestores de entidades de cadeias de abastecimento da indústria farmacêutica na tomada de decisões, relativamente a práticas de gestão, e a indicadores de desempenho, de forma a torná-las mais competitivas.

Palavras chave: Gestão da cadeia de abastecimento, *Lean*, Ágil, *Analytic Network Process*, Indicadores de desempenho, Capacidade de resposta.

Abstract

In order to cope up with a volatile and scarce environment, companies have had to adopt new ways of thinking. One of them is embracing Supply Chain Management (SCM) and considering it as a crucial asset if willing to compete in the marketplace. In the context of SCM, it is important to understand how Lean and Agile SCM paradigms are adopted as means of achieving an efficient Supply Chain (SC). Besides the mentioned paradigms, many Key Performance Indicators (KPIs) and management practices come along with SCM, and it is important that SC managers identify the ones that bring the most competitive advantages. This dissertation intends to design a model based on the Analytic Network Process (ANP) in order to assist SC managers from different entities of a pharmaceutical SC in exploring efficient decisions to be made, with respect to KPIs and management practices, as means of achieving a highly competitive SC.

Keywords: Supply Chain Management, Lean, Agile, Analytic Network Process, Key Performance Indicators, Responsiveness.

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List of abbreviations

AHP Analytic Hierarchy Process

AI Active Ingredient

AIs Active Ingredients

ANP Analytic Network Process

ASC Agile Supply Chain

CPFR Collaborative Planning, Forecasting and Replenishment

CR Consistency Ratio

ECR Efficient Consumer Response

GSC Global Supply Chain

IS Information Sharing

JIT Just-In-Time

KPI Key Performance Indicator

KPIs Key Performance Indicators

LSC Lean Supply Chain

MCDM Multi Criteria Decision Making

MS Microsoft

NPI New Product Introduction

OTIF On Time In Full delivery

PWC Pair-Wise-Comparison

PWCs Pair-Wise-Comparisons

RUD Responsiveness to Urgent Deliveries

SC Supply Chain

SCs Supply Chains

SCC Supply Chain Collaboration

SCM Supply Chain Management

SCP Supply Chain Performance

SKU Stock-Keeping-Unit

TPS Toyota Production System

VMI Vendor Management Inventory

WPM Weighted Product Model

WSM Weighted Sum Model

List of symbols

ω Eigenvector of a pair-wise comparison matrix

λ Maximum eigenvalue of the pair-wise comparison matrix

1. Introduction

1.1 Context

While markets have boosted as means of becoming extremely competitive in the last few decades, companies have had to improve their procedures and their way of thinking in order to keep up with the competitors. Actually the idea in the modern way of doing business is that it´s the Supply Chains (SCs) who compete, not companies, and the success or failure in the marketplace is ultimately determined by the end customer (Christopher and Towill, 2001; Li et al., 2005; Gunasekaran, 2008; Jain et al., 2008). To meet the requirements of the end consumer, all Supply Chain (SC) entities have to contribute equally in the selection of the strategies to adopt in order to reach the objectives of the SC (Kisperska-Moron and Haan, 2011). As a consequence, Supply Chain Management (SCM) has arisen to be not only a way to achieve competitive success and advantage, but also the key for survival. Ramanathan (2013) recognizes SCM as a powerful business tool to survive in a competitive marketplace, while Vonderembse (2006) states that embracing SCM is extremely important because it focuses on actions along the whole value chain.

Decision-making is crucial for companies who strive to improve their Supply Chain Performance (SCP). In order to make the right decisions, and thus, improve competitiveness, the global market has imposed that collaborative working across SCs is required. In doing so, companies enforce their partnerships and strengthen their business in the market. As a matter of fact, collaboration between companies, supported by flawless communication between their information systems has been identified a key enabler for company success on a continuously changing global environment (Jardim-Gonçalves and Grilo, 2006). In addition, companies are required to provide superior quality products, at low costs, with on-time delivery and thus, enhance performance and competitiveness (Agarwal et al., 2008).

SC managers must implement new strategies in order to respond rapidly and cost efficiently to unpredictable changes in the markets, both in terms of volume and variety (Azevedo et al., 2011). However, decision-making is also an important part when implementing the referred strategies, considering that they have to be carefully selected in order to cope with the objectives of each SC.

Management paradigms, Key Performance Indicators (KPIs), management practices and competitive priorities are a few of the SC characteristics involved in the strategic planning of a SC. These characteristics have to be involved in the decision-making process in order to strive for high SCP rates. In order to evaluate the referred characteristics, one has to be aware of the most sophisticated decision-making tool considering the structure of the problem and the marketplace. The Analytic

Hierarchy Process (AHP) and the Analytic Network Process (ANP) are two of the many available tools, but only after a literature review of each, can one decide on the best tool to adopt.

The challenge of this dissertation is to build a framework in order to figure out the best decisions to be made, in the strategic planning, when considering a highly regulated and competitive industry, the pharmaceutical industry.

1.2 Objectives

This dissertation has as its main objective to do a literature review of the Lean and Agile SCM paradigms and thus, the development of a decision-making model with the intent of aiding entities of the SC in their respective management issues and strategies. In this dissertation, the main focus rests in the distribution part of the SC. Still, manufacturing facilities are briefly described in the dissertation.

The model is constructed using the ANP, which is an extension of the AHP. It helps managers from different entities of the SC to decide on the best Key Performance Indicators (KPIs), management practices, SCM paradigms and competitive priorities to utilize with the ultimate objective of achieving a high SC performance and thus, competitive success.

1.3 Research methodology

This dissertation is motivated by the merging of the studies proposed by Agarwal et al. (2006) and Cabral et al. (2012), where decision-making models (ANP) are applied to the fast moving consumer goods and the automotive industry, respectively. Cabral et al. (2012) made some recommendations for the future work. For instance, they considered important to evaluate perceptions from different entities of the SC, in addition to developing a model for another industry and compare the findings with the ones of their study. Agarwal et al. (2006) modeled the metrics of Lean, Agile and Leagile SCs. They considered four main criteria to assess SC performance: Cost, Quality, Service Level and Lead Time. These criteria are the market winners and qualifiers for Lean and Agile SCs. In addition, the authors considered four different clusters where each cluster can be considered a macro-variable for the respective SC. Furthermore, each cluster has four different elements, or micro-variables. The study made by Cabral et al. in 2012 differs in some details. Besides the industry being different, they include different entities in their model, and instead of Lean or Agile SC variables, management practices and KPIs are linked to the paradigms.

Since the literature review showed no evidence on decision-making modeling in the pharmaceutical industry, the decision in developing one came up.

The research started with the proposal in realizing the dissertation in the pharmaceutical industry. After the approval, *Novartis Farma* was immediately contacted and the research started to be

conducted. Furthermore, and after understanding how the pharmaceutical SC worked, several other entities had to be involved in the research, as means of having a wider and a more diversified perspective of the respective SC. The entities involved directly are: *Novartis Farma, ETO* (pharmaceutical companies), *Lusomedicamenta* (secondary manufacturing), *Alliance Healthcare* (wholesaler), *Farmácia Allegro* (pharmacy), *and Farmácia Crespo* (pharmacy).

The procedure adopted in the development of this dissertation is described in the following.

The first part of the research was to conduct a literature review on three main issues: SCM, Lean and Agile SCM paradigms with the purpose of making a proper characterization of them. Initially it was supposed to be only on the paradigms, but it goes without saying that SCM comes along with the Lean and Agile SCM paradigms. In addition, a review on decision-making tools was made in order to understand and address a proper model into the pharmaceutical industry. The main aim of the review was to get answers for some questions, namely what is the historical background of Lean and Agile paradigms? How are these paradigms characterized? Which are the main attributes of Lean and Agile SCM? Which management practices are used in Lean and Agile SCs in order to enhance SCP? Which KPIs are mostly used for measuring these practices and SCP in general? Finally and interpretation of the review was made in order to organize the obtained information.

Meanwhile, an introductory visit was made to each company, with the intent of getting more knowledge about the companies and thus, about the SC. Several conversations in the form of semi-structured interviews were held with the experts of each entity in order to figure out how the industry works and how the theoretical background of the dissertation could be implemented into a real problem or model. After gathering the necessary information, it was decided that a decision-making model that enhances SCP would be constructed and applied to the pharmaceutical industry. This procedure took several months to conclude.

ANP was selected as the most appropriate decision-making tool based on the literature review.

Again, several conversations with experts from all of the companies belonging to the SC were held to decide on the elements to include on each cluster (Management practices, KPIs and competitive priorities) of the ANP. Afterwards, a questionnaire was made in order to gather the judgments of all existing Pair-Wise Comparisons (PWCs) made by the experts. The structuring and constructing of the questionnaires also took a significant amount of time and effort. Many practices and KPIs were suggested by the experts but only the most appropriate ones were selected in order to facilitate the understanding of the model in the experts' point of view. In addition, the number of pairwise comparisons lowers significantly, which reduces the time needed for answering the questionnaires (some experts may not be willing to answer questionnaires which take too much time in doing so). The most appropriate competitive priorities were also selected. The last step was to collect and analyze the

data to discuss the obtained results. Super Decisions software (version 2.2.6 beta) was used in the modeling of the ANP network.In order to better understand the research methodology, a diagram is illustrated in figure 1.1.

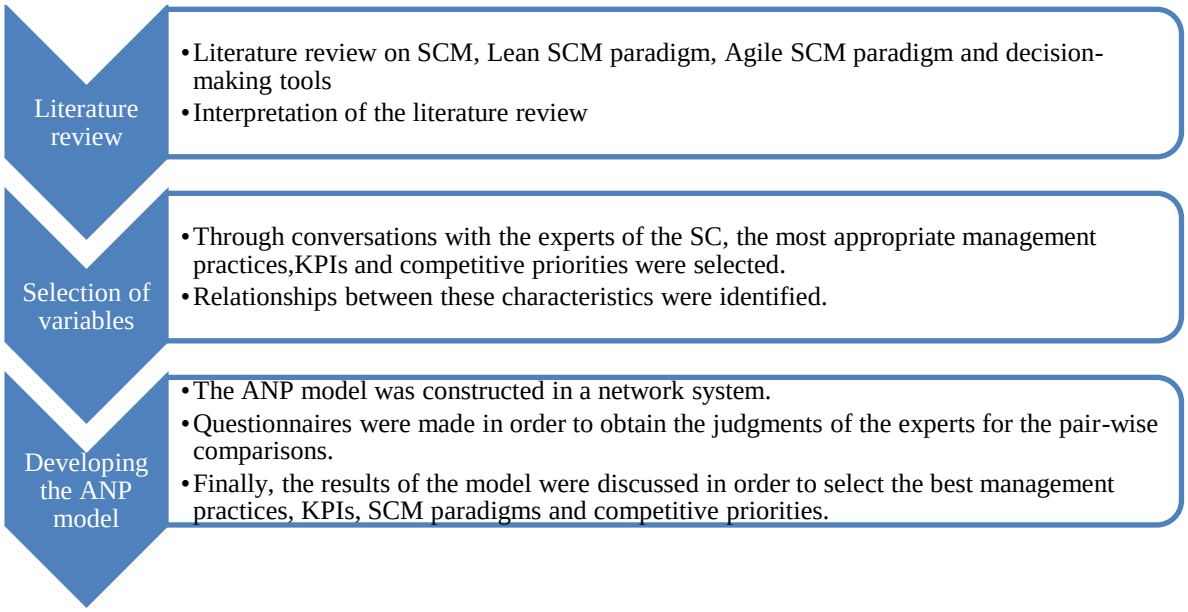

Figure 1.1 - Research methodology diagram

1.4 Structure of the dissertation

This dissertation is divided into 5 chapters.

It begins with the present introduction chapter where the context of the dissertation was described, objectives outlined, research methodology explained and finally the structure described.

In the second chapter a literature review is done. It begins with SCM and its relevance. Afterwards Lean and Agile historical background and the scientific characteristics of each of the paradigms are emphasized. Decision-making tools are also reviewed. The chapter also includes the description of how the actual literature review was conducted.

The third chapter describes the case study, a pharmaceutical SC. It also characterizes each entity belonging to the SC separately.

The fourth chapter is related to the application of the ANP into the case study. The analysis of the results is also part of this chapter.

The fifth and final chapter draws out conclusions of the dissertation and makes suggestions for future work.

Finally the bibliography and the annexes are illustrated at the very end of the dissertation.

2. Literature Review

The literature intends to obtain answers for the following questions:

What is supply chain management? How does it affect a company´s performance in today's volatile and extremely competitive marketplace? What comes along with it? Which are the essential constructs that enhance supply chain performance?

Lean and Agile paradigms are two essential concepts that come along with supply chain management. It's essential for managers to understand how these concepts are related to each other and how they differ. This literature review must cover the aspects in which each of these paradigms tend to focus; which is the operational performance that distinguishes them and more importantly, whether these systems compete or complement each other?

Which are the decision-making tools available to assist supply chain managers in their complex decisions? How do they differ from each other and what is the most adequate and most up to date tool available?

2.1 Relevance and review of the main topics

In this section the relevance and review of each topic is handled separately. The main topics are the following: Supply Chain Management (SCM), Lean SCM paradigm, Agile SCM paradigm, and models for decision-making. In addition, a review of Leagility or Hybrid strategies is made.

2.1.1 Supply chain management

Naylor et al. (1999) defines a supply chain (SC) as a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via a feed forward flow of materials and feedback flow of information. Azevedo et al. (2012) describes SCM as promoting the integration between companies and their suppliers through the development of supplier partnerships and strategic alliances.

SCM is a critical factor for achieving and maintaining competitive advantage (Mohammed, 2008). Li et al. (2005) agrees stating that SCM is an essential prerequisite in order to stay in the competitive global race to growing profitability. Martin and Patterson (2009) claim that due to the need for company and overall SC efficiency, companies are forced to review, evaluate and consider the adoption of SCM concepts. The aim of SCM is to create sourcing, making and delivery processes and logistics functions across the SC as an effective weapon.

Lambert et al. (2005) identified the three key SC elements required to make products available to end customers: i) SC network, ii) SC processes the network operates with and supports and iii) SC decisions required for managing the network.

The SC network consists of the suppliers, manufacturing sites and warehouses, where raw-material, semi-finished and finished inventory flows between the entities with the intent of satisfying end-customer demand (Stavrulaki and Davis, 2010). SC processes refer to a set of activities used to carry out the flow of material through the network. In addition, SC processes include production and logistics processes as the council of SCM professionals suggests. More specifically, logistics processes include the activities related to the storage and flow of goods (forward and reverse), i.e. warehousing and transportation. At last, when it comes to management and decision-making, they cover the aspects of planning, organizing, implementing and controlling of SC processes (Davenport et al., 1995).

Collaboration plays a huge role among Supply Chains (SCs) willing to improve their overall performance, where all chain entities benefit from it (Simatupang and Sridharan, 2005). In order to support SCM and to improve Supply Chain Performance (SCP), several collaborative tools are being adopted by SC operators, e.g. Vendor Management Inventory (VMI) and Collaborative Planning and Forecasting Replenishment (CPFR) (Ramanathan, 2013). Manufacturers have increased their profits and achieved cost reduction when practicing Supply Chain Collaboration (SCC) and advanced information sharing (IS) with other SC entities (Kulp, 2004). These are two of the many benefits which come along with SCC. However, to generate these benefits, available information must be properly used in the right context among partners (Moinzadeh, 2002). In addition, Cao and Zhang (2010) state that collaboration and the derived benefits are absent when SC entities purse their own objectives.

As mentioned above, SCP is one of the main issues that SC managers have to deal with when embracing SCM. How to enhance performance? What should be the measures/ Key Performance Indicators (KPIs) considered to enhance SCP? During the recent years, SCP measurement has been on the top of business research list meaning that it´s a crucial asset linked to success (Najmi and Makui, 2012). Likewise, Gunasekaran and Kobu (2007) assure that good performance measures and metrics will facilitate a more open and transparent communication between people leading to a co-operative supported work and thus, improve organizational performance. The performance measures and indicators will be reviewed in section 2.1.5.

Another issue which has gained importance in recent years is the fact that uncertainties have become a bigger of a concern in SCs, as well as the consequently increasing inventories and distorting demand forecasts have. Besides, these forecast errors amplify as we move upstream in the SC (phenomenon known as the bullwhip effect). In order to prevent this from happening, the SC should have a centralized and collaborative planning supported by effective use of IT tools (Agarwal et al., 2005). Akyuz and Erkan (2010) provide an extensive literature review on SCP measurement.

Lambert et al (2005) identified the three key elements to make products available to the customers, in a generalized way. Li et al. (2005) in turn, identified 6 constructs (Information sharing, information

quality, strategic supplier partnership, customer relationships, postponement, internal lean practices) of SCM considering delivery dependability and time to market as performance outcomes. These constructs are more related with actual management practices and measures. Delivery dependability is the ability of to meet quoted or anticipated delivery dates and quantities on a consistent basis (Nair, 2005). Time to market is the extent to which an organization is capable of introducing new products more quickly than major competitors (Carvalho et al., 2012).

One of the constructs, is the above mentioned Information Sharing (IS). According to Li et al. (2006), IS refers to "the extent to which critical and proprietary info is communicated to one's SC partner". IS that bear on key performance metrics and process data, not only enables efficient decision-making but also improves the SC visibility. However, shared information within SC partners is only beneficial if the information is relevant, accurate, timely and reliable; i.e. information quality has to be good (another construct). Data acquisition, processing, storage, presentation, retrieval, and broadcasting of demand and forecast data, inventory status and locations, order status, cost-related data and performance status are some of the elements that IS consists of. Generally speaking, IS facilitates the flow of goods in the SC (Cachon and Fisher, 2000).

Strategic supplier partnership is Li's another SCM construct and it´s defined as the long-term relationship between the organization and its suppliers. Direct long-term association, mutual planning and problem solving efforts are emphasized by strategic partnerships (Gunasekaran et al., 2001). The purpose is to promote shared benefits among the entities and enable them to work more effectively with a few important suppliers who are in compliance with sharing responsibility for the success of the products (Killing, 1995).

Another construct is customer relationships and they involve practices related to customer complaints management, long-term relationship building with customers. It also improves customer satisfaction, which is in fact, an important variable of SC agility (Agarwal et al., 2006). An organization can differentiate its products from companies through maintaining close customer relationships (Li et al., 2005). It also sustains customer loyalty and increases the perceived value of the product to the customers (Magretta and Dell, 1998).

Postponement is also a construct. It's defined as the practice of moving forward one or more operations of activities (making, sourcing and delivering) to a further point in the SC. Three types of postponement have been recognized in literature: form, time and place.

Li et al. (2006) refers to one more construct which is related with practices of the Lean SCM paradigm, which are detailed in section 2.1.2.

2.1.1.1 Aligning products with supply chains

Vonderembse et al. (2006) state that the product is the soul of the SC. Mason-Jones et al. (2000) add that a SC has to adopt a strategy matching both their particular product and marketplace. In order to develop that strategy, the constraints of the marketplace have to be well understood.

A function of the product characteristics and expectations of the final customers should always be considered when designing a SC (Fisher, 1997). Vonderembse et al. (2006) go even further arguing that the product is the soul of the SC. Hence, several authors have proposed through frameworks, the strategic alignment of products with the right kind of SCs considering their demand and supply characteristics (Mohammed, 2008).

To successfully meet customer demands and consequently designing a SC, it's essential to understand the characteristics of the product (Vonderembse et al., 2006). According to Mason-Jones et al. (2000), there are three types of products: standard, innovative and hybrid.

- If demand is stable and can be accurately forecasted; when production requirements and design characteristics change slowly/incrementally over time; if these prerequisites are met, the product is considered standard. This type of products generally has long-term relationships, which leads to high quality materials and quantity discounts through Just-in-Time (JIT) delivery (Mason-Jones et al., 2000; Vonderembse et al., 2006), e.g. fast-moving-consumer-goods, groceries (Reichhart and Holweg, 2007).
- If demand is uncertain, product designs/manufacturing capabilities unstable and sophisticated; if the product is aimed to new customers or new markets and if it satisfies needs that are still to articulate, it is considered to be an innovative product. In addition, these products require close customer contact and they're adaptable to changing customer requirements. Normally this type of product has a premium price which enhances profitability. These products suffer a transformation into standard products when demand increases and competitors appear, e.g. fashion apparel (Vonderembse et al., 2006). For that matter, Bruce and Daly (2011) provide an example, through a case study, concluding that companies in textiles and clothing industry need to be able to respond quickly to changing markets and be able to provide quick replenishment. However, large quantities of inventory should not be accumulated due to the short life cycle of the respective products and due to the market being seasonal.
- These products include a mix of standard and innovative. If products are complex, have several components and are considered to be major purchases made periodically by customers (after careful consideration), they're considered to be hybrid. Hybrid products have a long life cycle with a few improvements and innovations offered periodically, e.g. automobile industry, furniture.

