**UNIVERSIDADE DE SÃO PAULO**
**ESCOLA DE ENGENHARIA DE SÃO CARLOS**
**DEPARTAMENTO DE ENGENHARIA DE PRODUÇÃO**

# ANÁLISE DE DESEMPENHO DA GESTÃO ENXUTA E ÁGIL DA CADEIA DE SUPRIMENTOS

*Trabalho de Conclusão de Curso II realizado sob a orientação do Prof. Fernando César Almada Santos da Universidade de São Paulo e Prof. Dr. Sebastian Bertsch da Leibniz Universität Hannover.*

Marcos Vinícius Guimarães Gandra
Orientador: Prof. Dr. Fernando César Almada Santos (USP)
Prof. Dipl.-Wirtsch.-Ing Sebastian Bertsch (LUH)
Prof. Dipl.-Wirtsch.-Ing. Sebastian Beck (LUH)

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**UNIVERSITY OF SÃO PAULO**
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**DEPARTMENT OF PRODUCTION ENGINEERING**

# PERFORMANCE ANALYSIS OF LEAN AND AGILE SUPPLY CHAIN MANAGEMENT

Marcos Vinícius Guimarães Gandra
Tutor: Prof. Dr. Fernando César Almada Santos (USP)
Prof. Dipl.-Wirtsch.-Ing Sebastian Bertsch (LUH)
Prof. Dipl.-Wirtsch.-Ing. Sebastian Beck (LUH)

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## ABSTRACT

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The current market environment of global competition shows the necessity of more adapted management systems and strategies. Nowadays the companies must work together seeking the same goals and therefore the Supply Chain Management is widely employed. Nevertheless, there is not just one paradigm of SCM, but also several. This paper aims, from a broad literature review, to define, analyze and compare two of the main discussed and used paradigms, the lean SCM and the agile SCM. Its originality comes from the deep performance analysis employed, through several metrics and over five fields of performance proposed by Gunasekaran *et al.* (2001): Plan, Source, Production, Delivery and Customer & Service Satisfaction. Thus, this study gives a better understanding and a broader picture of lean and agile SCM and expects to provide a theoretical contribution to this subject still little explored.



Keywords: *Supply Chain Management; Performance Analysis; Agile Supply Chain; Lean Supply Chain*

## RESUMO

GANDRA, M. V. G. **Análise de desempenho da gestão enxuta e ágil da cadeia de suprimentos.** 2013. 58p. Trabalho de conclusão de curso - Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos. 2013.

O atual ambiente de mercado de grande competição global apresenta uma necessidade de sistemas e estratégias de gestão mais adaptados. Hoje em dia as empresas devem trabalhar juntas buscando os mesmos objetivos e dessa forma a Gestão da Cadeia de Suprimentos é amplamente utilizada. Contudo, não existe apenas um tipo de gestão, mas sim vários. Este trabalho visa, a partir de uma ampla revisão bibliográfica, definir, analisar e comparar dois dos mais discutidos e empregados tipos, a gestão enxuta e a gestão ágil da cadeia de suprimentos. A sua originalidade advém da profunda análise de desempenho aplicada, através de diversas métricas divididas por cinco campos de performance propostos por Gunasekaran *et al.* (2001): Planejamento, Fornecimento, Produção, Entrega e Satisfação do Consumidor. Assim, este estudo oferece uma melhor compreensão e uma mais ampla imagem da gestão enxuta e da gestão ágil, e espera dar uma contribuição teórica a este assunto ainda pouco explorado.



Palavras-chave: *Gestão da Cadeia de Suprimentos; Análise de desempenho; Gestão Enxuta; Gestão Ágil*

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# 1. Introduction

## 1.1. Problem Statement

The management thinking of an independent enterprise, with production, process and decisions centralized in one company with a traditional hierarchical organizational structure was famous and intensively used and applied during the last century, especially in the first half. However, with the growth of the internal and external competition, the increase of costumer's requirements and the necessity of a better use of resources, different types of management became necessary. (COOPER et al., 1997, p. 4)

Nowadays, the enterprise is not alone anymore. It is part of a complex structure composed of many companies and several processes. And in the modern business management the competition is no longer as individual business or solely autonomous entities, but rather within supply chains. "Business management has entered the era of inter-network competition" (LAMBERT, 1998). Thus, the Supply Chain Management became an important tool to manage and organize it.