Table 2.1 confirms that the functional product is related to an efficient supply, which in turn, can be linked to "Lean" supply strategies. The innovative product is aligned with responsive supply, which is, as opposed to the efficient supply, linked to "Agile" supply strategies. These two strategies or philosophies will be described in detail starting from section 2.1.2 of the present literature review.

Table 2.1 - Product supply matrix.

Adapted from: Fisher M., 1997

	Functional Product	**Innovative Product**
Efficient Supply	Alignment	Misalignment
Responsive Supply	Misalignment	Alignment

2.1.2 Lean thinking

"*Lean emerged slowly over the years, rather than that it was invented as a grand theory*" – (Kisperska-Moron and de Haan, 2011)

2.1.2.1 Historical background

The literature review showed that the Lean philosophy and its evolution have been widely discussed in literature so there's a lot of feasible material related. However, it officially emerged in the post-war era (WW2) in Japan, where competing markets were short on resources implying that companies had to make the most out of them. In this context, Toyota designed a production system that utilized some of Ford's mass production techniques and combined it with a small-batch production system and some concepts from its loom business. Meanwhile, the Toyota Production System (TPS) was born. The goal was to eliminate "muda"[1] in all possible forms, i.e. eliminate defects in production, overproduction, inventories, unnecessary processing, unnecessary movement of people, unnecessary transport of goods and waiting by employees (Ohno, 1988). One element was added to the list by Womack and Jones (1996), the waste of goods and services that fail to meet the needs of the customers. Since then, TPS has continuously evolved (Reichhart and Holweg, 2007). However, it only became known in the west in the beginning of the 90's as just-in-time (JIT) production. Furthermore, emerged the term "Lean", originally conceived by a MIT researcher called John Krafak. Although the term wasn´t coined by Womack and Jones, it was the launching of their seminal book "The Machine that changed the World" (1990) where the premise of lean production was introduced to the business world. In their book it was stated that a lean company uses "less of everything compared with mass production – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering

[1] Means waste in Japanese.

hours to develop a new product in half the time". Womack and Jones (1994) also examined operations and work methods utilized by automotive industries in Japan, U.S. and Germany and showed how the Japanese outperformed their U.S. and German competitors.

Extension of lean operations to the so called "extended company" started raising attention in literature. The extended company is a group of individuals, functions and operationally synchronized companies with a common goal, which is to analyze and focus on the value stream so that everything related to supplying a good or a service is done from the client's perspective. In the extended company, there can be no boundaries, and an ethos of trust and commitment must prevail (Christopher, 2000). In the past few decades, this has been a major concern for the SC managers.

"*The narrower the scope of responsibility, the more easily a company can calculate costs and the benefits it generates and see the results of its improvement efforts. Therefore, the value stream should be segmented so that each company is responsible for a narrow set of activities.*" (Womack and Jones, 1994)

According to Womack and Jones (1996) and Hines et al. (2004) the philosophy of contemporary lean thinking can be abbreviated as maximizing the relative value delivered[2] by reducing waste and consequently operational costs.

Lean production has been largely debated in literature and it´s in many cases (companies) implemented almost perfectly, but when it comes to service operations, there´s still much to discuss. Lean distribution was introduced in the late 1980's.

Reichhart and Holweg (2007) define lean distribution as "minimizing waste in the downstream SC, while making the right product available to the end customer at the right time and location". Extending lean beyond the factory depends upon the type of the product. However, in many SCs the main focus still rests on the manufacturing operation, mostly due to the uncertainty in extending lean into the downstream part of the chain (Holweg and Pil, 2004). Furthermore, Womack introduced lean consumption in 2005. However, this dissertation will not review this concept further because it´s out of context.

2.1.2.2 Lean SCM paradigm

Lean thinking can be described from two different points of views, either from the philosophical perspective related with guiding principles and global objectives, or from the more practical one

[2] The relative value delivered can be defined as the value a certain product has to a specific customer divided by the cost, at which this value is created.

consisting of a set of management activities, techniques and tools which can be observed directly. This doesn´t necessarily mean disagreement when it comes to the meaning of lean production, but it sure undermines conceptual clarity (Hines et al., 2004).

In the Lean Supply Chain (LSC) operating costs and efficiency as well as quality and reliability are essential (market winner and qualifiers). This is consistent with Christopher (2000) who states that Lean management focuses on process efficiency generating the most outcome out of the least input through minimization of wastes. Vonderembse et al. (2006) contradicts stating that quality should be a market winner in addition to cost. A LSC focuses on employing continuous improvement efforts with its main concern being the elimination of waste and non-value adding tasks[3] across the chain, e.g. excess time, labor, equipment, space, inventories, transport and movement (Vonderembse et al. 2006; Mollenkopf et al., 2010). These improvement efforts favor the internal manufacturing flexibility (for already available products) considering that the manufacturing process gets more and more perfect. It also reduces setup time, which enhances cost reduction and consequently, profitability.

Some authors prefer to separate the "obvious" wastes from the "less obvious" ones, referring to excessive setup times, unneeded processes, unreliable machines and wastes associated with variability, respectively (De Treville and Antonakis, 2006). Meanwhile, the LSC lacks responsiveness to customer demands which requires flexibility in product design, planning and scheduling and distribution in addition to manufacturing. Some authors claim that Lean is simply JIT philosophy restructured. Sugimori et al. (1977) defined JIT as follows: "only the necessary products, at the necessary time, in the necessary quantity".

One of the main assets of the lean thinking is waste reduction and consequently the minimization of inventory. According to Anupindi et al. (1999), inventory can be reduced either by maintaining excess capacity or by lowering throughput time. Considering that excess capacity goes against the principles of lean production, it´s preferable to lower the throughput time by enabling continuous flow production without the stop and go characteristic of a batch production. To achieve continuous flow, it´s necessary a dedicated and efficient work force. The "less obvious" waste referred above, variability, has to be well managed in terms of supply, processing time and demand, in order to successfully minimize inventory (De Treville and Antonakis, 2006 ; Hopp and Spearman, 2004).

In order to manage variability successfully, a company must know the underlying causes of the respective variability, i.e. supply variability occurs when a supplier doesn´t deliver the right quantity at the right time and location (Womack et al., 1990). In order to minimize supply variability, Shah and

[3] Activities that consume resources but generate no redeeming value in the eyes of customers (Womack and Jones, 1996).

Ward (2007) suggest the creation of an involved and dependent supplier base consisting of a few key suppliers with long term contracts. As means of reducing processing time, lean production has many different tools, one of them being specifying work until its ultimate detail and consequently enabling line balancing, which makes forecasting of produced inventory much easier and more precise. In addition, it´s important to avoid rework and have cross-trained employees who can step in for absent employees without disrupting flow, quantity or quality of work.

Through a case study, Jimenez et al. (2012) concluded that lean practices implemented in the Spanish wine industry reduced inventory, and redundant information was eliminated through the use of advanced technologies.

Sundin et al. (2011), in turn, applied lean production principles on recycling center operations and concluded that existing flow problems could be decreased. For instance, they stated that these recycling centers have to be managed in a better way in terms of choosing a suitable layout, signs, and opening hours. In addition, they concluded that considering lean production engineering philosophy, several improvements were achieved, e.g. shorter visiting times and cleaner waste fractions.

2.1.2.3 How to measure leanness?

Shah and Ward (2007) identified, through a reliable empirical test, the ten dimensions of lean production, including internal and external constructs (supplier, customer and internal). They argue that every one of the ten dimensions is an important contributor and that none should be eliminated, due to their inter-relations. These dimensions allow researchers to test the lean implementation in companies.

The dimensions are the following:

- Supplier feedback – suppliers must be informed in a regular basis about their performance.
- JIT delivery by suppliers – ensures that suppliers deliver the right quantity at the right time in the right place.
- Supplier development - suppliers must be developed so they can be more involved in the production process of the focal firm.
- Customer involvement – focuses on a company's customers and their needs.
- Pull – facilitates JIT production including "kanban" cards.
- Continuous flow – Establishes a mechanism that enables and eases the continuous flow of products.
- Setup time reduction – reduces process downtime between product changeovers.
- Total productive maintenance – achieves a high level of equipment availability.
- Statistical process control – ensures that each process will supply defect free units.

- Employee involvement – employees' role in solving problems and their cross functional character is crucial.

2.1.3 Agility

"Agility is an important factor in supply chains" - (Christopher, 2000).

2.1.3.1 Historical background

Agility as a concept received attention later when compared to lean (Naylor, et al., 1999). Mc Cullen and Towill (2001) suggest through a case study, that agile manufacturing can be a precursor to lean manufacturing. Others claim that leanness is foundational to agility (Katayama and Bennett 1999; Sharp et al 1999). Gunasekaran (2008) states that agile manufacturing is a natural development of the original concept of Lean production. However, while lean thinking has its origins clearly defined and directly related to the TPS, agility's origins aren't that explicit (Stratton and Warburton, 2003). Anyway, the concept of agility as an organizational orientation was born and brought to public in 1991 by a group of scholars (at Iaccoca Institute of Lehigh University in the U.S.) who believed that the route to manufacturing flexibility was through capacity to enable rapid changes, i.e. to ensure a greater responsiveness to changes in product mix or volume (Yusuf et al., 1999; Christopher, 2000).

The concept has raised a lot of interest amongst practitioners and academics alike, due to the need for organizations to become more responsive towards the needs of customers, whereas the conditions of competition are changing and markets have increased levels of economic and environmental turbulence (Aronsson, et al., 2011).

2.1.3.2 Agile SCM paradigm

When discussing leanness, efficiency is a central characteristic related to the paradigm. When it comes to agility, the main characteristic is responsiveness. An Agile Supply Chain (ASC) must be responsive to the market. In order to achieve this characteristic, it's required speed and high level of maneuverability (Agarwal et al., 2006). Harrison and Van Hoek (2005) mentioned that a company's speed capabilities are elevated when having an agile approach.

Some may have confused responsiveness, agility and flexibility between each other, until Reichhart and Holweg (2007) provided a clarification for that matter. They defined responsiveness as a form of external flexibility, i.e. visible to the customer and triggered by a customer order. Internal flexibility focuses on manufacturing and inbound logistics. Both types of flexibility are key prerequisites to a company´s agile capability.

Responding to unpredictable market changes (or unforeseen events) and capitalizing on them through fast delivery and lead-time flexibility is the main focus in an ASC (Swafford et al., 2008;

Vonderembse et al., 2006). However, SCs with high flexibility are more costly than SCs with low flexibility. Still, SC managers would prefer high flexibility over low flexibility, being the benefits of flexibility in general, obvious. More specifically, to implement ASC successfully, a firm must be able to respond to rapidly changing and continually fragmenting global markets by being dynamic, growth-oriented, context-specific, flexible across the organization and more importantly, driven by customer. In addition, if a company wants to be able to respond better to the changing expectations and requirements of the end-consumers, collaborative relationships with suppliers should be developed (Bruce and Daly, 2011). Moreover, the ASC paradigm is related to the interface between markets and companies (Vonderembse et al., 2006).

The critical elements in the ASC differ from the ones in the LSC. In the ASC innovation, speed, and flexibility are essential. Quality and reliability are obviously still important elements. As customers demand new and innovative solutions, it goes without saying that operating costs and efficiency have a reduced amount of significance. This is consistent with Christopher (2000), who states that agility refers to effective, flexible accommodation of unique customer demands. Furthermore, products are processed only after demand becomes known, i.e. speculative notions are ignored. Hence, ASC employs make-to-order supplying instead of make-to-stock replenishment used in the LSC, i.e. ASC doesn't accumulate inventory (Stavrulaki and Davis, 2010).

Goldsby (2006) confirms that flexibility throughout the SC is a key factor when providing agile response. In manufacturing, this would mean being capable of, or having the capacity to produce in different sized batches when necessary, minimizing the wastes associated with machine setups and product changeovers. Agility might also require flexible workforce, with cross-trained employees. The products should also be designed in a way that raw materials can be easily and quickly converted into final products. For agile market accommodation, the firms must be responsive throughout the SC. In general, response-based SCs have few or no intermediaries, and frequent and open information sharing among entities is essential. In addition, suppliers should be located nearby. If the previous prerequisites are met, a firm is able to respond directly to the end-customer demand, which is the goal in an ASC. In order to get a proper response, the Efficient Consumer Response (ECR), the use of IT tools and Supply Chain Collaboration (SCC) play a huge role, i.e. increases visibility throughout the SC. With these improvements, it´s possible to capture data on sales directly from the point of sale and thus, responding properly to unpredictable market changes (Vonderembse et al., 2006).

Swafford et al. (2008) concluded, through a framework, that IT integration enhances SC flexibility, which in turn, enhances SC agility and furthermore a higher competitive business performance is achieved.

In an ideal situation, all virtual SC entities should be linked with a common information system. Gunasekaran (2008) agrees stating that effective SCM requires a strong partnership between suppliers

and customers and thus, a common information system. The referred virtual chains are based on information rather than inventory, as the business community is learning that the visibility of demand reduces complexity of control. Furthermore, information systems must be up-to-date and information has to be correct. In addition, communication between partners should be easy and painless (Kisperska-Moron and de Haan, 2011). Christopher (2000) also states that agility embraces not only organization structures and mind-sets, but also information systems. The author also adds that a truly agile SC must possess a few distinguishing characteristics. An ASC must be market sensitive, virtual, network-based and must embrace process integration. Agarwal et al. (2007) made an update on Christopher's (2000) publication and came up with the following description on each of the referred characteristics:

- Market sensitiveness – it is closely connected to the end-user and must provide daily P.O.S[4]. feedback, capture emerging trends and listen to consumers.
- Information driven virtual integration – it has a shared information system among all SC partners on real demand, end-to-end visibility and collaborative planning.
- Centralized and collaborative planning (network based) – it focuses on the core competencies, leverages partners' capabilities and acts as a network orchestrator.
- Process integration and performance management– it has a high degree of process interconnectivity between the network members meaning supply is synchronous, inventory is co-managed and product design is also collaborative.

In addition, Yusuf et al. (1999) summarizes agile manufacturing as high quality and highly customized products; products and services with high information and value-adding content; mobilization of core competencies; responsiveness to social and environmental issues; synthesis of diverse technologies; response to change and uncertainty; intra and inter- company integration.

2.1.3.3 Agility variables

According to Christopher and Towill (2001) and Van Hoek et al. (2001), the agility of a SC is dependent on quality improvement, cost minimization, lead time reduction and service level improvement. The study made in 2007 by Agarwal et al., confirmed that SC agility depends not only on these variables but also on customer satisfaction, delivery speed and new product introduction. In this article, the author claims that literature hasn´t taken into account the influence of interrelationships among the variables.

[4] P.O.S.= Point of Sale

An agile manufacturing program constantly strives for improvement in performance in areas such as responsiveness, product customization, new product lead time shortening, and reduced system changeover costs and times and efficient scaling up and down of operations (Brown and Bessant, 2003).

2.1.4 Hybrid strategies

The goal of SCM is to achieve a perfect hybrid system mixing these two paradigms (or more) along the SC, in order to adjust the strategy to the market.
The leanness or agility needed depends upon the total SC strategy, in particular by considering the positioning of the decoupling point and market knowledge (Naylor 1999).
According to Christopher and Towill (2002), lean and agile paradigms can be implemented together within a SC, as long as they remain separated by time or space. Separation by time means that a SC can have an agile approach during summer and lean during winter. Separation by space means that one product is produced in a lean site whilst the other is manufactured in an agile plant. Cagliano (2004) claims that both paradigms perform better than traditional ones, but neither of them has a clear advantage over each other.

As a matter of fact, the lean and agile paradigms point out the same competitive priorities, even though they emphasize different elements. Christopher (2000) assures that quality, service level and lead time are market qualifiers for leanness, being cost the market winner. Likewise, Mason-Jones et al. (2000) claim service level to be the market winner for agile manufacturing, whereas cost, quality and lead time are qualifiers. Christopher and Towill (2001) is consistent with the service level being market winner for agile manufacturing. Table 2.2 shows the market qualifiers and winners for the ASC and the LSC.

Table 2.2 - Market winners and qualifiers for the ASC and the LSC Adapted from Mason-Jones et al. (2000).

	Market Qualifiers	Market Winners
Agile Supply Chain	Quality, Cost, Lead Time	Service Level
Lean Supply Chain	Quality, Lead Time, Service Level	Cost

In order to better understand this concept of mixing the two paradigms, a few examples described by Goldsby (2006) are shown in the following:

- **Example 1:** The first example embraces the Pareto rule, where 20% of the products generate 80% of a company's profits. The dominant fast moving inventories (20%) should be manufactured in a Lean, Make-to-stock (MTS) manner. In these cases demand is relatively stable meaning the supply should be made in an efficient way in order to prevent stock outs.

Meanwhile the remaining 80% should be produced in a less anticipated, agile manner, maybe even in a Make-to-Order (MTO) manner.

- **Example 2:** The second hybrid SC involves the characteristic of producing according to the demand, especially when it peaks. Most companies experience a stable demand during the year. Hence, demand is accommodated in a lean manner and a level schedule (Heijunka) is implemented to maintain highly efficient operations. However, there're indeed some periods over the year where demand peaks, e.g. promotion periods. Therefore, agile operations are adopted and extra buffer capacity or flexibility must be available in order to accommodate demand of these distinct time windows.
- **Example 3:** The third example is related to form-postponement. It calls for lean operations until reaching a generic or semi-finished Stock-Keeping-Unit (SKU) and in the customization process it uses the agile approach. When diverse needs are accommodated efficiently, one can refer to "mass customization".

Finally, table 2.3 represents the characterization of both management paradigms, Lean and Agile, in addition to their respective SC characteristics.

Table 2.3 - Characterization of lean and agile supply chain management paradigms

Category	Lean	Agile
Definition	"Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule." (a)	Agility is defined as the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety. (e)
Purpose	Focuses on cost reduction and flexibility for already available products while employing continuous improvement efforts with its main concern being the elimination of waste and non-value adding tasks across the chain. (b,d)	Focuses on being able to respond to unpredictable market changes and capitalizing them through fast delivery and LT flexibility. Aims to produce in any volume to a wide variety of market niches simultaneously. (b)
Manufacturing focus	Efficiency (High average utilization rate). (b,c)	Flexibility/Responsiveness (Deploys excess buffer capacity). (b,c)
Product design	Cost conscious (Maximize performance and minimize cost). (b,c)	Specialized (Designed to meet individual customer needs). (b,c)
Length of product life cycle	Standard products have long cycle times (>2 years). (b)	Innovative products have short cycle times (3 months – 1 year). (b)
Forecast accuracy	High (Forecasting error <10 %). (b,c)	Low (Forecasting error can exceed 50%). (b,c)
Served markets	Only current market segments. (b)	Open to new markets, new product introductions and acquires new competencies. (b)

Category	Lean	Agile
Profit margin, product variety and order lead time	Low (c)	High (c)
Logistics processes focus	Efficiency (c)	Flexibility (c)
Bullwhip effect	Likely (c)	Less likely (c)
Number of intermediaries	Large (c)	Small (c)
Inventory strategy	High inventory turnover rate [5]. Minimizes inventory throughout the chain. (b)	Makes inventory in response to direct customer demand. (b)
Approach to choosing suppliers	Supplier attributes involve low cost and high quality. (b)	Supplier attributes involve speed, flexibility and quality as well. (b)
Organizational structure	Uses a static organizational structure with few levels in the hierarchy.	Creates virtual organizations with partners that vary with different product offerings that change frequently.
Alliances with suppliers and customers	At the operational level it uses traditional alliances such as partnerships and joint ventures. The demand information is spread along the chain. (f)	It uses a type of alliance known as virtual organization, which has a shared information system among all SC partners.

Legend: (a) Shah and Ward, 2007; (b) Vonderembse, et al., 2006; (c) Stavrulaki and Davis, 2010; (d) Mollenkopf, et al., 2010 (e) Christopher, 2000 (f) Carvalho et al., 2009

2.1.5 SCM practices and Key Performance Indicators

In order to improve SCP, a set of management practices have to be implemented. In addition, the impact of the implementation of each practice has to be measured through KPIs.

In table 2.4, a few Lean and Agile SCM practices and KPIs are highlighted. The literature (Carvalho et al., 2009; Azevedo et al., 2011; Carvalho et al., 2012) offered a vast number of SCM practices and KPIs, but only a few were selected. All practices should contribute to effective SC, based on the principle of each paradigm. Some practices may belong to both of the paradigms; the same goes for the KPIs.

[5] $Inventory\ turnover = \frac{Sales}{Inventory}$

Table 2.4 - SCM practices and Key Performance Indicators.
Adapted from: Azevedo et al., 2012; Carvalho et al., 2012; Carvalho et al., 2009; Azevedo et al., 2011

SCM practices		Key Performance Indicators
Lean	**Agile**	
Just-in-time	Deploy excess buffer capacity	Delivery speed, Transportation flexibility, On time delivery, Responsiveness to urgent deliveries, Inventory carrying costs, Level of safety stocks.
Information spreading throughout the chain	Integrated supply chain/ Virtual corporation	
Traditional alliance	Ability to change delivery times and quantity of suppliers orders	
Inventory minimization	Developing visibility towards a clear view of of upstream and downstream inventories, supply conditions, and demand conditions.	
Single sourcing	Use of IT tools to coordinate activities in procurement/logistics and distribution	

A conceptual model has been proposed by Azevedo et al. (2011) in order to assess the relationships between SCM practices and SC performance measures. Table 2.5 shows the influences of some SCM practices on the following SC operational and economic performance measures: Inventory level, quality of products, customer satisfaction, time and cost.

Table 2.5 - SCM measures versus management practices
Adapted from: Azevedo et al., 2011

SCM Practices	Operational Performance				Economic Performance
	Inventory Levels	Quality	Customer satisfaction	Time	Cost
Just in time	↓		↑	↓	↓
Supplier relationships	↓	↑		↓	↓
Speed in improving responsiveness to changing market needs			↑	↓	
Ability to change delivery times of suppliers order	↓			↓	
Developing visibility to a clear view of upstream inventories and supply conditions	↓	↑			↓
Lead time reduction			↑	↓	

For instance, the proper implementation of JIT practices lowers inventory levels and consequently reduces cost. It also reduces time and enhances customer satisfaction.

2.1.6 Models for decision-making

People are known to believe that logical thinking is the one and only way to face and solve problems, i.e. to make good decisions. Yet, this goes against the fact that our mind besides rational, is also

emotional. The emotional side is associated with feelings intuitions and hunches, whereas the rational side is related with logical and structured reasoning (Saaty, 1990; Saaty, 1994). Rational decision-making is the talent we possess to be more effective in implementing our ideas in the real world (Saaty, 2005).

Our intuition is capable of dealing with simple problems, but has to be supported by rationality as the degree of complexity of the problem gets higher. Since complex problems normally have so many related variables, logical thinking may also be quite difficult, due to the sequences of ideas that are so tangled that their interconnections are not immediately discerned. As a matter of fact, rationality only applies to the objective and measurable parts of the problem, being incapable of capturing the subjective and qualitative aspects. Thus, there´re situations where neither logic nor intuition is of much help, unless combined (Saaty, 1990; Saaty, 1994).

These multi-criteria decision-making (MCDM) methods facilitate decision-making by organizing perceptions, hunches, judgments and memories into a framework that shows the forces that influence a decision. It has been demonstrated by practitioners that multi criteria logic gives different and better answers than ordinary logic and does it in an efficient way (Saaty, 1994). Besides, the role of the inconsistency is emphasized. This framework deals with decisions in a structured way, by rigorously structuring the problem as a hierarchy or a network of all the factors and the influences among them, and by establishing the intensities of the influence relations through pairwise comparison judgments (Zammori, 2010). These judgments are elicited to express people's understanding of the preference or importance of these elements on the final outcome achieved by synthesizing the priorities derived from different sets of pairwise comparisons (Whitaker, 2007). Pairwise comparisons are made through a comparison of two objects, where one has to decide on which is the smaller or lesser one according to a certain property or attribute. Afterwards, considering it as the unit, we ask how many times more dominant the larger one is with respect to that property than the smaller or less important one. This is a powerful way to derive priorities through judgments, as well as a several times validated one (by comparing the closeness of the derived outcome with actual measurements). Relative measurement makes it possible to create a hierarchic and network structure that relate diverse criteria which have bearing on the outcome of an issue or decision and determine the most likely outcome of these influences thus giving our creative thinking to structure problems greater effectiveness.

Hence, all the relevant knowledge and intuition that contributes to the decision are 'scientifically" converged as means of discovering the rationale behind the best choice to be made and understanding how quantitative reasoning underlies and guides the decision. Furthermore, sensitivity analysis is performed to determine the stability of the outcome to wide perturbations in the judgments (Saaty, 2005).

Yet, there were no effective means to combine rationality and hunches in a structured and mathematical way until the introduction of the Analytic Hierarchy Process (AHP) and its generalization to dependence and feedback the Analytic Network Process (ANP). According to Whitaker (2007), the AHP/ANP is fundamentally a way to measure intangible factors by using pairwise comparisons with judgments that represent the dominance of one element over another with respect to a property that they share. It is a process of laying out a structure of all the essential factors that influence the outcome of a decision. Besides decision-making tools, the ANP/AHP are also used in prediction rather effectively (Zammori, 2010).

Science and engineering has plenty of knowledge and proper scales when it comes to measuring tangible factors, but in the other hand the intangible ones are much more of an unknown. However, intangibles can have huge effect on our decisions and we must cope with these factors by including them in our thinking. In order to have more trustworthy solutions to problems, intangibles must be considered (Saaty and Sagir, 2009).

In addition to AHP or ANP, several MCDM methods have been proposed in literature (Zammori, 2010). Amongst these are for instance the ELECTRE method, the Weighted Sum Model (WSM), the TOPSIS method and the Weighted Product Model (WPM). These are just to name a few in addition to many others that exist. However, AHP/ANP has proven to have the most benefits over the other MCDM methods, such as they:

- provide a realistic description of the problem
- support group decision-making
- structure the decision-making process
- incorporate both quantitative and qualitative factors
- express the relative importance of the factors
- allow the decision makers to focus on each small part of the problem
- facilitate the evaluation of alternative scenarios, by supporting what if and sensitivity analysis.

2.1.6.1 Analytic Hierarchy Process

The AHP is a decision-making theory that has facilitated our understanding and approach to decision-making. It was introduced by Saaty in 1977 as an aid to help solve unstructured problems in economics, social, and management sciences (Yucenur, et al., 2011). The AHP turns a complex problem into a simple hierarchy, where a large number of quantitative and qualitative factors are evaluated in a systematic way under multiple criteria. In other words, AHP deals with MCDM problems that consider the distribution of goal amongst the elements being compared and judges the elements that have a greater influence on the goal.

The AHP for decision-making is a theory of relative measurement based on paired comparisons used to derive normalized absolute scales of numbers whose elements are then used as priorities. There are two ways to form the pairwise comparison matrices. The first is to provide judgments to estimate dominance using absolute numbers from the 1 to 9 fundamental scale of the AHP (table 2.6), while the other is to directly construct the pairwise dominance ratios using actual measurements. The AHP can be applied to both tangible and intangible criteria based on the judgments of experts (Saaty, 2007).

Table 2.6 - The fundamental scale.
Adapted from Saaty, 2008

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another, its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity is of the highest possible order of affirmation
2,4,6,8	Intermediate values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it

Islam and Saaty (2010) describe the AHP method consisting in four steps.

Step 1: Decomposition

A complex problem is decomposed into a hierarchy where each level consists of a few manageable elements. Each element is also decomposed.

Step 2: Prioritization

Pair-wise comparisons are done separately in reference to each of the elements of the level above, in order to assess the impact of the respective elements of the hierarchy.

Step 3: Synthesis

The priorities are pulled together through the principle of hierarchical composition to provide the overall assessment to the available alternatives.

Step 4: Sensitivity analysis

This process tests the stability of the outcome to changes in the importance of the criteria.

2.1.6.2 Analytic Network Process

The AHP can be considered as the starting point for the ANP. Likewise, the ANP can be considered an extension of the AHP. The ANP is a multi-criteria approach that generalizes the AHP without making assumptions about the independence of higher level elements in a hierarchy or about the independence of the elements within a level. As a matter of fact, in the ANP there's no need to specify levels, utilizing a network instead. This allows the decision maker to structure a decision in the most general way conceivable (Saaty, 2005). Influence is a central concept in the ANP. A hierarchy is linear, with the goal in the top level and the alternatives in the bottom level. The ANP is a nonlinear structure that deals with sources, cycles and sinks (Saaty, 1999). The ANP captures the outcome of dependence and feedback between components of elements (Saaty, 2001)

As opposed to the hierarchy, the network structure makes possible the representation of any decision problem without concern for what comes first and what comes next (Saaty, 1999)

In order to better understand the structural difference between the AHP and the ANP, figure 2.1 provides a clarification.

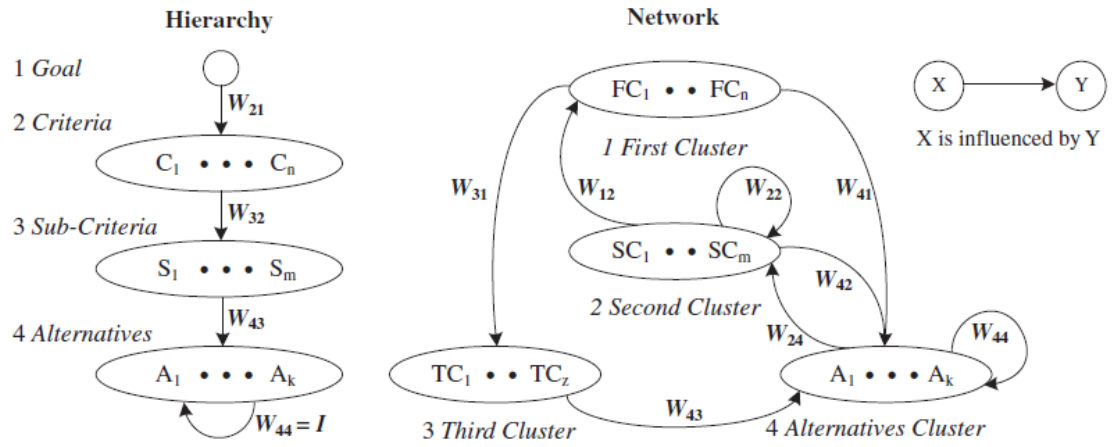

Figure 2.1 - Comparison of a hierarchy with a network
Source: Zammori, 2010, p.1006.

As can be observed in figure 2.1, a hierarchy is a linear top down structure with no feedback from bottom to top levels. In a network there is no need for organizing the clusters in a hierarchy, meaning they can spread in any direction. The elements of the system are represented as nodes. If an interaction between the nodes is identified, they shall be connected with an arrow. In addition, the orientation of the arrow shows the direction of the influence between two nodes. Loops denote inner dependencies amongst nodes of the same cluster. The strength of the dependencies is given by a matrix (Wij) containing numerical entries of the priorities of the strengths of influences of the i^{th} cluster nodes on the elements of the j^{th} cluster. Thus, the k^{th} column of Wij contains the priority vector obtained

through the pairwise comparisons of the ith cluster's nodes with respect to the kth elements of the jth cluster

In the following section steps of the ANP will be outlined in order to better understand the methodology.

2.1.6.2.1 Outline the steps of the ANP

Step 1: Model construction and problem structuring

In this stage the clusters and elements belonging to the respective clusters have to be determined, meaning decision-makers have to determine a Goal cluster, a criterion and sub-criterion cluster, and an alternatives cluster. The possible influences between them have to be identified.
In order to facilitate further analysis, the problem should be clearly expressed and decomposed into a rational system such as a network.
The framework can be determined based on the experts' opinions via brainstorming or other appropriate methods (Chang, et al., 2009; Chang, et al., 2007).

Step 2: Pair-wise comparisons matrices and priority vectors
Elements regarding each cluster are compared pair-wise in terms of their importance for their control criterion. Decision-makers are left with the task of responding to a series of pair-wise comparisons in which two elements at a time are compared in terms of their contribution to the respective upper-level criteria. In addition, if inner dependencies exist among elements within the same cluster, pair-wise comparisons must be performed, and consequently an e-vector can be obtained for each element in order to determine how it is affected by other elements. The relative importance values are determined based on the Saatys' fundamental scale. A reciprocal value is assigned to the inverse comparison (Meade and Sarkis, 1999; Agarwal et al., 2006).

Pairwise comparisons are performed in a matrix, and a local priority vector can be determined as an estimate of the relative importance of the elements being compared as follows:

$$A * \omega = \lambda_{max} * \omega \quad (2.1)$$

, where A denotes the matrix of pair-wise comparison; ω denotes the eigenvector, and λ_{max} denotes the largest eigenvalue of A. If *A* denotes a consistency matrix, then eigenvector *X* can be determined as follows:

$$(A - \lambda_{max} I)X = 0 \quad (2.2)$$

The consistency index (CI) and consistency ratio (CR) have to be calculated to verify the consistency of the comparison matrix. They are calculated through equations (2.3) and (2.4), respectively:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2.3)$$

$$CR = \frac{CI}{RI}, \quad (2.4)$$

, where n denotes the matrix size and RI denotes the average consistency index for numerous random entries of same-order reciprocal matrices. Table 2.7 shows the average RI for various matrix sizes.

Table 2.7 - Average RI for corresponding matrix size.
Adapted from: Chang et al., 2007

(n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
(RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Estimates are accepted if ≤ 0.1, otherwise a new comparison matrix is required until CR value achieves the desired one.

In order to synthesize priorities, the following procedure is adopted (Chang, et al., 2009; Chang, et al., 2007):

- Sum the values in each column of the pair-wise comparison matrix.
- Divide each element in a column by the sum of its respective column. The resultant matrix is termed the normalized pair-wise comparison matrix.
- Sum the elements in each row of the normalized pair-wise comparison matrix, and divide the sum by the n elements in the row. These final numbers can be adopted to estimate the relative priorities of the elements being compared with respect to their upper-level criteria. Priority vectors must be determined for all comparison matrices.

Step 3: Supermatrix formulation

In order to determine global priorities in a network, the previously determined pairwise comparisons are used as inputs in the formation of the supermatrix structure. Their respective local priority vectors are entered in the appropriate columns, which in turn, form the supermatrix, i.e. the supermatrix is a partitioned matrix, where each matrix segment denotes a relationship between two nodes of the network (Meade and Sarkis, 1999 ; Chang, et al., 2007). The local priority vectors are grouped and located in appropriate positions in the supermatrix which is based on the flow of effect from one element to another, or from a cluster to itself as in the loop. This is called the unweighted supermatrix which may not be stochastic. Hence, a transformation is required in order to achieve a weighted, stochastic supermatrix. That transformation is made by multiplying the values of an unweighted supermatrix with their affiliate cluster weights. When a matrix is raised to powers, long-term stable set of weights is obtained. To converge these weights, the weighted supermatrix is raised to the power of $2k+1$, where k is an arbitrarily large number, and the obtained matrix is called the limit supermatrix. Now the final priorities of all the elements in the network can be determined by normalizing each block of the limit supermatrix (Agarwal, et al., 2006, Chang, et al., 2007, Vinodh, et al., 2012)

Step 4: Determining the score for each element

The priority weights of the elements can be found in the columns of the normalized supermatrix.

2.1.6.3 AHP versus ANP

One of the drawbacks related to the AHP is the fact that it does not consider the interdependencies amongst elements. Thus, ANP has been used to overcome this drawback. It´s a holistic approach in which all attributes and alternatives included are connected in a network system that considers/includes the interdependencies (Vinodh, et al., 2012; Yan, et al., 2009). It also provides a non-linear analysis of strategies among the decision attributes (Meade and Sarkis, 1999). However, the ANP is not as intuitive as the AHP. The judgments to be made in a network system are also a much bigger of a problem in terms of complexity.

Five types of criticisms have been addressed in the literature by (Saaty, 2008). The first one is the fact that once the structure of the decision is changed, occurs the so called rank reversal, i.e. illegitimate changes in the ranks of the alternatives. Rank reversal is believed to be legitimate only when criteria or priorities of criteria or changes in judgments are made. The second one is related to inconsistent judgments and their effect on aggregating such judgments or on deriving priorities from them. Moreover, the third criticism is related to irrelevant alternatives which attempt to preserve rank by combining the comparison judgments of a single individual using the geometric mean in order to derive priorities on different criteria by using multiplicative weighting synthesis. The fourth one is related to people who are keen to change the fundamental scale despite the fact that it is theoretically derived and tested by comparing it with numerous other scales on a multiplicity of examples for which the answer was known. The fifth and last one is related to the pairwise comparisons principles and to the fact that whether they are spontaneous and behavioral in nature to actually provide judgments or not.

Both methods and their potentialities have been proved in many successful applications in almost all the areas of management (Zammori, 2010). Table 2.8 describes some of them.

Table 2.8 - AHP/ANP applications made by different authors

Author	Contribution	Specific Area	Applications
(Yuksel and Dagdeviren, 2007)	SWOT Analysis with AHP/ANP	SWOT Analysis	Marketing
(Dagdeviren et al., 2008)	Faulty behavior risk in work system by fuzzy AHP/ANP	Work safety	Engineering
(Wijnmalen, 2007)	Benefits, opportunities, costs and risks with the AHP/ANP. A critical validation	BCOR Validation	Validation
(Whitaker, 2007)	Validation examples of the Analytic Hierarchy Process and Analytic Network Process	World chess championship outcome validation/Market share for the airline industry	Sports outcomes/Marketing
(Zammori, 2010)	The analytic hierarchy and network processes: Applications to the US presidential election and to the market share of ski equipment in Italy	Presidential election/ market share	Politics/Marketing
(Chang et al., 2007)	Evaluating digital video recorder systems using analytic hierarchy and analytic network processes	Security technology	Technology

Author	Contribution	Specific Area	Applications
(Agarwal et al., 2006)	Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach	Maximizing supply chain performance in the FMCG industry	SCM
(Cabral et al., 2012)	A decision-making model for LARG supply chain management	Maximizing supply chain performance in the automotive industry	SCM
(Gencer and Guerpinar, 2007) and (Sanayei et al., 2010)	Analytic network process in supplier selection: A case study in an electronic firm & Group decision-making process for supplier selection with VIKOR under fuzzy environment-	Supplier selection	Logistics

2.2 Material collection

When it comes to a literature review, defining boundaries is an extremely important procedure to delimitate the research and to analyze only desired articles. Considered articles were chosen based on the respective abstract.

The main focus is to integrate Lean and Agile practices in the pharmaceutical SC in the best way possible, i.e. by making optimal decisions. Therefore, the material collected has the purpose of gathering together the articles which provide a link between SCM, lean and agile SCM paradigms and decision-making tools. Publications related to the pharmaceutical industry were also searched with the purpose of reviewing recent studies in the industry and to verify if decision-making tools have been implemented in the industry's SC.

In the following are the non-included publications:

- Publications related with service SCs were not considered
- Publications related with the Green management paradigm.
- Publications focusing in the reverse logistics channels.
- Publications referring to lean or agile production in other areas than SCM, e.g. Lean or agile software development.

2.3 Search for related papers

To ensure the credibility in this research, only validated material was considered. The review aims at publications with clear conceptual or empirical evidence. Papers providing anecdotal evidence weren't considered. As means of collecting information about the development of each paradigm and their integration on western companies the material considered was from 1980 onwards. When it comes to scanning the publications, the period was set for the last five years (2008-2013), although older publications had to be included due to relevant information and publications considered as milestones of the above referred four main topics i) SCM, ii) Lean SCM paradigm, iii) Agile SCM paradigm and iv) models for decision-making. All articles were published in English.

The search engine used was Web of Knowledge, which in turn, uses many different databases.
A total of 102 journals were considered relevant for the research, i.e. journals that were useful in terms of developing the literature review. The journals are detailed in the next chapter.

Three lines for searching were followed, although rarely taken advantage of them all. Mostly the search was made using two lines, namely "Lean thinking" in the Topic box and "2008-2013" in the year published box.

After the searches were executed, a quick analysis was made on each publication through reading the abstract, in order to decide whether or not to include the publication. If accepted, the publication was saved and a proper analysis was made in order to make the most use of each publication.

2.4 Descriptive analysis

To create a better understanding of the current state of this technology and its respective development, descriptive dimensions were used to classify the papers.

Table 2.9 shows the number of papers by journal.