However, as it may be seen in the practical field, in many cases not all the SCM tools and techniques are applicable. The reason for that lies in the fact that not all supply chains deal with the same customers, same products and same partners. And, therefore, in order to improve the performance of the supply chain management, different paradigms - that fits to the specifics environment where the company is inserted - .must be used and explored correctly

Furthermore, according to Gunasekaran *et al.* (2001) "measures and metrics are needed to test and reveal the viability of strategies without which a clear direction for improvement and realization of goals would be highly difficult." Thus, Gunasekaran *et al.* (2001) proposes metrics to analyze the performance of SCM on five different fields: Plan Performance, Source Performance, Production Performance, Delivery Performance and Customer Service and Satisfaction.

There are not so many works, which analyze the performance of different paradigms of Supply Chain Management. Besides, the literature exhibits a mismatch between two of the main paradigms: Lean and Agile. (GATTORNA et al., 2009)

In order to clarify and give a broader view of them, this work seeks to evaluate and analyze two of the main paradigms of management of a supply chain: Lean and Agile Supply Chain Management.

### 1.2. Objective

This essay is a theoretical approach, which aims to develop a theoretical construct on the Supply Chain Management literature based on published materials such as books and papers.

This Final Project Work seeks to explore the interesting researching field of Supply Chain Management. The objective is to identify, discuss and evaluate two different paradigms of Supply Chain Management: Lean and Agile.

First, it was realized a Literature Review in depth, which presents the definition and framework of SCM that was the reference for this study.

There are several works in the literature regarding different paradigms of SCM without a consensus of which is the basis model of each paradigm, especially the Lean and Agile approaches. So the next step was the identification and exhibition of two types of Supply Chain Management (SCM) proposed by Gattorna et al. (2009) for Lean and Agile SCM, which was used as groundwork for this essay.

In the last part of the Literature Review, it presents the framework for evaluation performance in SCM Proposed by Gunasekaran et al. (2001). This phase aims to define the evaluation's process and the metrics. It guides this essay.

In order to produce a clearer view of these two types of SCM, the next part of the essay analyzes the performance of these two main types of SCM under five fields proposed by Gunasekaran et al. (2001): plan, source, production, delivery and customer service & satisfaction. And in the last part, it was realized a discussion about the findings in the essay.

### 1.3. Study design

This topic describes the structure of this study. The essay is divided into 8 Chapters: Introduction; Management Components of Supply Chain Management; Lean Supply Chain Management; Agile Supply Chain Management; Performance Analysis of Supply Chain Management: Proposal of Metrics; Performance Analysis of Lean Supply Chain Management; Performance Analysis of Agile Supply Chain Management; Conclusions.

Chapter 2, called Supply Chain Management: Overview, presents a review of the relevant literature of Supply Chain Management.

Chapter 3 and Chapter 4 present, respectively, a literature review of Lean and Agile Supply Chain Management.

Chapter 5 contains the proposal of metrics, which was further applied on the analysis and discussions.

Chapter 6 and 7 show the evaluation of performance of Lean and Agile SCM, respectively.

Chapter 8 presents the conclusions based on the studies and results of this project.

## 2. Supply Chain Management: Overview

### 2.1. Supply Chain: Definition and Framework

Before understanding the Supply Chain Management, it is important to understand and define the Supply Chain and its structure. As Mentzer *et al.* (2001) noted the definition of Supply Chain (SC) is common across the authors. Thus, we use the definition proposed by him: "a **supply chain** is defined as *a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer*" (MENTZER *et al.*, 2001, p.4). Figure 1 shows a view of the supply chain network structure is proposed by Lambert, Cooper and Janus (1998).