Table 2.9 - Distribution of the papers related to journals

Journal	Quantity
Applied Mathematical Modelling	1
Applied Soft Computing	1
Asian Academy of Management Journal	1
Business Process Management Journal	1
Clean Technologies and Environmental Policy	1
Computers and Chemical Engineering	1
Computers and Industrial Engineering	1
Computers in Industry	1
Engineering Applications of Artificial Intelligence	1
European Journal of Operational Research	1
Expert Systems and Applications	1
Harvard Business Review	3
Ieee Transactions on Engineering Management	1
Industrial Marketing Management	2
International Journal of Advanced Manufacturing Technologies	1
International Journal of e-Education, e-Business, e-Management & e-Learning	1
International Journal of Information Sciences	3
International Journal of Information Technologies and Decision-Making	1
International Journal of Management Science	4
International Journal of Operations and Production Management	4
International Journal of Physical Distribution & Logistics Management	3
International Journal of Production Economics	13
International Journal of Production Research	6
Journal of Business Logistics	3
Journal of Cleaner Production	1

Journal	Quantity
Journal of International Business Studies	1
Journal of Management Information Systems	1
Journal of Operations Management	4
Journal of Purchasing and Supply Management	1
Journal of Systems Science and Systems Engineering	1
Logistics Research	1
Management and Service Operations Management	1
Mathematical and Computer Modelling	3
Omega	1
Revista Real Academia de Ciencias	1
Robotics and Computer Integrated Manufacturing	1
Production Planning & Control	2
Safety Science	1
Supply Chain Management: An International Journal	1
The Accounting Review	1
The International Journal of Logistics Management	3
The International Journal of Management Science	2
The Journal of Applied Business Research	1
Waste Management	1
Others	16
Total	**101**

A total of 101 publications were considered relevant in the literature review. As can be observed in table 2.9, forty-five distinct journals were considered in the literature review, although most of them only contributed to the review with one publication. The *International Journal of Production Economics* contributed by far with the most publications, which is in fact, understandable when reviewing the journals' official web page, where the following is delineated:

"It focuses on topics treating the interface between engineering and management. All aspects of the subject in relation to manufacturing and process industries, as well as production in general are covered. The journal is interdisciplinary in nature, considering whole cycles of activities, such as the product life cycle - research, design, development, test, launch, disposal - and the material flow cycle - supply, production, distribution."

There are journals with similar aims, but the number of publications found is lower due to the also lower dimension (in terms of publications) of the journal. There is clearly a dominance of management and production related journals, but also journals from different research areas such as business and information sciences have been used as publication channel.

Furthermore, Figure 2.2 shows the distribution of publications across the time period. Which years are the most relevant and why?

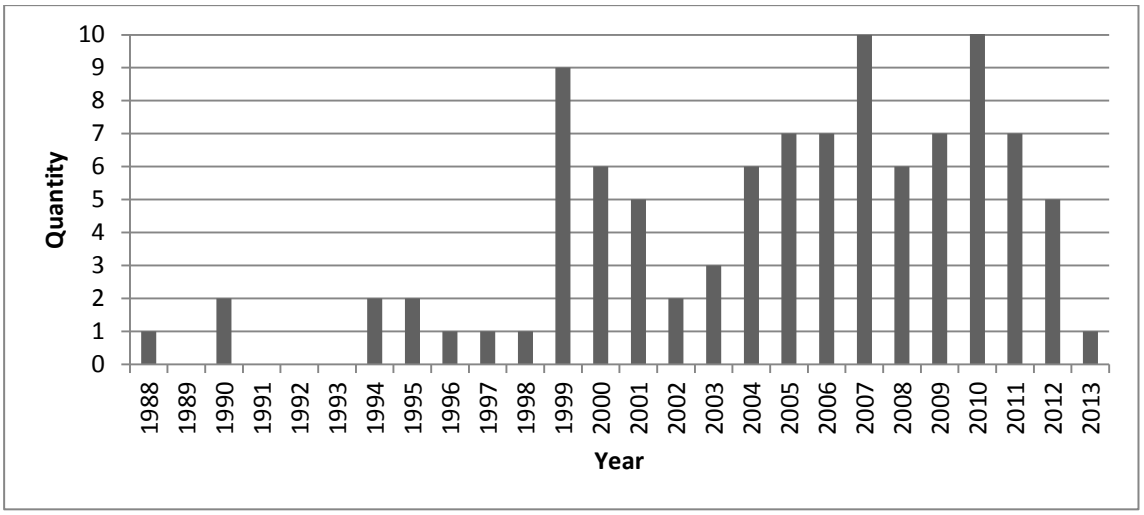

Figure 2.2 - Number of publications across the time period 1988-2013

Evidence shows that a particularly high number of publications are found from 2005 onwards. One of the reasons is obviously the previously set time period for the search (past five years). Interestingly, the year of 1999 shows a peak in the distribution. It is clearly the year were publications related to agile manufacturing started to appear, meaning it is the point in time were it raised interest among academics and companies. Likewise, it means that the markets changed into more volatile ones where uncertainty became a serious issue, and thus, companies realized that agile manufacturing is the key for future success in terms of competitiveness and performance.

Finally, figure 2.3 represents the distribution of the publications by their main topics,

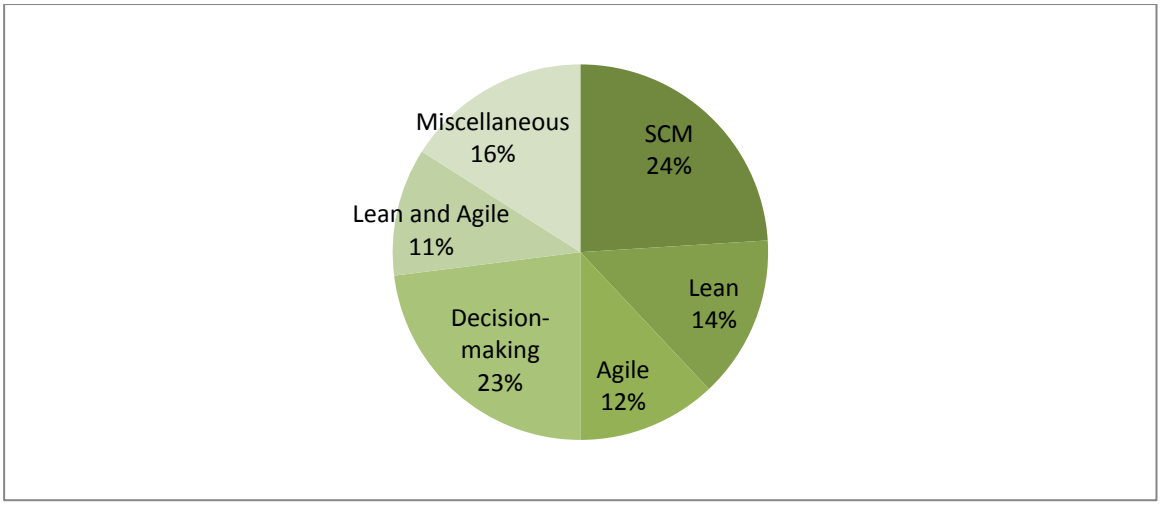

Figure 2.3 - Distribution of the publications by content

Interestingly, SCM and decision-making share almost same percentage of publications, 27% and 26%, respectively), as well as Lean and Agile, 14% and 12%, respectively (when observed separately). Still, it is easily explained. When SCM is reviewed in terms of the literature, as well as the models for decision-making is, the models have to be detailed also in terms of their respective methodologies.

Lean and Agile paradigms aren´t proportional either, which is quite obvious due to the long historical background of the Lean paradigm.

2.5 Interpreting results of the literature review

In the present literature review, the aim was to review two SCM paradigms, Lean and Agile. It was almost immediately observed that SCM came along with the two paradigms. SCM is without a doubt, a crucial asset of a company willing to survive in today's marketplace. The lean and agile paradigms are two 'philosophies" or mind-sets belonging to SCM. Neither of them can be considered the best, instead they are both efficient if implemented in the right context or marketplace.

Generally, the aim of a literature review is to identify research gaps. In the decade of the 90's, it is quite evident that SCM and the respective SCM paradigms (lean and agile) were well defined conceptually[6] (Christopher, 2000; Mason-Jones et al., 2000; Naylor et al., 1999; Yusuf et al., 1999; Womack, 1990; Womack, 1994), but the actual empirical evidence on the paradigms was lacking from literature. Frameworks based on empirical evidence turned out to be an evident focus starting from the beginning of the 21st century until now, and will certainly be the focus for the future (Narasimhan, et al., 2006; Shah and Ward, 2007; Goldsby, 2006; Cagliano 2004; Agarwal, 2007).

Another research gap is related with pharmaceutical SCM. There are few publications linking SCM with the pharmaceutical industry.

More recent publications show an evident focus on SCM practices and respective measures or Key Performance Indicators (Carvalho et al., 2009; Azevedo et al., 2011; Carvalho et al., 2012; Azevedo et al., 2012; Gunasekaran et al., 2001). In the older publications, SCM clearly focuses on reducing waste throughout the chain and in extending the company beyond the focal one. Yet, the fact that it's the SCs that compete and not companies, has become obvious. Moreover, recent literature is clearly keen to develop alliances where the whole SC would become linked virtually, which turns the spotlight into the agile paradigm. In addition, recent literature related with SCM clearly highlights SC responsiveness and flexibility, considering that waste reduction is a prerequisite for competitiveness (Bruce and Daly, 2011; Li et al., 2006; Agarwal et al., 2006; Merschmann and Thonemann, 2011).

Decision making has always been a part of our life. Nowadays it still remains a part of our life, but the way in which we make our decisions has changed. Literature shows evidence on many different decision-making tools, which have become more and more sophisticated across time (Saaty, 1990;

[6] Lean emerged a long time before agile. The agile SCM paradigm only became known in the 90"s, but its evolution was fast.

Saaty, 1999; Zammori, 2010). These tools have been validated in many different research areas including SCM. For instance, Agarwal et al. (2006) and Cabral et al. (2012) managed to combine SCM, Management paradigms and decision-making successfully, in order to achieve enhanced SC performance and competitiveness.

The main conclusion drawn upon the facts of the present literature review, is that literature will focus more and more in empirical investigation linking measures and practices considering the aim of achieving enhanced SC performance and consequently, high level of profitability and competitiveness.

3. Pharmaceutical supply chain

3.1 The Industry

The global economic crisis is hitting Portugal particularly hard. As a natural consequence, the pharmaceutical industry is also heavily affected. As a matter of fact, this industry is one of the most affected, due to its high degree of regulation and control set by the government, whose expenses with the industry are also high.

The government controls such issues as the pricing of the drugs, profit margins throughout the chain, approved active ingredients, to name but a few. Some serious consequences have arisen from the governments´ recent regulations. The most recent cuts in the pharmacies' profit margins have made it very difficult for the pharmacies to survive and to keep business going. Innumerous ones have already closed and more keep closing as time goes by (Source: Pharmacist of Farmácia Crespo).

Another issue is the pricing. Some drugs have been set with a price lower than their manufacturing cost, which means production of these drugs has to stop. Moreover, the VAT regarding electricity has risen significantly which means higher manufacturing costs (Source: Logistics manager of Lusomedicamenta). Booth (1999) adds that the logistics costs in the industry are relatively high.

One of the most controversial issues in today's pharmaceutical industry is the so called parallel trade. It means that drugs under a protection of a patent are placed into circulation in one market, and then imported by an intermediary into a second market without the authorization of the local owner of the intellectual property right. Parallel trade exists when there are significant price differences between countries, making the trade attractive, which is the case in the EU where prices are not governed by free competition laws, but are fixed, as mentioned, by the government. Almost all of the stock outs in the pharmacies exist due to this phenomenon, meaning it creates disagreement amongst supply chain (SC) entities (Source: Head supply chain manager of Novartis Farma).

The SC has to be managed in order to absorb all these measures imposed by the government, in addition to other issues concerning the industry. Critical decisions have to be made at each level of the SC in order to be able to compete in the marketplace, or as in many cases, to survive in the marketplace.

In order to create a better understanding and notion of the industry's volume in Portugal, in the EU and Worldwide, some statistics and numbers will be exhibited in the following.

Figure 3.1 provides the volume of the pharmaceutical industry in the European countries in millions of Euros between 2007 and 2010. It can be observed that the Portuguese market decreased 1,8% and represented 2,3%[7] of the total industry in 2010. The European Association of Pharmaceutical Industry doesn´t have more up to date numbers yet, meaning that the recent cuts are not accounted. Still, the prediction would be that the market in Portugal decreased in an even higher rate than in 2010.

Países Countries	2007	2008	2009	2010	Tx. Cresc. 07/10 Growth 07/10
Alemanha / Germany	25.241	26.523	27.047	27.022	7,1%
Áustria / Austria	2.736	2.921	2.996	3.022	10,5%
Bélgica / Belgium	3.932	4.189	4.320	4.428	12,6%
Bulgária / Bulgaria	542	617	616	671	23,8%
Chipre / Cyprus	174	188	n.d.	200	14,9%
Dinamarca / Denmark	1.860	2.006	2.073	2.150	15,6%
Eslováquia / Slovakia	846	1.057	1.064	1.092	29,1%
Eslovénia / Slovenia	487	493	509	519	6,6%
Espanha / Spain	13.209	13.949	14.744	14.858	12,5%
Estónia / Estonia	137	141	189	192	40,1%
Finlândia / Finland	1.848	1.978	1.979	2.005	8,5%
França / France	25.501	26.196	27.146	27.334	7,2%
Grécia / Greece	5.503	5.573	5.850	5.047	-8,3%
Holanda / Netherlands	4.616	4.680	4.654	4.686	1,5%
Hungria / Hungary	1.955	2.091	1.984	2.064	5,6%
Irlanda / Ireland	1.902	1.760	1.888	1.766	-7,2%
Itália / Italy	16.734	17.824	18.540	19.909	19,0%
Letónia / Latvia	257	291	277	276	7,4%
Lituânia / Lithuania	404	436	478	479	18,6%
Polónia / Poland	4.237	5.014	4.484	5.016	18,4%
Portugal	**3.490**	**3.660**	**3.716**	**3.428**	**-1,8%**
Reino Unido / United Kingdom	14.493	12.826	12.512	13.583	-6,3%
República Checa / Czech Republic	1.586	1.832	1.895	1.976	24,6%
Roménia / Romania	1.601	1.914	1.909	2.113	32,0%
Suécia / Sweden	3.052	3.172	2.771	3.172	3,9%
Total UE 27 / Total EU 27[1]	136.343	141.331	143.641	147.085	7,9%
Suíça / Switzerland	2.726	2.919	3.235	3.235	18,7%
Noruega / Norway	1.360	1.345	1.350	1.350	-0,7%

Figure 3.1 - Total pharmaceutical industry in Europe.
Units: Millions of Euros.
Source: EFPIA - European Association of Pharmaceutical Industry, 2012

When it comes to the manufacturing of raw materials and pharmaceutical products, it has decreased 12,9% between 2010 and 2011 in Portugal (Figure 3.2).

[7] $\frac{3428}{147085} * 100 = 2{,}3\ \%$

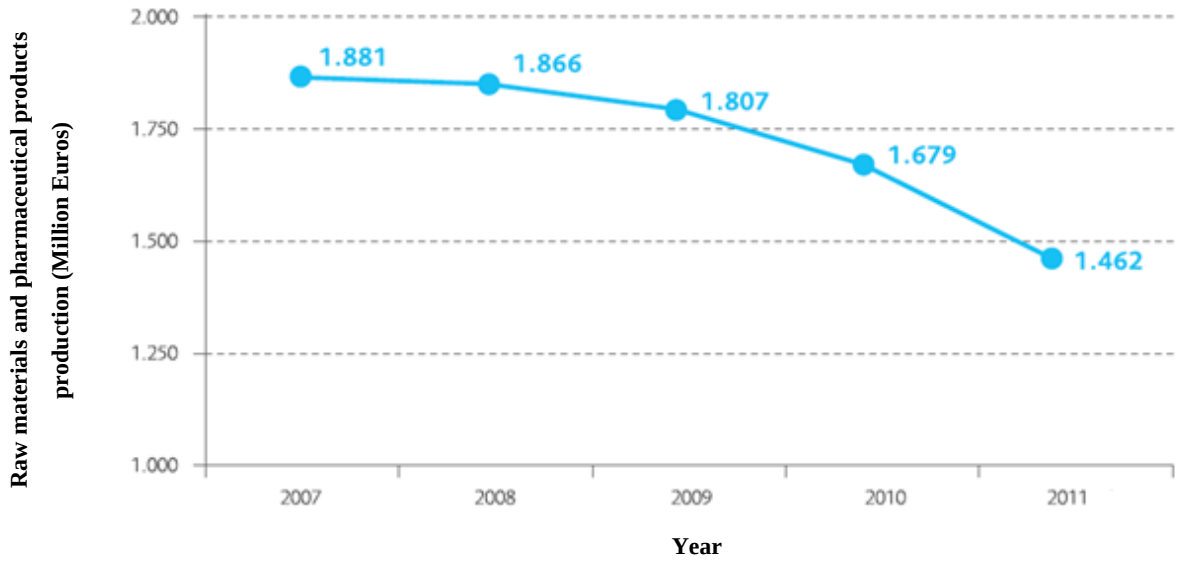

Figure 3.2 - Manufacturing of raw materials and pharmaceutical products in Portugal. Source: INE, Infarmed, Apifarma, 2012

3.2 The case study supply chain entities

Figure 3.3 illustrates the whole SC related to Novartis Farma. However, the case study SC is only a part of it (marked with a rectangle). The four levels of the SC can also be observed in the left side of the rectangle.

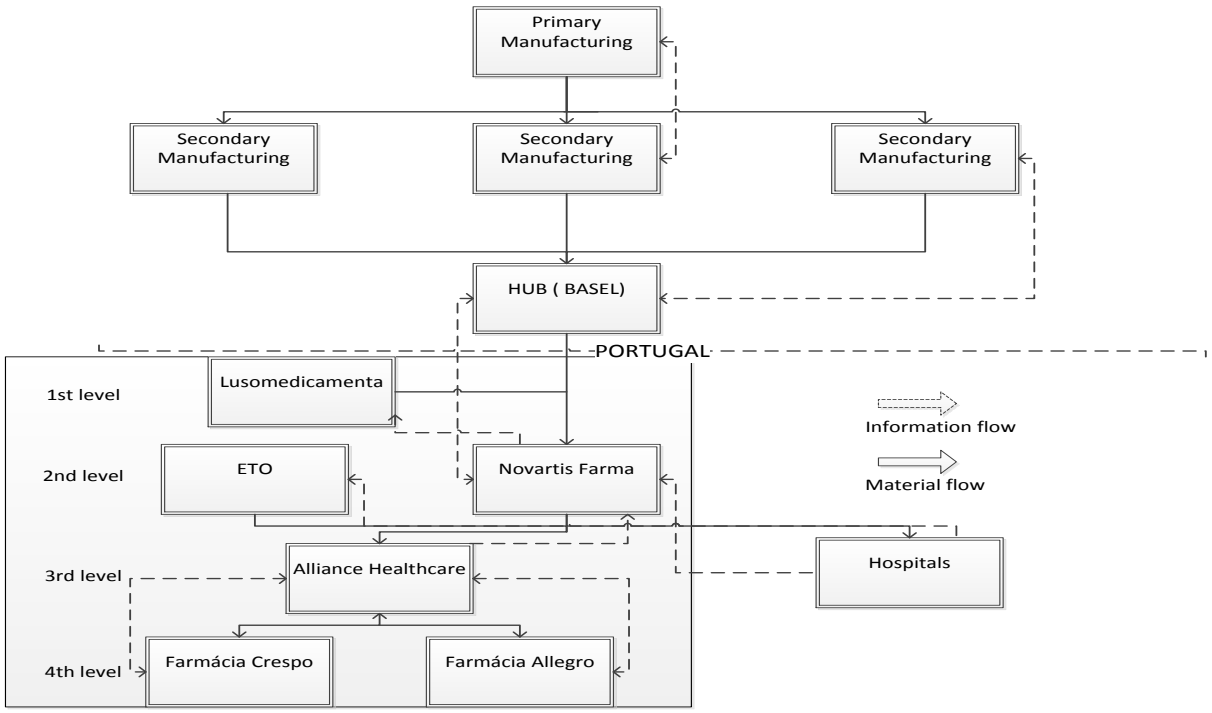

Figure 3.3 - Pharmaceutical Supply Chain (Case study)

3.2.1 Primary manufacturing

The SC involves several different entities. In the upstream part of the chain the first entity is the primary manufacturing site. Its function is to produce the Active Ingredient (AI), which involves either the several chemical synthesis and separation stages in order to come up with the molecules involved, or fermentation and product recovery and purification in the case of biochemical processes. This stage has long cycle times which make it difficult to ensure end-to-end responsiveness. Most of the Active Ingredients (AIs) are produced through multistage processes. These processes not only accumulate inventories between levels but also imply quality control checks, which can introduce additional delays into the SC. It goes without saying that this mode of operation reduces responsiveness and consequently contributes to some of the poor Supply Chain Performance (SCP) metrics of the industry and enhances the so called "bullwhip" effect. Thus, the primary production can be considered to be a push process, driven by medium- and long-term forecasts (Shah, 2004).

However, the manufacturing of the AI´s can be outsourced. This type of strategy is a growing one, as research-oriented companies tend to focus on the discovery and development activities (Shah, 2004).

3.2.2 Secondary manufacturing

The second level of the SC consists in the secondary manufacturing sites which use the active ingredients produced and mix them with excipient inert materials along with further processing and packaging to produce the final product, the drug. Generally five steps have to be executed in order to reach the end product:

1. Granulation: to add all the excipient materials
2. Compression: forming the pills
3. Coating
4. Quality control
5. Packaging

The secondary manufacturing sites are geographically separated from the primary manufacturing sites, and each one of them strategically distributed as means of meeting the demand for each region.

Each region and/or country has its specific demand which is calculated through a group of marketing experts. In most of the cases, the demand is determined for the next five years to come (Source: Head supply chain manager of Novartis Farma). The tools used in determining demand are based in historical data and fore coming events. For example: Introduction of a generic product in the market. When the patent expires, a generic product can enter the market, which means probably demand will decrease. In case of a New Product Introduction (NPI), the demand is calculated according to historical data on similar products or on the same product already introduced in the market by a

competitor. In innovative products demand has to be reviewed weekly due to its huge variability. In addition, the safety inventory level must be dynamic.

Another important issue in secondary manufacturing sites is to maintain a high utilization rate required in order to achieve lean production and to ensure a level schedule (Source: Logistics manager of Lusomedicamenta). This can be achieved with the implementation of Vendor Managed Inventory (VMI) and with relatively large inventory levels of AI held at the manufacturing sites. However, the drugs aren´t transferred directly to the respective countries. They´re indeed transported to a huge "hub" located in Basel, Switzerland, the firms´ home country. Furthermore, this hub covers the demand for each region transferring the right quantity of product to all of the Novartis distributors over Europe (Shah, 2004).

3.2.2.1 Lusomedicamenta

Lusomedicamenta is a company working as a secondary manufacturing site, meaning it only produces the end products ordered by customers, e.g. Novartis Farma, therefore leaving the manufacturing of the active ingredients to subcontracted companies (primary manufacturing facilities). Producing the end products means besides the manufacturing of the actual drug, the coating and packaging [8] related to it. In March 2012, the company produced over 5 million packages, while service level was around 98 % (Source: Logistics manager of Lusomedicamenta).

When it comes to supplying the AIs, it lacks flexibility due to the few suppliers available in the market. In most of the cases these suppliers have an actual monopoly in their hands, meaning the conditions, quantities and prices are for them to decide. Thus, demand quantities may not be met, leading to an unstable production of the drugs and low utilization rate, which goes against the Lean principles. There´re some products however, striving for a level schedule (Source: Logistics manager of Lusomedicamenta).

The company emphasizes continuous training of its cross-trained employees as it faces a regulated industry where no mistakes are tolerated as means of producing the drugs. Quality control is extremely rigorous dictating quality of the product as the market winner. In addition, everything is produced in batches.

The manufacturing of a drug is a non-stop process which only starts when all the components are available. Pending work only exists at the packaging area.

[8] Packages directed to different countries differ from each other

Most of the company's production is set for exportation (60-70%) to forty different countries (Source: Logistics manager of Lusomedicamenta). All the products must be licensed in order to be exported. Some setbacks come with the practice of exportation, mostly related to regulation issues at the customs delaying the flow of the products. Therefore, a stagnant product means loss of business and consequently the patients are left without their medicine. In these cases, the patient may choose to go for the same family of product of a competitor brand.

3.2.3 Distributor – Novartis Farma and ETO

This dissertation will focus on the downstream part of the chain, where Novartis Farma is the pharmaceutical company, and it goes all the way until the end-customers, the pharmacies.

Novartis is one of the largest pharmaceutical companies worldwide. The net sales in 2011 were 58 566 million USD (Source: http://www.novartis.com/).

Novartis doesn´t have manufacturing facilities in Portugal, working only as a distributor. The quantity of products received is synchronized with the local demand and a VMI approach is implemented meaning there is full visibility in the upstream part of the chain. However, visibility ends at this level.

All the drugs manufactured by Novartis' own facilities are stored in the "Hub" located in Basel, which serves as a distributor for the different regions established by Novartis (figure 3.3). However, Novartis farma doesn't supply all the drugs from the "Hub", having some drugs ordered from subcontracted laboratories, namely Lusomedicamenta, which is one of the few Portuguese drug manufacturing facilities still in business.

When it comes to distribution and storage, Novartis Farma doesn´t have its own warehouse, instead it uses a "Pre-wholesaler." i.e. a subcontracted company which deals with all of their logistic issues without billing the drugs on its own behalf. This type of outsourcing started to be used in the Portuguese pharmaceutical industry since 2002 (Source: Head supply chain manager of Novartis Farma), as the companies came to realize that it was more profitable to add this entity in the SC, than simply just renting a warehouse and process logistic operations internally.

As opposed to the British case, Direct-to-pharmacy[9] supply still doesn´t exist in Portugal. However, besides supplying the wholesaler, Novartis Portugal practices Direct-to-hospital supply.

[9] Direct-to-pharmacy means the laboratory supplies the pharmacies without the participation of the wholesalers. The wholesalers work simply as a logistics company who doesn´t bill the drugs on its behalf, just like the pre-wholesaler.

ETO is the other pharmaceutical company involved in the case study. It is a biopharmaceutical company that discovers, develops and commercializes innovative therapeutics in areas of unmet medical need. The company's mission is to advance the care of patients suffering from life-threatening diseases worldwide.

ETO in Portugal has been in operation since February 1996. It doesn't have manufacturing facilities in Portugal.

3.2.4 Wholesaler – Alliance Healthcare

Alliance healthcare is a wholesaler that supports a significant network of independent pharmaceutics. It is one of the leading European pharmaceutical distribution company, providing value adding services to pharmaceutics and laboratories. In addition, Alliance Healthcare provides pre-wholesaling through Alloga.

Alliance healthcare Portugal has around 430 collaborators in Lisbon, Porto, Almancil and Castelo Branco. Furthermore, it distributes drugs and health products to over 2000 pharmacies all over the country. In addition, it possesses a unique portfolio consisting of its own brands, thus being one of the largest companies in Portugal, when it comes to the total turnover (Source: http://www.alliance-healthcare.pt/).

3.2.5 Pharmacies

The pharmacies are the end-customers of the case study SC. The pharmacies involved in the study are Farmácia *Crespo* and Farmácia Allegro, located in Várzea de Sintra and Alfragide, respectively.

Both are located in regions where population density is high. Farmácia Crespo is one of the biggest pharmacies in Sintra, whereas Farmácia Allegro is located in the Allegro shopping center.

One important issue is that nowadays, it is the pharmacies that are empowered to decide which products to sell, meaning the demand can be more accurately forecasted. The doctors simply describe the active ingredient in their prescriptions.

3.2.6 Flow of information and material through the supply chain

Upstream→Novartis Farma

As mentioned in section 3.2.3, the upstream part of the SC until Novartis Farma works in a VMI approach, meaning full visibility and flow of information is available in that level of the SC. Still, products ordered from outsourcing manufacturing facilities (e.g. Lusomedicamenta) are not ordered in a VMI approach, being instead ordered in the traditional way (on request).

Novartis Farma→ Alliance Healthcare

Between these levels of the SC, visibility ends and the flow of information is limited. The wholesaler (Alliance Healthcare) makes an order request which is either approved or denied by the distributor (Novartis Farma). The approval depends mostly on the quantities ordered, considering a minimum order quantity negotiated on behalf of the two entities. In addition, the order cannot be too large in terms of volume in order to respect the previously calculated demand for the respective country. If approved, the order is processed and material sent through Novartis Farmas' pre-wholesaler to the customer (Alliance Healthcare).

Alliance Healthcare→ Pharmacies

Between these two levels of the SC exists a common information system, where the pharmacies are able to observe the inventory levels of the supplier for every single product. If willing to order a product, the pharmacies simply put a desired order quantity into a box. Furthermore, the order is processed in a short time period and sent as soon as possible. The wholesaler provides a distribution service into the pharmacies up to three times a day. In addition, the wholesaler informs the pharmacies of available promotions, in order to sell bigger quantities at a time.

4. Analytic network process approach to assess pharmaceutical supply chain management

Many decision-making tools have been recognized in the literature. Due to the objective and the context of this dissertation, the Analytic Network Process (ANP) was selected. ANP has been validated as a powerful decision-making tool in many different areas including Supply Chains (SCs). Still, none related to pharmaceutical supply chain (SC) in particular. In the SC context the ANP is known to be extremely useful in helping managers to make the wright strategic decisions when it comes to selecting the best alternatives, which in this context means the appropriate SCM practices to be implemented.

The ANP was selected precisely because it deals with dependence within a set of elements (inner dependence) and among different sets of elements (outer dependence). In addition, the network structure of the ANP enables the representation of any decision problem without the concern for what comes next as in the hierarchy.

4.1 Data gathering

Necessary data was gathered based on conversations held with the experts of the SC entities. The clusters and respective elements had to be selected in order to build the ANP model. The selected clusters and elements belonging to each one of them were the following:

1. **Achieve SC performance and competitiveness** – This cluster is considered to be the goal of the model where the only included element is "Achieve SC performance and competitiveness".
2. **Competitive priorities** – Cost, service level and delivery time.
3. **Key Performance Indicators** – On-Time-In-Full delivery, inventory value and responsiveness to urgent deliveries.
4. **Management practices** – Just-In-Time, promoting visibility throughout the SC and promoting the ability to change delivery dates and/or quantities.
5. **SC entities** – Lusomedicamenta (secondary manufacturing), Novartis Farma and ETO (pharmaceutical companies), Alliance healthcare (wholesaler) and two pharmacies.
6. **Supply Chain Management paradigms** – Lean and Agile.

A more detailed description on the selection method of the clusters and elements is available on section 4.2.

The relationships between the elements were gathered using questionnaires. The objective was to obtain the relative weights of the elements of each cluster. The questionnaires were presented as a

form of interviews to obtain the most likely answers. Even though the questionnaires were revised several times, the decision of doing the interview was made in order to validate and to test if the questionnaires were intuitional.

Six questionnaires were sent to the experts. A total of five responded questionnaires were received from the experts, meaning the rate of responded questionnaires was 83%. A questionnaire directed to the Novartis Farma head SC manager can be found in annex I.

To obtain the most appropriate and precise answers, the questions were carefully constructed. The aim was to construct the questions in a way that not only an expert of the logistics department would understand the questions, but also for experts from other departments could answer them, e.g. pharmacist. However, the most adequate professionals possible were selected to answer the questionnaires, as they have an insight into the whole SC from the perspective of each entity.

The judgments may not correspond to the desired results, due to some limitations in the ANP model, e.g. the scale may be difficult to understand because every individual has to decide the intervals by itself, meaning the same value may signify a different answer.

The experts from whom answers were obtained were the following:

- **Distributors: Novartis Farma and ETO** – Head supply chain manager and replenishment manager, respectively.
- **Wholesaler: Alliance Healthcare** – Replenishment manager and Administrator.
- **Pharmacies: Farmácia Crespo and Farmácia Alegro –** Two pharmacists, two pharmacists.

Unfortunately the logistics manager of Lusomedicamenta couldn't be contacted when trying to obtain answers for the questionnaire.

4.2 Model construction and problem structuring

The first step in the construction of the model was to build a network consisting of clusters, elements and the respective relationships. The network was constructed based not only on literature but also, as suggested by Zammori (2010) the experts[10] were included right in the beginning in order to construct a valid model.

[10] Experts included in the construction of the ANP model were from Novartis Farma, Alliance Healthcare and Lusomedicamenta.

The head SC manager of Novartis Farma, provided his vision of what he considers to be the main pillars that increment value for the SC in the pharmaceutical industry. The pillars are described in the following:

- Bi-directional visibility (operational perspective), where an entity is aware of the demand (lower level entity) and of the inventory level in the upper level entity. This results in proper management of inventory. Entities must always be in compliance with the respective norms in order to prevent misunderstandings.
- Promote transparency (community perspective) between entities, meaning they should share their vision and goals besides exchanging key data as a routine.
- Utilization of IT tools, through the implementation of a common information system, which provides knowledge and information sharing between entities, besides simple communication. Additionally, shared data must be timely and accurate.
- Promote collaboration, with the intent of joint value creation and to maintain sustainable collaborative relationships, e.g. promotion of a product in a pharmacy.
- Business processes should be innovated. Business process modeling must be assessed and SC services extended. Business process modeling means that the processes are explicated into their ultimate detail and ameliorated. Extending SC services means to be proactive, e.g. offering a cholesterol test in a pharmacy, and if results indicate high cholesterol, the customer is informed about the product available in treating the disease.

The first step in constructing the model was to define the clusters to be included in the model. A total of six clusters had to be included[11]. Several conversations were held with the experts to decide on which clusters and elements should be included in the ANP model. Saaty (2001) suggests that a maximum of nine elements should be included in each cluster. There are two clusters in the model in which the number of elements could have been changed (Key Performance Indicators (KPIs) and the management practices). However, if nine elements were included in each one of these clusters a total of 1312 (Table 4.1) pairwise comparisons and questions should have been made instead of the actual 88. Hence, only three elements were included in the clusters. After deciding on the clusters and respective elements, one has to connect with arrows the identified influences/relationships between them.

[11] A "product type" cluster should´ve been included including two elements, namely standard and innovative products. However, the idea was abandoned due to a significant increase in the number of questions included in the questionnaires.

Table 4.1 represents the possible number of pair-wise comparisons to be made per element and the total, depending on the number of elements (n) for the sub-criteria (KPIs) and alternatives (management practices) cluster.

Table 4.1 - Number of pair-wise questions (different scenarios)

n	Per element	Total
3	3	88
4	6	172
5	10	296
6	15	466
7	21	688
8	28	968
9	36	1312

All elements were selected based on the elements suggested by the experts of the different entities of the case study SC.

In the following, a description of the clusters and respective elements is provided:

4.2.1 1st Cluster

Achieve SC performance and competitiveness (Goal): This cluster represents the purpose of the implementation of each SCM practice, which is to achieve SC performance and thus, competitiveness, as means of competing against other SCs and to survive in the marketplace.

4.2.2 2nd Cluster

Competitive priorities (Criteria): In this cluster Cost, Service Level and Delivery Time were selected as competitive priorities. Mason-Jones et al. (2000) suggests that Cost, Service Level, Lead Time and Quality, are market winners and qualifiers for the Lean and Agile SCs. However, although quality is considered an important criterion for assessing Supply Chain Performance (SCP), it was left out of the model because in the pharmaceutical industry it´s considered a prerequisite. Also rigorous quality controls are made in the respective industry meaning high quality must prevail.

Moreover, these criteria are also considered as key enablers to achieve SC competitiveness. The cluster is connected to the Goal cluster meaning these three elements contribute to the evaluation of SC performance and competitiveness. In addition, the cluster also contains inner dependencies, i.e. if delivery time increases, it is very likely that service level decreases and that cost increases too. If a rapid response is provided towards an unpredictable change in demand, the service level increases and the cost might therefore increase as well.

Definition of each criteria:

- Cost – Aggregated costs along the supply chain
- Service level – On-time delivery in the right quantity.
- Delivery time – The period of time between the placement of the order (by customer) and its respective delivery.

4.2.3 3rd Cluster

Key Performance Indicators (Sub-criteria): In this cluster KPIs were selected in order to measure the competitive priorities. Besides being connected to the competitive priorities cluster, this one is also connected to the fourth cluster which represents the management practices and the purpose of this connection is to measure the impact of implementation of each management practice. Although inner dependencies exist in this cluster, they were not considered as means of simplifying the model. Section 2.1.5 suggested some KPIs. However, the purpose was to determine the most appropriate ones according to the industry's SC. That's where the experts of different entities hop in. The KPIs suggested by the experts of each entity of the case study SC were the following:

a) Novartis Farma:
   - Number of back orders - Number of orders with delay in supply.
   - On-Time-In-Full delivery (OTIF). This KPI verifies besides the delivery time, if the quantity is fully satisfied.
   - Lead-time adherence – Degree of compliance/fulfillment in the agreed time period to place an order.
   - Number of order change requests –Number of order change requests considering delivery time and/or quantity.
   - Minimum order quantity adherence – Degree of compliance of previously agreed minimum order quantities.
   - Number of complaints – Number of complaints related with the quality of the product, service or transportation, to name but a few.
   - Time in dealing with devolution – Time dealt with devolutions/ inverse logistics.
   - Forecast accuracy – This KPI is the basis to elaborate the supply plan.
   - Inventory value – Value of inventory in terms of coverage (number of days/weeks/months).

b) Alliance Healthcare:
   - Service Level (provided orders/requested orders)
   - Inventory value
   - Average stock (stock value/ value of sales)
   - Delivery time

c) Lusomedicamenta:
   - OTIF – On-Time-In-Full delivery related with supply and for the customers' orders.
   - Lead-time adherence.
   - Service level for the quality control. Verifies the degree of compliance related with the previously established lead times with respect to the quality control. The same goes for the production.

Inventory value is also one of the most important KPIs in the pharmacies.

The method in selecting the KPIs consisted in analyzing the ones suggested by the experts and then transforming them according to the literature review. The KPIs selected were the following:

i. "OTIF" was selected because it is clearly a common KPI for all of the entities in the SC.
ii. "Inventory value" was selected due to the same reason as the previous one.
iii. "Responsiveness to Urgent Deliveries (RUD)" was selected due to its relationship with lead-time adherence. If the previously established lead time (with customers) for placing orders is not met, the company must treat the order as an urgent one, and thus, respond to it as means of trying to deliver the product in time.

Definitions of the KPIs:

- On-Time-In-Full delivery (OTIF). The percentage of fully covered orders, i.e. orders that arrive on time and in the right quantity.
- Inventory value – Quantity of inventory that meets the demand, measured in weeks.
- Responsiveness to urgent deliveries – The ability of the SC to respond to urgent deliveries and to orders placed outside the previously established time period.

4.2.4 4th Cluster

Management practices (alternatives): In this cluster management practices are proposed for the companies to implement, in order to enhance SC performance and competitiveness. This cluster is connected to the criteria and sub-criteria cluster in order to measure the impact of its implementation on the competitive priorities and KPIs, respectively. Furthermore, management practices were discussed with the experts. The most important practices clearly focused in integration and communication between SC entities through an information system. In an ideal situation, the following information should be made available to all SC entities:

- Order status, e.g. information on whether the order was correctly received and integrated, if it is being processed, if problems with expedition are detected.
- Information on the quantities being supplied or not.

- Prediction of the delivery date, logistics related data for the products.
- Information that makes possible the products' respective prioritization.

The management practices selected were the following:

i. "Just-In-Time (JIT)" was selected due to its clear relationship with the Lean philosophy, in order to test its importance despite the exclusion of this practice from the experts' list.
ii. "Promoting visibility throughout the SC" was selected because it's clearly a practice for the future as means of enhancing SCP (considered by the Novartis Farma Head SC manager).
iii. "Promoting the ability to change deliver dates and/or quantities" was selected due to its obvious relationship with the KPI suggested by the Novartis head SC manager "number of order change requests".

Definitions of the management practices:

- **Just-In-Time –** It is a philosophy that strives to reduce waste in the form of time, material and information, through simplification of processes, such as inventory reduction and batch size reduction.
- **Promoting visibility throughout the supply chain –** It promotes visibility between the entities of the SC, making the gathering of detailed information related with the orders possible, and about the inventory levels, therefore making the prioritization of the orders possible.
- **Promoting the ability to change delivery dates and/or quantities –** It promotes the ability of a supplier to cope up with changes in the quantity and/or delivery times of the customers' order.

4.2.5 5th Cluster

SC Entities: In this cluster the four entities involved in the case study SC are represented. The entities are Lusomedicamenta (secondary manufacturing site), Novartis Farma (Distributor), Alliance Healthcare (Wholesaler) and two pharmacies (end-customers). These elements are central to the decision-making, which makes this cluster crucial if willing to analyze different perspectives. This cluster is connected to the management practices/KPIs cluster because in implementing these practices, companies may increase the respective KPI values and thus, the respective competitive priorities values. The connection to these clusters in addition to the SCM paradigms cluster is also for the purpose of evaluating which management practice/KPI/SCM paradigm is the most important in each level of the SC.

4.2.6 6th Cluster

SCM Paradigms: In this cluster two elements (SCM paradigms) are included: Lean and Agile. The inner dependencies are not included in the framework for the same reason as in the sub-criteria cluster, simplification of the model.

The network obtained after deciding on the clusters and elements to include in the model, is illustrated in figure 4.1.

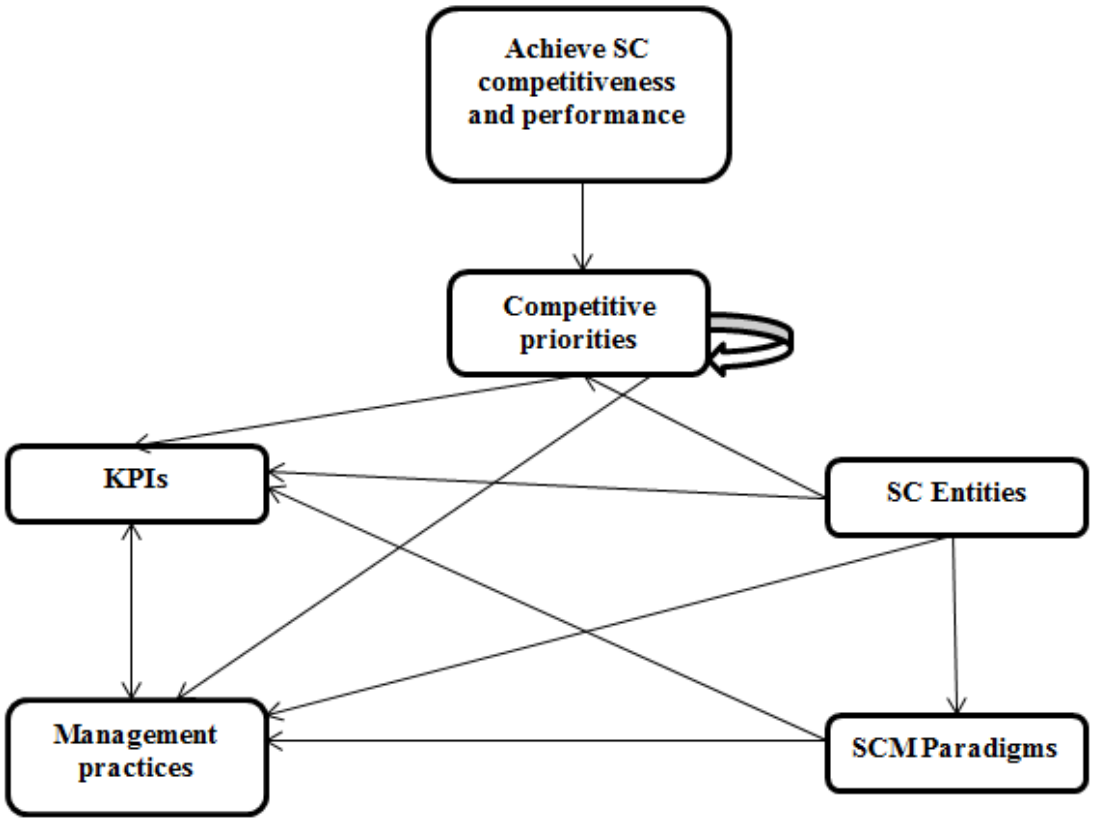

Figure 4.1 - ANP network

Figure 4.1 represents the ANP network. An arrow shows that one cluster influences another, namely if an arrow goes from the "Achieve SC performance and competitiveness" cluster to the competitive priorities cluster it means that the "Achieve SC performance and competitiveness" cluster value depends on the judgments of the competitive priorities cluster.

Table 4.2 summarizes the selected clusters and respective elements.

The objective is to discuss what the real importance of the suggested KPIs/ management practices is, in order to achieve the proposed goal of the study which is to achieve SC performance and competitiveness in the pharmaceutical industry.

Innovative and standard products were supposed to be included in the model to stay consistent with the literature review, but the questionnaires were already so large[12] that the idea was abandoned.

Table 4.2 - Clusters and respective elements considered in the ANP model

Cluster	Elements
Achieve SC performance and competitiveness	Achieve SC performance and competitiveness
Competitive priorities	Cost, Service level and Delivery Time
KPIs	OTIF, Inventory value and RUD
Management practices	JIT, Promoting visibility throughout the SC and Promoting the ability to change delivery dates and/or quantities
SC entities	Lusomedicamenta, Novartis Farma and ETO, Alliance Healthcare, Farmácia Crespo and Farmácia Allegro
SCM paradigms	Lean and Agile

Once the clusters and respective elements were selected, the respective relationships identified and the model constructed, the pair-wise comparisons between the elements will be conducted.

4.3 Conducting the pairwise comparisons between elements and obtaining relative weights

This section consists in conducting all existing pair-wise comparisons which are obtained through the experts' evaluations using the fundamental scale. Each comparison has a respective question, e.g. "With respect to achieving SC competitiveness and performance, which criterion is more important, cost or service level, and to what degree?" The same question is made for all elements that have an impact on other elements, whether they belong to the same cluster (inner dependence) or to another cluster (outer dependence). The point in doing the comparisons is to obtain their relative weights, i.e. each element/cluster has a certain importance in the network/model, which is represented by weights.

Table 4.3 shows the pair-wise comparisons to be made from one cluster with respect to another. It also shows the number of matrices included in the cluster to be compared, in addition to the total number of comparisons/questions to be made for each influence/relationship. To calculate the number of questions, equation 4.1 was used:

$$N * n(n-1)/2 \quad (4.1)$$

[12] The act of filling the questionnaires took over 20 minutes in average.

,where N delineates the number of matrices[13] in the cluster to be compared and n delineates the number of elements in the origin cluster[14].

Super Decisions (v.2.2.6 beta) software was used in conducting the pairwise comparisons. The software was developed by Thomas L. Saaty and designed by William J.L. Adams.

Table 4.3 - Description of the pair-wise comparisons

Pair-wise comparison of cluster (Origin cluster)	With respect to cluster	Number of Wij matrices (N)	Number of questions $N * n(n-1)/2$
Competitive priorities elements	Achieve SC performance and competitiveness	1	3
Competitive priorities elements	Competitive priorities	3	9
KPI elements	Competitive priorities	3	9
KPI elements	Management practices	3	9
KPI elements	SCM Paradigms	2	6
KPI elements	SC entities	4	12
Management practices	KPIs	3	9
Management practices	SCM paradigms	2	6
Management practices	Competitive priorities	3	9
Management practices	SC entities	4	12
SCM Paradigms	SC entities	4	4
TOTAL		30	88

Since multiple judgments were made on each level of the SC, a synergistic aggregation of individual judgments has to be made. Individual identities are lost with every stage of aggregation and a synthesis of the network produces the group's priorities (Forman, 1998). When aggregating individual judgments, a geometric mean must be used (Wu et al., 2008).

In order to obtain the geometric mean, Wu (2008) suggests the use of equation 4.2.

$$A = [a_{ij}]_{n*n} = \begin{bmatrix} 1 & \sqrt[m]{\prod_{k=1}^{m} a_{12}^{k}} & \cdots & \sqrt[m]{\prod_{k=1}^{m} a_{1n}^{k}} \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} a_{12}^{k}}} & 1 & \vdots & \sqrt[m]{\prod_{k=1}^{m} a_{2n}^{k}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{\sqrt[m]{\prod_{k=1}^{m} a_{1n}^{k}}} & \cdots & \frac{1}{\sqrt[m]{\prod_{k=1}^{m} a_{2n}^{k}}} & 1 \end{bmatrix} \quad (4.2)$$

,where α delineates the judgments made by the experts and *m* represents the number of experts.

[13] The number of matrices represents the number of elements of the origin cluster.
[14] The same formula was used to calculate the different scenarios in table 4.1.

In the following an example of a geometric mean calculus is shown for the competitive priorities elements with respect to the goal cluster:

$$A = [a_{ij}]_{n*n} = \begin{bmatrix} 1 & \sqrt[2]{5*1} & \sqrt[2]{5*7} \\ \frac{1}{\sqrt[2]{5*1}} & 1 & \sqrt[2]{1*9} \\ \frac{1}{\sqrt[2]{5*7}} & \frac{1}{\sqrt[2]{1*9}} & 1 \end{bmatrix}$$

After calculating each cell of the matrix, the obtained values were inserted into the software.

Firstly, the geometric means were obtained for each entity belonging to the SC and finally the global geometric mean was calculated.

The aggregation includes the judgments made by experts from all the entities belonging to the case study[15]. However, the pair-wise comparisons will also be conducted from three different perspectives, i) Pharmaceutical company, ii) Wholesaler and iii) Pharmacy. Regarding these perspectives, a geometric mean is also calculated regarding the SC entities cluster in order to analyze separately the most important competitive priorities, KPIs management practices and SCM paradigms. After aggregating all the judgments, they are inserted as inputs in the Super Decisions software, in the form of matrices.

4.3.1 Pair-wise comparison of the clusters

This section shows the relative weights of the pair-wise comparisons of the clusters. The first pair-wise comparison delineates the comparison of clusters with respect to the competitive priorities cluster (Table 4.4).

Table 4.4 - Clusters with respect to the competitive priorities cluster

Competitive priorities	0.097
KPIs	0.333
Management practices	0.570
Inconsistency	**0.024**

Management practices (alternatives) obtained the highest score (0.570), followed by KPIs (sub-criteria) (0.333) and by the competitive priorities (criteria) (0.097). The competitive priorities (criteria) are therefore most influenced by the management practices, meaning an implementation of the

[15] In order to obtain the global geometric mean, judgments are firstly aggregated at each level and afterwards aggregated as a whole.

practices has a great impact on the competitive priorities. Inconsistency equals 0.024, meaning the judgments are consistent.

Table 4.5 represents the influence of clusters on the SCM paradigms cluster.

Table 4.5 - Cluster comparison with respect to SCM paradigms

KPIs	0.333
Management practices	0.667
Inconsistency	**0.000**

Management practices (alternatives) influence SCM paradigms the most, with a score of 0.667. This judgment considers that the management practices is the most important cluster and the respective measurement of the impact of their implementation is the second most important one. Inconsistency equals zero whenever only two clusters/elements are being compared.

The last cluster comparison refers to the stakeholders cluster (table 4.6).

Table 4.6 - Cluster comparison with respect to the stakeholders

Competitive priorities	0.073
KPIs	0.326
Management practices	0.506
SCM paradigms	0.095
Inconsistency	**0.050**

Clearly the management practices (alternatives) have the most influence on the stakeholders (score of 0.506), followed by the KPIs (sub-criteria) (0.326), SCM paradigms (0.095) and finally by the competitive priorities (criteria) (0.073). Inconsistency is once again acceptable (0.050).

The management practices (alternatives) cluster is the most important cluster in the model. However, without proper measures (KPIs) the impact of implementing the management practices couldn't be measured, meaning the KPIs are the second most important cluster. The competitive priorities are the least important cluster. This is because they aren't as precise as the KPIs for the purpose of measuring the referred impact of implementation of management practices. The same goes for the SCM paradigms, which are indeed philosophies that are hard to define precisely.

4.3.2 Pair-wise comparison of the elements

The goal cluster (achieve SC competitiveness and performance) is influenced by the management practices (criteria) cluster. Therefore, a Pair-Wise Comparison (PWC) matrix must be conducted in order to determine which competitive priority is more important in achieve a competitive SC. Table 4.7 represents the matrix for the relative weights of the competitive priorities regarding SC competitiveness and performance.

Table 4.7 - Competitive priorities with respect to SC competitiveness and performance

Cost	0.134
Service level	0.734
Delivery time	0.132
Inconsistency	**0.006**

The results obtained from the aggregated value of the judgments made by the different entities in the SC, show that service level is clearly the most important competitive priority when assessing SC performance and competitiveness with a corresponding score (relative weight) of 0.734. Cost and delivery time share almost the same score, 0.134 and 0.132, respectively. The consistency ratio (CR) equals 0.006, meaning it is below 0.1 and thus, the judgments are considered consistent. In the pharmaceutical industry, service level is clearly the most important competitive priority, which is in fact quite understandable due to the purpose of the whole industry, to produce drugs to cure people, i.e. if the drug isn´t available to the patient in that moment, it´s very likely that he chooses to buy a different branded product or go to another pharmacy to buy the same product, i.e. competitiveness and performance decreases.

The next pair-wise comparisons (PWCs) represent inner dependencies between the elements in the competitive priorities cluster. Table 4.8 shows the influence of service level and delivery time on cost.

Table 4.8 – Competitive priorities elements with respect to Cost

Service level	0.771
Delivery time	0.229
Inconsistency	**0.000**

The competitive priority influencing cost the most, is service level, with a score of 0.771. It means that if the product isn't delivered accordingly, the cost will increase due to a likely increase in the cost of opportunity in sales, generating a stock-out in the entities downstream the SC. Delivery time also has some influence in cost, because the longer a company takes to process an order, the lower the cost is. When comparing only two elements, inconsistency doesn't exist, meaning CR value is 0.

The next PWC evaluates the influence of cost and delivery time on service level (Table 4.9).

Table 4.9 - Competitive priorities elements with respect to Service level

Cost	0.734
Delivery time	0.266
Inconsistency	**0.000**

As expected, cost influences service level the most with a score of 0.734, just like service level influences cost the most. However, a little bit of variation is observed when comparing to the previous PWC. That is most likely due to the actual variation in the experts' evaluation. Interestingly, the

experts consider that the increase of cost negatively affects more the service level than a longer delivery time.

The next PWC (table 4.10) illustrates the influence of cost and service level on delivery time.

Table 4.10 - Competitive priorities elements with respect to Delivery time

Cost	0.500
Service level	0.500
Inconsistency	**0.000**

The criterion influencing delivery time the most is divided between cost and service level, each with a score of 0.500. The experts consider that each criterion has the same influence in the variation of delivery time. When service level decreases, it may provoke a long delivery time. If cost increases, delivery time will be affected negatively, meaning a shorter delivery time is observed.

The fore coming PWCs will evaluate the importance of the KPIs in influencing the competitive priorities. Table 4.11 illustrates the influence of the KPIs on Cost.

Table 4.11 - KPI elements with respect to Cost

Inventory value	0.607
OTIF	0.262
RUD	0.131
Inconsistency	**0.100**

In order to measure cost, the results indicate that the inventory value suits best for the purpose (0.607), followed by "On-Time-In-Full (OTIF) delivery" (0.262) and "Responsiveness to Urgent Deliveries (RUD)" (0.131). The CR value equals 0.100 meaning it is still equal to 0.1, meaning judgments are consistent. "Inventory value" is clearly considered to be one of the main KPIs when measuring costs along the SC. Interestingly, "RUD" scored lowest for that purpose. One could believe that as means of responding to an urgent delivery the costs would increase, but clearly when having that ability, it means that the SC is designed in a way that this type of responsiveness doesn´t increase too much cost. Additionally, if the proper response is provided, it means that service level will increase, meaning that costs decrease.

The next PWC illustrates the importance of the KPIs in measuring service level (table 4.12).

Table 4.12 - KPI elements with respect to Service level

Inventory value	0.196
OTIF	0.470
RUD	0.334
Inconsistency	**0.062**

To measure service level, "OTIF" scores the highest (0.467), followed by "RUD" (0.334) and by "Inventory value" (0.196). CR value is 0.062, meaning it is acceptable. Although "OTIF" obtained the highest score, it would have been expectable that the score was higher, due to its obvious relationship with the competitive priority of service level.

The following PWC evaluates the importance of the KPIs on measuring delivery time (table 4.13).

Table 4.13 - KPI elements with respect to Delivery time

Inventory value	0.196
OTIF	0.470
RUD	0.334
Inconsistency	**0.06224**

To measure delivery time, "OTIF" was considered the best KPI, with the score of 0.470, followed by "RUD" (0.334) and by the almost insignificant "Inventory value" (0.196). Inconsistency is 0.062 meaning it is acceptable. The relationship between "OTIF" and delivery time is the most obvious, because if the order doesn´t arrive on-time, it means that the previously established delivery time was longer than expected. When responding to an urgent delivery, it means that the previously established delivery time will have to be shorter in order to meet the exceptional customer demand.

The following PWCs evaluate the influence of implementing each management practice on the competitive priorities. In the first comparison, the influence of implementing the practices on the cost was assessed (table 4.14).

Table 4.14 – Management practices elements with respect to Cost

JIT	0.605
Promoting the ability…	0.137
Promoting visibility…	0.258
Inconsistency	**0.002**

Cost is influenced the most by the implementation of "JIT" (0.605). "Promoting visibility throughout the SC" scores 0.258, being the second most influencing management practice, leaving the least importance to "Promoting the ability to change deliver dates and/or quantities" (0.137). The experts believe that "JIT" reduces cost over two times more than when implementing proper visibility in the SC. "Promoting the ability to change delivery dates and/or quantities" also reduces cost, although not so significantly. The CR value is 0.002 meaning it's acceptable.

Table 4.15 shows the impact of implementing the management practices on service level.

Table 4.15 - Management practices elements with respect to Cost

JIT	0.353
Promoting the ability…	0.251
Promoting visibility…	0.397
Inconsistency	**0.073**

The implementation of "Promoting visibility throughout the SC" and "JIT", influence service level the most, with a score of 0.397 and 0.353, respectively. The implementation of "Promoting the ability to change delivery dates and/or quantities" scored 0.251. The CR value equals 0.073, meaning it is acceptable. Results show that there is not a significant difference between the scores, meaning these PWCs reveal that service level may not be the most adequate competitive priority to measure the implementation of the management practices, due to the more or less similar distribution of practices' importance on service level.

The next PWC illustrates the influence of the management practices on delivery time (table 4.16).

Table 4.16 - Management practices elements with respect to Delivery time

JIT	0.434
Promoting the ability…	0.222
Promoting visibility…	0.343
Inconsistency	**0.010**

Delivery time is also the most influenced by the implementation of "JIT", although all practices have quite an increased amount of influence on the criterion. "JIT" scored 0.434, followed by "Promoting visibility throughout the SC" (0.343) and by "Promoting the ability to change delivery dates and/or quantities" (0.222). CR is below 0.1 and thus, judgments are consistent.

The fore coming PWCs evaluate the importance of the KPIs related to the management paradigms. Table 4.17 evaluates the importance of the KPIs on the Lean SCM paradigm.

Table 4.17 - KPI elements with respect to the Lean SCM paradigm

Inventory value	0.442
OTIF	0.482
RUD	0.076
Inconsistency	**0.005**

To measure leanness, the most important KPIs in the experts' perspective was "OTIF" (0.482) followed by "Inventory value" (0.442). "RUD" was left almost with no significance (0.076). The results are the expected ones. One of the lean principles is to produce standard products, meaning demand is known with high accuracy. This means that a level schedule is implemented, and that inventory level is the lowest possible and that the end-customer isn´t willing to wait, i.e. stock-outs have to be prevented. This means that inventory level and "OTIF" measure equally as good the leanness of a SC. A Lean Supply Chain (LSC) is efficient, not responsive.

The next PWC (table 4.18) shows the importance of the KPIs on the Agile SCM paradigm.

Table 4.18 – KPI elements with respect to the Agile SCM paradigm

Inventory value	0.111
OTIF	0.372
RUD	0.517
Inconsistency	**0.097**

To measure SC agility, "Responsiveness to urgent deliveries (RUD)" scored the highest (0.517), followed by "OTIF" (0.372) and by "Inventory value" (0.111). Again the results come to confirm that the experts made judgments that are consistent with the paradigms' theoretical basis. "RUD" scored the highest, as expected, when considering that agility and responsiveness are linked together. "OTIF" lost importance when comparing to leanness, but is still important. "Inventory value" has the lowest score, due to the fact that an Agile Supply Chain (ASC) shouldn´t be measured by its inventory levels. An ASC can have zero inventory level or high inventory level, as long as it remains flexible. Flexibility can be in terms of semi-finished inventory buffer capacity or manufacturing buffer capacity. Inconsistency remains acceptable (0.097).

The following PWCs (tables 4.19 and 4.20) intend to evaluate the leanness or agility of each one of the management practices.

Table 4.19 – Management practices elements with respect to the Lean SCM paradigm

JIT	0.637
Promoting the ability…	0.110
Promoting visibility…	0.253
Inconsistency	**0.053**

"JIT" was considered as the management practice that influences leanness of a SC the most (0.637), followed by "Promoting visibility throughout the SC" (0.253) and by "Promoting ability to change delivery dates and/or quantities" (0.110). CR value is also consistent (0.053). The results are actually the expected ones. JIT practices are directly related to reducing waste by using only the necessary products, at the necessary time, in the necessary quantity (Sugimori et al., 1977). "Promoting visibility throughout the SC" scored second which is also quite expectable, since a LSC doesn't implement the virtual network, relying instead on traditional alliances and long-term contracts, which in turn, is a form of visibility. In addition, a LSC lacks external flexibility (De Treville and Antonakis, 2006), which in this case means it is not able to change delivery dates or quantities.

Table 4.20 – Management practices elements with respect to the Agile SCM paradigm

JIT	0.306
Promoting the ability…	0.558
Promoting visibility…	0.136
Inconsistency	**0.097**

"Promoting ability to change delivery dates and/or quantities" proved to be the management practice influencing SC agility the most (0.558), followed by "JIT" (0.306) and surprisingly, the least influencing was "Promoting visibility throughout the SC" (0.136). The judgments are once again consistent, with a CR value of 0.097. Interestingly "JIT" scored higher than visibility, meaning the experts consider "JIT" more linked to agility than to leanness.

The following PWCs (tables 4.21 to 4.23) are between the KPIs cluster and the management practices cluster. This is a special comparison, because the feedback between the clusters is in both directions. However, the next comparisons will determine the most important KPIs to measure the impact of implementation of each management practice.

Table 4.21 - KPI elements with respect to management practice "JIT"

Inventory value	0.350
OTIF	0.176
RUD	0.474
Inconsistency	**0.097**

The experts rated "RUD" as the most important KPI to measure the impact of implementing the management practice "JIT" with a score of 0.474, followed by "Inventory value" (0.350) and "OTIF" (0.176). CR is value (0.097) is acceptable. JIT delivery, for instance, requires rapid response from suppliers to cope up with the customers' requirements, meaning the higher the score for "RUD", the more the SC leverages JIT practices. Actually this goes against the theoretical basis, due to the clear relationship of JIT practices with leanness, opposed to the relationship of "RUD" with agility. "Inventory value" is the second most important KPI to measure "JIT", meaning that they are directly proportional, i.e. when "Inventory value" increases, inventory levels are high, meaning the SC isn´t implementing JIT practices[16].

Table 4.22 - KPI elements with respect to management practice "Promoting visibility throughout the SC"

Inventory value	0.135
OTIF	0.690
RUD	0.175
Inconsistency	**0.000**

When implementing the management practice of "Promoting visibility in the SC", the experts consider "OTIF" to be the most important KPI to measure the respective impact, with a score of 0.690. "RUD" and "Inventory value" have reduced amount of significance for that matter, scoring 0.175 and 0.135, respectively. The CR value is almost zero, which tells about the consistency of the judgments on the

[16] JIT reduces waste through reduction of inventory levels,time,material and abundant information.

different levels of the SC. When "OTIF" value increases, one of the reasons is certainly the better visibility that allows companies to provide on-time delivery in the right quantity for their respective customers.

Table 4.23 - KPI elements with respect to management practice "Promoting the ability to change the delivery date and/or quantity"

Inventory value	0.165
OTIF	0.645
RUD	0.190
Inconsistency	**0.099**

To measure the management practice "Promoting the ability to change deliver dates and/or quantities" the results are similar to the ones in the previous PWC. "OTIF" is the most important KPI (0.645) to measure the impact of the practices' implementation, followed by "RUD" (0.190) and "Inventory value" (0.165). CR value is acceptable (0.099).

The PWCs of the management practices cluster with respect to the sub-criteria cluster (KPIs) take place in tables 4.24 to 4.26. The first one measures the impact of implementation of the practices on the KPI "Inventory value", or in other words, which practice is more suitable to improve a certain KPI value, which in table 4.24 is "Inventory value".

Table 4.24 – Management practices elements with respect to the KPI "Inventory value"

JIT	0.736
Promoting the ability…	0.112
Promoting visibility…	0.151
Inconsistency	**0.100**

Unanimously, the experts evaluated "JIT" as the best management practice to improve the value of "Inventory value", with a score of 0.736. "Promoting visibility throughout the SC" scored second highest (0.151) and "Promoting the ability to change deliver dates and/or quantities" scored lowest (0.112). CR value equals 0.1 and thus it isacceptable.

Table 4.25 – Management practices elements with respect to the KPI "OTIF"

JIT	0.359
Promoting the ability…	0.128
Promoting visibility…	0.513
Inconsistency	**0.099**

To improve "OTIF" value, promoting visibility throughout the SC turned out to be the best practice (0.513) followed by JIT (0.359) and by "Promoting the ability to change delivery dates and/or quantities" (0.128). CR value is 0.099 and thus, acceptable. With a clear view of up- and downstream inventories and information on orders that makes their respective prioritization possible, "OTIF" value increases significantly.

Table 4.26 – Management practices elements with respect to the KPI "Responsiveness to urgent deliveries"

JIT	0.213
Promoting the ability…	0.523
Promoting visibility…	0.265
Inconsistency	**0.094**

"Responsiveness to urgent deliveries" is mostly influenced by "Promoting the ability to change delivery dates and/or quantities" (0.523). "Promoting visibility throughout the SC" scored second highest (0.265), followed by JIT (0.213). CR value is acceptable (0.094).

4.3.3 Pair-wise comparisons of the elements from the different perspectives of the supply chain

In this section the PWCs of the elements from different perspectives takes place, meaning all PWCs linked to the "stakeholders" cluster will be assessed. The judgments were aggregated by entity through a geometric mean.

4.3.3.1 Pharmaceutical company

The perspective of the different levels of the SC is going to take place in the following. Firstly, the most upstream entity, the pharmaceutical companies' perspective on the best criteria, KPIs, management paradigms and management practices is evaluated.

The first PWC (table 4.27) is a special case, since it isn't the comparison of the best criteria in the company's perspective, but the contribution of the entities experts' judgments on criteria with respect to the goal cluster.

Table 4.27 – Competitive priorities with respect to the Goal cluster (Pharmaceutical company perspective)

Cost	0.060
Service level	0.709
Delivery time	0.231
Inconsistency	**0.069**

Service level clearly dominates the judgments of the pharmaceutical companies' experts, with a score of 0.709. Delivery time and cost scored 0.231 and 0.060, respectively. CR equals 0.069 and thus, it is acceptable.

Table 4.28 represents the most important KPIs in the perspective of the pharmaceutical companies.

Table 4.28 - Most important KPIs in the perspective of the pharmaceutical company

Inventory value	0.229
OTIF	0.700
RUD	0.075
Inconsistency	**0.073**

Clearly on-time delivery in the right quantity is a KPI with a high priority (0.700) for the pharmaceutical companies. Furthermore, this KPI has to be considered not only for the company's customers, but also with respect to its suppliers. "Inventory value" still remains significant, but with a low score (0.229). This is because the company organizes its respective procurement through a Vendor-Management-Inventory (VMI) replenishment system where the supplier takes full responsibility for maintaining an agreed inventory level, meaning that the "Inventory value" generally doesn't depend on the company. The respective inventory level depends upon the forecasted demand for each region and consequently for each country. Since the company doesn't implement direct-to-pharmacy practices, the "Responsiveness to urgent deliveries" remains almost insignificant (0.075), with an exception of some urgent needs, which are directly related to the hospitals (which the company supplies directly). Inconsistency is again acceptable (0.073).

The next PWC (table 4.29) evaluates which management practice is the most important in the company's point of view.

Table 4.29 - Most important management practices (Pharmaceutical company)

JIT	0.055
Promoting the ability…	0.266
Promoting visibility…	0.679
Inconsistency	**0.096**

As observed, "Promoting visibility throughout the SC" is the ultimate management practice to be implemented in the company's perspective, with a score of 0.679. Some of the additional "Inventory value" of the company is directly related to lack of visibility downstream the SC. Some progresses have been made in recent years by acknowledging minimum order quantities with wholesalers, but still no additional information is provided by wholesalers in terms of the respective orders. Inventory levels aren't provided either by the wholesalers meaning the company isn't capable of organizing its production nor inventory levels in a way that waste could be reduced accordingly. "Promoting the ability to change delivery dates and/or quantities" scored the second highest (0.266), followed by "JIT" (0.055). CR equals 0.096 meaning it is acceptable.

JIT practices have almost no importance for the pharmaceutical companies, due to the above referred VMI system. In addition, the wholesalers have the delivery dates established with the company, meaning a JIT system cannot be implemented.

In table 4.30, the most important SCM paradigm is evaluated in the pharmaceutical company's perspective.

Table 4.30 - Most important SCM paradigm (Pharmaceutical company)

Agile	0.459
Lean	0.541
Inconsistency	**0.000**

Lean is more important but not in a clear way (score of 0.541), since it cannot be implemented due to the large number of innovative drugs produced by the company, which cannot be produced in a Lean manner. The agility is also related to the direct delivery of products to the hospitals.

4.3.3.2 Wholesaler

In this section, the perspective of the wholesaler takes place. Table 4.31 illustrates the most important competitive priorities in the wholesalers' opinion.

Table 4.31 – Competitive priorities with respect to the Goal cluster (Wholesaler perspective)

Cost	0.195
Service level	0.717
Delivery time	0.088
Inconsistency	**0.090**

The judgments show that service level is the most important criteria (0.717), by far. The second highest is cost (0.195) followed by delivery time (0.088). The inconsistency is once again acceptable (0.090).

The next PWC evaluated the importance of the KPIs for the wholesaler (table 4.32).

Table 4.32 - Most important KPIs in the perspective of the Wholesaler

Inventory value	0.285
OTIF	0.653
RUD	0.062
Inconsistency	**0.071**

The wholesalers consider "OTIF" to be the most important KPI, with a score of 0.653. It is important not only to receive the full delivery on-time from the suppliers, but also deliver the products on-time to the pharmacies. "Inventory value" has a reduced amount of importance for the respective entity, scoring 0.285. It means that the inventory level remains a concern for the wholesalers since they cannot entirely implement "JIT", i.e. JIT is implemented only for its customers, not for the suppliers.

In table 4.33, the most important management practice was evaluated in the wholesalers' perspective.

Table 4.33 - Most important management practices in the perspective of the Wholesaler

JIT	0.101
Promoting the ability…	0.674
Promoting visibility…	0.226
Inconsistency	**0.082**

"Promoting the ability to change delivery dates and/or quantities" proved to be the most important management practice, with a score of 0.674. This is related with the alignment of the inventory levels according to the demand. In this way the wholesaler only delivers the right quantity at the right time. Even though they could deny the implementation of this practice in order to sell more products, they wouldn't benefit from it at all, since all excess products in the pharmacy are empowered to send them back at a total reimbursement. "Promoting visibility throughout the SC" scored 0.226, followed by "JIT" which scored 0.101. The significant value of "Promoting visibility throughout the SC" shows some progress in terms of constructing the so called virtual network in order to enhance SC agility (Christopher, 2000). However, this score still remains pretty low, meaning that the process of becoming entirely virtual still has a long way to go. Like mentioned above, JIT is only important for the company's customers, not for the supplier, meaning it has a reduced amount of significance when comparing to the other management practices.

The judgments of the experts relating to the best SCM paradigm were assessed in table 4.34.

Table 4.34 - Most important SCM paradigm in the perspective of the Wholesaler

Agile	0.167
Lean	0.833
Inconsistency	**0.000**

Table 4.34 confirms that agility still remains quite insignificant for the wholesalers (score 0.167), which are considered to be the link between pharmacies and the pharmaceutical companies. As opposed to agile, lean scored 0.833. It means that the wholesalers consider waste reduction to be the most important asset to enhance the company's performance, considering that the agility and the respective responsibility that comes to producing some of the products (innovative ones) is left with the pharmaceutical companies. However, this lack of visibility and the full responsibility on the pharmaceutical companies' shoulders, results in overproduction or stock-outs, meaning additional costs are accumulated across the SC. In addition, forecast accuracy for innovative products is lower.

4.3.3.3 Pharmacy

This section will assess the perspective of the pharmacies on the importance of the different elements.

Firstly, the competitive priorities that the pharmacists consider the most important for the SC were evaluated (table 4.35).

Table 4.35 . Competitive priorities with respect to the Goal cluster (Pharmacy perspective)

Cost	0.230
Service level	0.662
Delivery time	0.107
Inconsistency	**0.002**

Once again, service level is the most important competitive priority for the SC, in the pharmacists' opinion, with a score of 0.662. Cost and delivery time scored 0.230 and 0.107, respectively. CR value is 0.002 meaning it is acceptable. Results indicate that the pharmacies consider service level to be the most important competitive priority when striving to improve SC performance and competitiveness.

The most important KPIs in the perspective of the pharmacy are shown in table 4.36.

Table 4.36 - Most important KPIs in the perspective of the pharmacy

Inventory value	0.084
OTIF	0.445
RUD	0.471
Inconsistency	**0.003**

"RUD" and "OTIF" scored the highest in the pharmacists' perspective, scoring 0.471 and 0.445, respectively. "Inventory value" isn't significant (score of 0.084) since the pharmacies generally work in a JIT basis which is confirmed in table 4.37. Additionally, most of the products are totally reimbursed if not sold. Inconsistency value equals 0.003 meaning it is acceptable.

Table 4.37 - Most important management practices in the perspective of the Pharmacy

JIT	0.741
Promoting the ability…	0.146
Promoting visibility…	0.112
Inconsistency	**0.000**

"JIT" is the most important practice for the pharmacies, with a score of 0.741. JIT supply is possible since the wholesaler supplies the pharmacies up to three times a day with no additional costs (as long as the product is available). Generally JIT supply is implemented, for almost all products, whether they are standard, innovative or hybrid (figure 4.2 and figure 4.3). Only cheap products or products with promotions offered by wholesalers may be supplied in large quantities, as can be confirmed from figure 4.3. "Promoting the ability to change deliver dates and/or quantities" remains quite insignificant (score of 0.146), since this practice is already implemented through a common information system linked to the wholesalers, where the pharmacy can enter the amount of product to be ordered. This input in the information system can also be altered as long as the order hasn't been expedited yet. "Promoting the visibility throughout the SC" is the least important practice (score of 0.112), since enough visibility is already provided in the perspective of the pharmacies. For instance, in the

common information system the pharmacy is able to see the inventory level of the wholesaler, regarding all products.

Figure 4.2 shows the statistics of the orders (red) and sales (green) from the past 12 months considering a standard product to treat cholesterol problems named Zarator. As observed, the quantity ordered equals the quantity sold (with a few exceptions). It means that the pharmacy only orders more product when a respective unit is sold, meaning it is a pure JIT supply. In addition, the blue line represents the safety stock, which remains more or less ate the same level across time (4 units). This pharmacy (Allegro) is considered a pharmacy with a large sales volume, due to its location, so almost every product is available. In many pharmacies, there are a lot of products where the supplying is on a make-to-order (MTO) basis, i.e. the pharmacy only orders the product when it's requested by the patient. As can be observed, the product is sold on a constant basis, which is indeed a characteristic of a standard product.

Figure 4.3 shows an example of JIT supply considering an innovative product (Livazo) designed for the same purpose of a standard one (Zarator), i.e. to treat high cholesterol.

Figure 4.3 shows that the product is also supplied on a JIT basis, which is expectable considering the delivery services provided by the wholesalers (three times a day). Hence, whether it was a standard or an innovative product, the supply strategy adopted by the pharmacies remains the same. The only difference observed when comparing the innovative product with the standard one, is related with its demand, which in this case isn't constant.

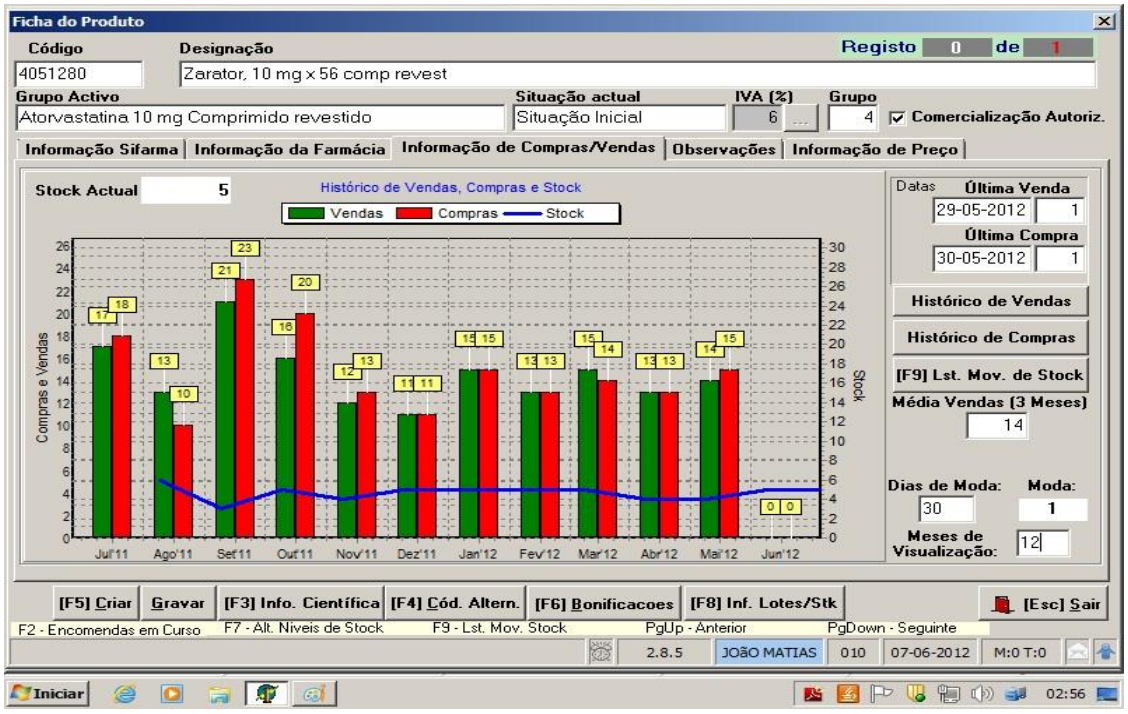

Figure 4.2 - JIT supply example considering a standard product

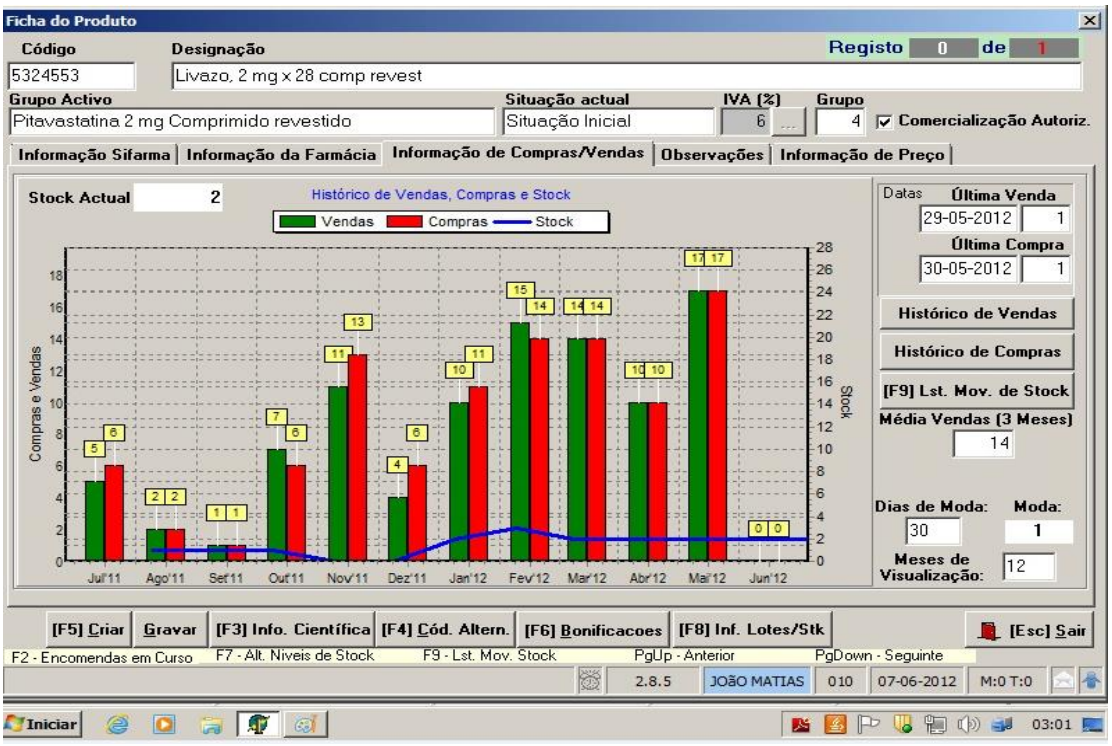

Figure 4.3 - JIT supply example considering an innovative product

Furthermore, figure 4.4 shows an example of a product bought in large quantity due to a discount or simply because the product has a low price and huge demand over the year. Some product may also be acquired in bigger quantities due to the products being seasonal, e.g. flu shots.

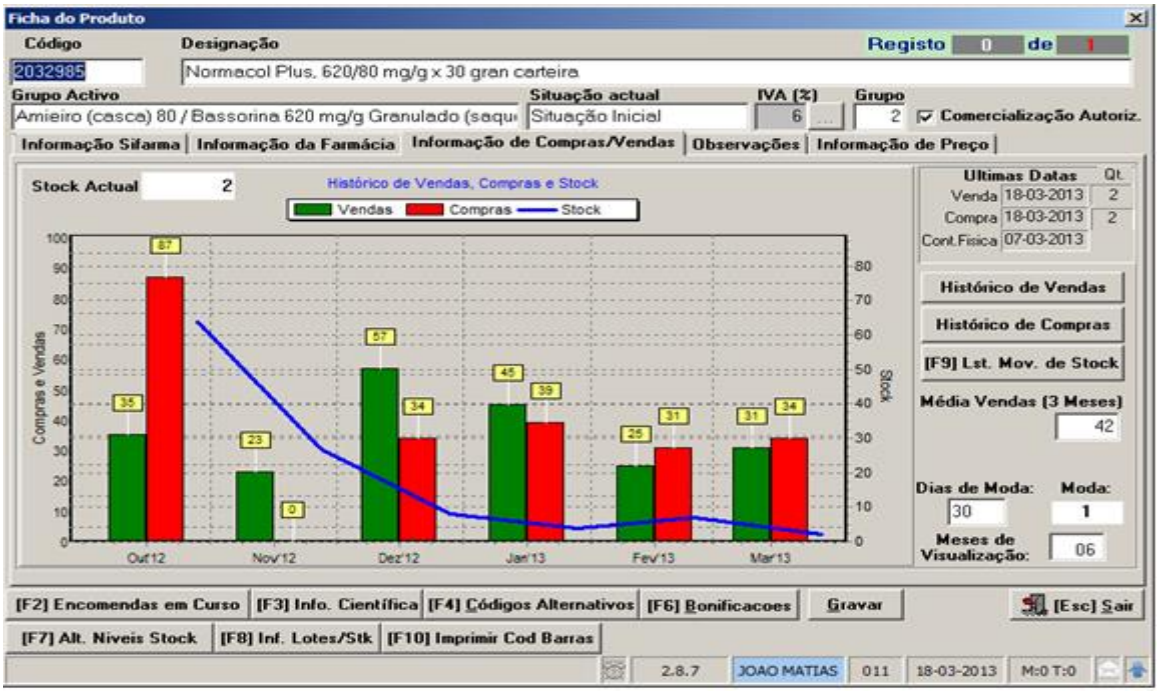

Figure 4.4 - Example of a product that is occasionally supplier in large quantities

It can be observed from figure 4.4, that in October 2012, the product was supplied in a large quantity (87 units) due to a discount provided by the wholesaler. However, this practice is only related with products were demand is high.

Table 4.38 illustrates the importance of each one of the SCM paradigms to the pharmacies.

Table 4.38 - Most important SCM paradigm in the perspective of the Pharmacy

Agile	0.309
Lean	0.691
Inconsistency	**0.000**

Lean is the most important management paradigm for the pharmacies, with a score of 0.691. That is mostly due to the clear relation of Lean with waste reduction and low inventory levels.

4.4 Determining the score for each element

In order to obtain the final priorities for the alternatives, the previously determined pairwise comparisons are used as inputs in the formation of the supermatrix structure. The method can be reviewed in section 2.1.6.2.1.

The un-weighted supermatrix, weighted supermatrix and limit matrix are calculated by the Super Decisions software (v.2.0.6 beta)[17]. Afterwards, the respective columns are normalized and final priorities obtained, as illustrated in figure 4.5.

[17] Super Decisions v. 2.0.6. had to be used in order to obtain the experimental priorities because the newest version doesn't provide that functionality any longer. All relative weights of the ANP model remain the same when calculated with the older version.

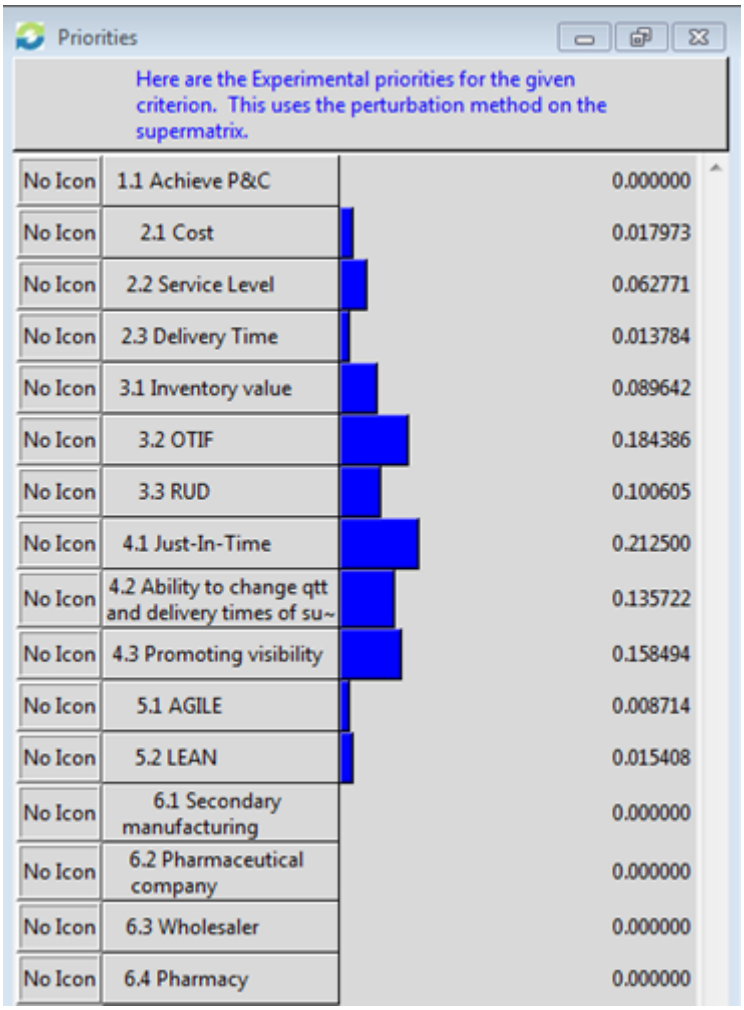

Figure 4.5 - Experimental final priorities for the ANP model

The next section handles the discussion of the results with respect to the final priorities of the elements in the ANP model.

4.5 Discussion of the results of the model

4.5.1 Global anaysis

Figure 4.5 shows the global final priorities for the elements. When analyzed globally, the management practices are clearly the most important elements in the SC, followed by the KPIs. Hence, "Just-In-Time" management practice is the most important element within the SC (score of 0.213). Interestingly, the KPI "On-Time-In-Full delivery (OTIF)" was considered more important in the experts' perspective than the other KPIs, with a score of 0.184. "Promoting visibility throughout the SC" was considered the third most important element involved in the model, with a score of 0.158, followed by "Promoting the ability to change dates and/or quantities" of suppliers' orders scoring 0.136. The other two KPIs, "Responsiveness to Urgent Deliveries (RUD)" and "Inventory value" were the next most important elements, scoring 0.101 and 0.090, respectively. Service level scored 0.063,

being the most important of the competitive priorities. Cost and delivery time remained insignificant as well as the lean and agile SCM paradigms.

The experts clearly consider important to focus on the implementation of the management practices and measure them properly with the appropriate KPIs as means of improving performance and competitiveness in the SC, namely by implementing JIT practices and delivering products on time and in the right quantity and therefore maintaining the ideal inventory levels. Interestingly, the agile SCM paradigm obtained a lower score than lean, but service level was given significantly more importance than cost. This goes against the theoretical basis were the lean SCM paradigm is considers cost to be the market winner.

4.5.2 Analysis by cluster

The most important competitive priority in the model is service level, with a respective score of 0.0628, followed by cost, which scores narrowly higher than delivery time, 0.0180 and 0.0138, respectively. Hence, the companies must emphasize the customers' needs in terms of delivering products at the right time in the right quantity. In the pharmaceutical industry service level is crucial, due to the nature of the industry, i.e. if a patient is sick, the drug must be available. If considering an automotive industry, service level is also important but the end-customer can wait a certain period before getting his product, meaning it is not a life or dead situation. If a high service level is achieved, the companies' second highest priority is to reduce costs, considering that the delivery times aren't that long either.

When it comes to the KPIs, "OTIF" has the highest score (0.184) in terms of importance in the SC. Furthermore, it is consistent with the fact that service level is the most important competitive priority. However, "OTIF" is more than two times more important than service level. That is due to the fact that "OTIF" is much more specific than service level. The cluster pair-wise comparisons also evidence that the sub-criteria cluster is more important than the criteria cluster. Moreover, the second most important KPI is "Responsiveness to urgent deliveries" with a score of 0.101, followed by inventory value which scored 0.090. "Responsiveness to urgent deliveries" still remains quite significant due to many exceptional demands made by the different entities. In addition, it is clearly related to the agile SCM paradigm and is also an important KPI to measure the implementation of management practices, namely JIT. Despite the inventory value being significant, it is the least important, since the pharmacies work in JIT and the pharmaceutical companies don't control their inventory levels in Portugal.

When it comes to the management practices, "JIT" obtained the highest score (0.213) meaning it's considered to be the most important practice in the pharmaceutical SC distribution, according to the experts. Interestingly, JIT is considered the most important practice and cost the least important

competitive priority. Normally JIT and cost are linked together, meaning if JIT is considered important the cost has to be too, i.e. companies strive to reduce costs through implementing JIT. However, in this case the explanation is that the present case study deals only with the distribution part of the chain, meaning products have to be delivered on-time in the right quantity no matter what the cost is, through the implementation of JIT delivery (in the perspective of the end-customer). As expected, "Promoting visibility throughout the SC" is ranked the second most important management practice, with a score of 0.158. Clearly, visibility is an important asset when implemented correctly. It permits the companies to organize their respective procurement to keep up with the demand without stock-outs and thus, achieve an effective management of their SC. "Promoting the ability to change quantity and delivery times (of suppliers') orders", had the lowest score (0.136). Despite having the lowest score, it still remains almost as significant as the practice of "Promoting visibility throughout the SC".

Finally, Lean was considered the most important SCM paradigm, with a corresponding score of 0.015. The Agile SCM paradigm scored 0.009. This clearly indicates that the distribution part of the SC isn't efficient enough and that non-value adding processes must be continuously eliminated from the downstream part of the SC resulting in a highly efficient distribution system.

5. Conclusions and recommended future work

Supply Chain Management (SCM) has proved to be a crucial asset for Supply Chains (SCs) to be able to compete against each other in this highly volatile and competitive marketplace. The appropriate way of thinking is on the basis of success for the companies, and thus, for the SCs. The objective of the dissertation was to assist managers of the entities of the Supply Chain (SC) with management issues and strategies. The analyzed Analytic Network Process (ANP) model permits the selection of the most important competitive priorities, Key Performance Indicators (KPIs), management practices, and finally the SCM paradigm for the case study SC.

Just-In-Time (JIT) is clearly still the most important element for the pharmaceutical SC and for its respective distribution. Many processes need to be optimized in order to concentrate efforts in new challenges and new improvements, namely visibility.

Collaboration and thus, visibility throughout the SCs is given a strong emphasis in the literature, for companies willing to perform and compete in the marketplace. The ANP results analysis proved that although visibility is an important asset in SCs it is not the most important one. There are clearly entities in the SC willing to promote visibility in order to improve the SC competitiveness, but also many barriers are identified, mostly on behalf of the wholesalers. Lack of trust and unwillingness of information sharing by the wholesalers are clearly some of those barriers. However, some improvements are identified for that matter, and the pharmaceutical companies believe that the future will bring improvements.

The competitive priorities were not given an importance as strong as expected, but service level was still considered to contribute significantly for achieving performance and competitiveness of the case study SC. Thus, companies must focus on the customers' needs in terms of delivering the products on time and in the right quantity.

The Key Performance Indicator (KPI) On-Time In Full (OTIF) delivery was given almost two times the importance of the service level, being the most important of the KPIs and the second most important element in the model. The expectation was for OTIF to be more important than service level, due to a more precise definition given by the different entities of the SC. Indeed, the results proved to be consistent with these expectations.

The SCM paradigms were given the least important cluster by the experts. Still, lean was considered to be (narrowly) the most important paradigm. It means that efficiency must be emphasized in the distribution part of the SC.

With the contribution of this dissertation, SC managers are able to evaluate the most important characteristics in the pharmaceutical industry, as means of turning the SC into a more competitive and more efficient one and consequently overcome the perceived difficulties.

When comparing the results of the pharmaceutical industry with the ones obtained by Cabral et al. (2011) in the automotive industry, some annotations are made.

In the automotive industry, Agile was considered more important than Lean, as opposed to the pharmaceutical industry. One of the reasons is that in the focal company of that SC, the processes were already so optimized that the need to implement the lean philosophy wasn't so high. The service level was considered the most important competitive priority in both industries, leaving cost as the least important one. Order fulfillment rate can be compared to On-Time-In-Full delivery, being both considered the most important KPIs in their respective industries. Hence, stock-out must be prevented in both industries. In the automotive case, it is absolutely crucial for its suppliers to deliver the right products (parts) in order to prevent production from stopping and thus, lowering the facilities high utilization rate. In the pharmaceutical industry it is important that the patients have their drugs on time not only to get cured, but also not to opt for another product from another manufacturer.

Some limitations are observed in the dissertation. For instance, if more experts at each level of the SC would have responded to the questionnaires, the results may have changed significantly due to different evaluations made by different experts within the entities belonging to the case study SC. Although the number of responses is considered acceptable, it does not necessarily mean that it is consistent. The more responses one can obtain at each level of the SC, the more consistent the study gets. Therefore, this limitation in the study leads to the first future work recommendation, which is to obtain a more consistent evaluation basis, meaning more experts from each entity could respond to the questionnaires in order to get a high percentage of validity in the study. If a large number of responses is obtained also a proper statistical analysis could be made, i.e. detect the respective outliers in the evaluations. That would reduce the variation in the judgments and consequently correspond more to reality. In addition, a sensitivity analysis should have been performed in order to test the validity intervals of the judgments made by the experts. The sensitivity analysis couldn´t be performed due to incompatibility of the Super Decisions software versions. The older version (v.2.0.6 beta) used to obtain the global priorities does not permit a sensitivity analysis. In turn, the newer version (v.2.2.6 beta) does not permit the calculation of the global priorities. In addition, each level of the SC should have its respective elements in each cluster, in order to properly analyze the best alternatives for each entity.

A few future work recommendations for academics and researchers alike were made in the following.

It would be interesting for researches to measure the actual leanness of the companies that claim lean SCM paradigms to be the most important. The same goes for the agile SCM paradigm. The measurements are proposed in this dissertation in sections 2.1.2.3 and 2.1.3.3.

In order to expand validations, it would be interesting to include more KPIs and management practices, namely the ability to introduce new products. Additionally, inner dependencies of all clusters where such are detected could also be included in the model, as means of studying an entirely real model.

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Annex I – Questionnaire designed for Novartis Farma

Please assign only one answer per row/question.

1. The following questions intend to evaluate the most important competitive priorities with respect to achieving performance and competitiveness of the Supply Chain (SC) in the pharmaceutical industry.

Considering the Performance and Competitiveness of the SC, which is the most important competitive priority?		**Evaluate the degree of importance when comparing the most important competitive priority with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Cost ☐	Delivery time ☐	☐	☐	☐	☐	☐
Cost ☐	Service level ☐	☐	☐	☐	☐	☐
Delivery time ☐	Service level ☐	☐	☐	☐	☐	☐

2. The following questions intend to evaluate the influence of the competitive priorities on each other.

Which is the competitive priority that influences Cost the most?		**Evaluate the degree of importance when comparing the most important competitive priority with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Delivery time ☐	Service level ☐	☐	☐	☐	☐	☐

Which is the competitive priority that influences Delivery time the most?		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Cost ☐	Service level ☐	☐	☐	☐	☐	☐

Which is the competitive priority that influences Service level the most?		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Cost ☐	Delivery time ☐	☐	☐	☐	☐	☐

3. The following questions intend to evaluate the most important Key Performance Indicators in influencing the competitive priorities

In order to measure <u>Cost</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

In order to measure <u>Delivery time</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

In order to measure <u>Service level</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

4. The following questions intend to evaluate the importance of the Key Performance Indicators in the management paradigms.

In the context of the Lean management paradigm, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

In the context of the Agile management paradigm, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

5. The following question intends to evaluate the importance of the Key Performance Indicators in the perspective of Novartis.

In the perspective of Novartis, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

6. The following questions intend to evaluate the importance of the Key Performance Indicators in measuring the impact of implementation of the management practices.

In order to measure the impact of implementation of the management practice <u>Promoting visibility throughout the SC</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

In order to measure the impact of implementation of the management practice <u>Just-In-Time</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

In order to measure the impact of implementation of the management practice <u>Promoting the ability of changing the delivery dates and/or quantities of the suppliers order</u>, which is the most important Key Performance Indicator?		**Evaluate the degree of importance when comparing the most important Key Performance Indicator with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Percentage of on-time deliveries in the right quantity ☐	Inventory value ☐	☐	☐	☐	☐	☐
Percentage of on-time deliveries in the right quantity ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐
Inventory value ☐	Responsiveness to urgent deliveries ☐	☐	☐	☐	☐	☐

7. The following question intends to evaluate the importance of the management paradigms in the perspective of Novartis.

In the perspective of <u>Novartis</u>, which is the most important management paradigm?		**Evaluate the degree of importance when comparing the most important management paradigm with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Lean ☐	Agile ☐	☐	☐	☐	☐	☐

8. The following questions intend to evaluate the importance of the competitive priorities in measuring the impact of implementation of the management practices.

When considering <u>Cost</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

When considering <u>Delivery time</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

When considering <u>Service level</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

9. The following questions intend to evaluate the importance of the management practices in improving the values of the Key Performance Indicators.

Considering the <u>Percentage of on-time deliveries in the right quantity</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

Considering the <u>Inventory value</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

Considering the <u>Responsiveness to urgent deliveries</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

10. The following questions intend to evaluate the impact of implementation of the management practices in the perspective of Novartis.

In the perspective of <u>Novartis</u>, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

11. The following questions intend to evaluate the importance of the management practices in the management paradigms.

In the context of the <u>Lean</u> management paradigm, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

In the context of the <u>Agile</u> management paradigm, which is the most important management practice?		**Evaluate the degree of importance when comparing the most important management practice with the least important.**				
		Equal importance	Moderate importance	Strong importance	Very strong importance	Extreme importance
Promoting visibility throughout the SC ☐	Just In Time ☐	☐	☐	☐	☐	☐
Promoting visibility throughout the SC ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐
Just In Time ☐	Promoting the ability of changing the delivery dates and/or quantities of the suppliers order ☐	☐	☐	☐	☐	☐

Annex II – Additional information of Lusomedicamenta

A guided visit was made into the company's warehouse, meaning that this entity will be described with more detail in the present annex.

When entering the warehouse, immediately the first thing to appear is the reception and expedition areas, which are side to side as can be observed in figure II.1. All sections are organized by aisles and there´s separated sections for finished products, components and semi-finished products.

Figure II.1 - Reception and expedition area

The warehouse is also divided into an internal (Figure II.2) and external area, where products are either set for the Portuguese market or the worldwide market, respectively. The internal area size is proportional to the percentage of products destined to the internal market, meaning it´s pretty small and works with a *kanban* system. In addition, there´s an appropriate area for refrigerated products and inverse logistics.

Figure II.2 - Internal area (PT)

Pallets are stored in single-deep racks with five levels and they´re in compliance with the respective norms. For instance, pallets are heat-treated as a means to prevent toxic substances to be released.

II.1 Management

Most of the company's clients have established lead-times enhancing confidence and trust between entities. The respective lead-times can vary from 7 weeks to 6 months.

The company can be considered flexible, as it has an ability to create a third shift in about 3 weeks. However, the respective shift is only made capable for small volumes.

In some cases the company works as a pre-wholesaler, i.e. deals directly with the customers´ customer. Yet, this is a rare practice due to lack of trust and confidence between entities.

The laboratory and the logistics department (warehouse) work both in the most efficient way possible. In order to have better performance levels, the machinery is the most sophisticated possible and its setups are optimized resulting in higher efficiency. Thus, setups are determined based on the orders, which are prioritized depending on the customers.

Just-In-Time (JIT) practices cannot be implemented due to limitations regarding the raw material supply, i.e. the supply of the active ingredients. This is consistent with Lu et al. (2010), who claims that Lean Supply Chains (SCs) are highly dependent on external resources.

II.2 Manufacturing

When a component/product arrives at the warehouse, it enters the reception area. Afterwards, it´s assigned by the system with a location in one of the aisles, in a certain position. The assignment

includes batch code, location, volume, danger level, lead times amongst other important data related with the product.

Once the product is given an order to proceed to the production (according to the right sequence), it´s weighted and transported to the manufacturing area through the elevator shown in figure II.3.

Figure II.3 - Elevator leading to manufacturing area

Manufacturing operations have become more refined, e.g. in March of 2011 the company used 2000 extra hours to meet the demand, while in March of 2012 it used only 200 extra hours to meet the same demand (Source: Logistics manager of Lusomedicamenta).