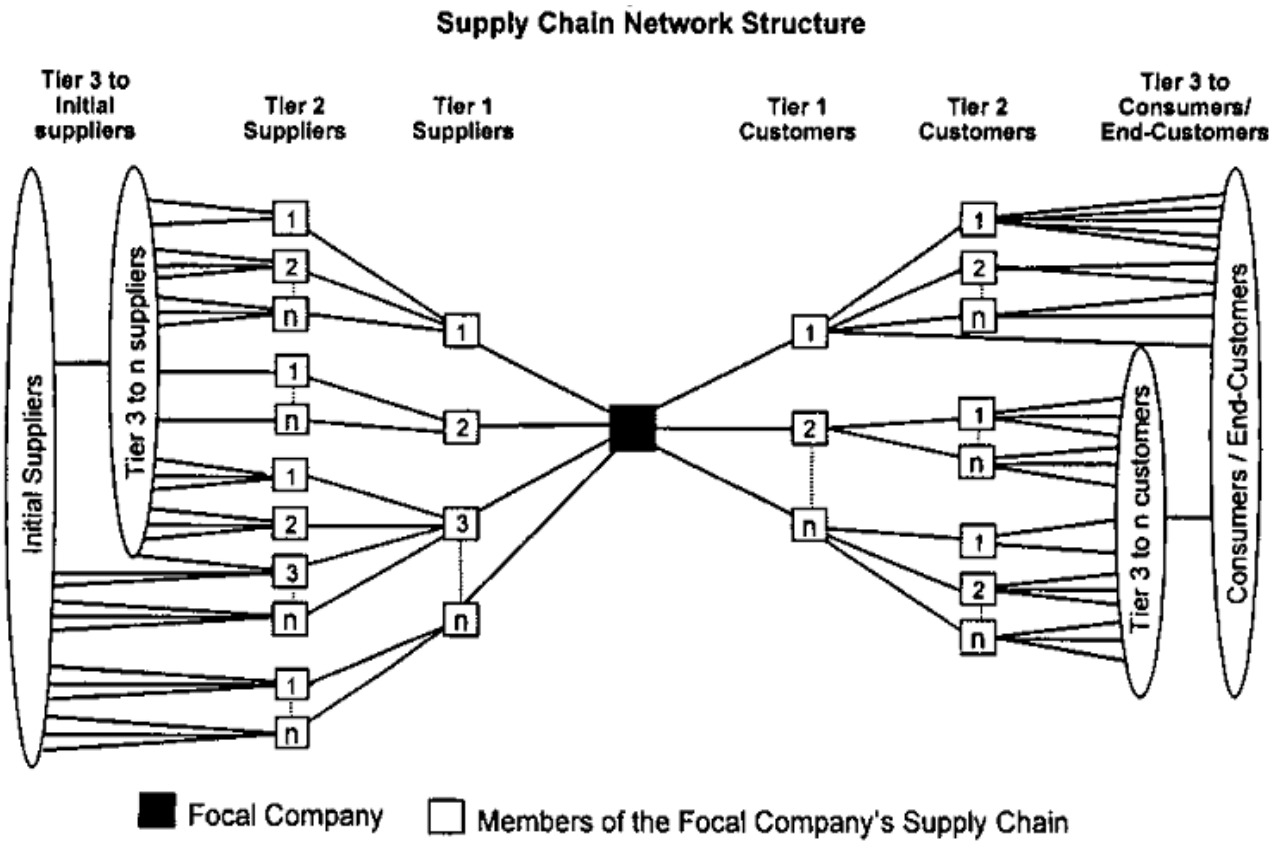


Figure 1 - Supply Chain Network Structure – Source: LAMPERT; COOPER; JANUS, 1998.

The structures of a supply chain diversify from each supply chain or product production. To clarify it, Mentzer *et al.* (2001) identify three degrees of supply chain complexity: a "direct supply chain," an "extended supply chain," and an "ultimate supply chain", as shown in Figure 2. All of the three involve the upstream and/or down-stream flows

of products, services, finances, and/or information. The main difference is the number of suppliers and customers involved. The “direct supply chain” considers only the first supplier and customer; the “extended supply chain” considers also the immediate suppliers and customers; and the “ultimate supply chain” has a wider view, including all organizations involved, besides the immediate supplier and customers, like financial providers, stakeholders and third party suppliers.

Figure 2 shows the structure of a supply chain can reach a high level of complexity, with several organizations involved in different stages. Furthermore, one organization can have different roles in different supply chains. It can be supplier in one and costumer in another stage. This variety will occur according to the product or service resultant of the supply chain.

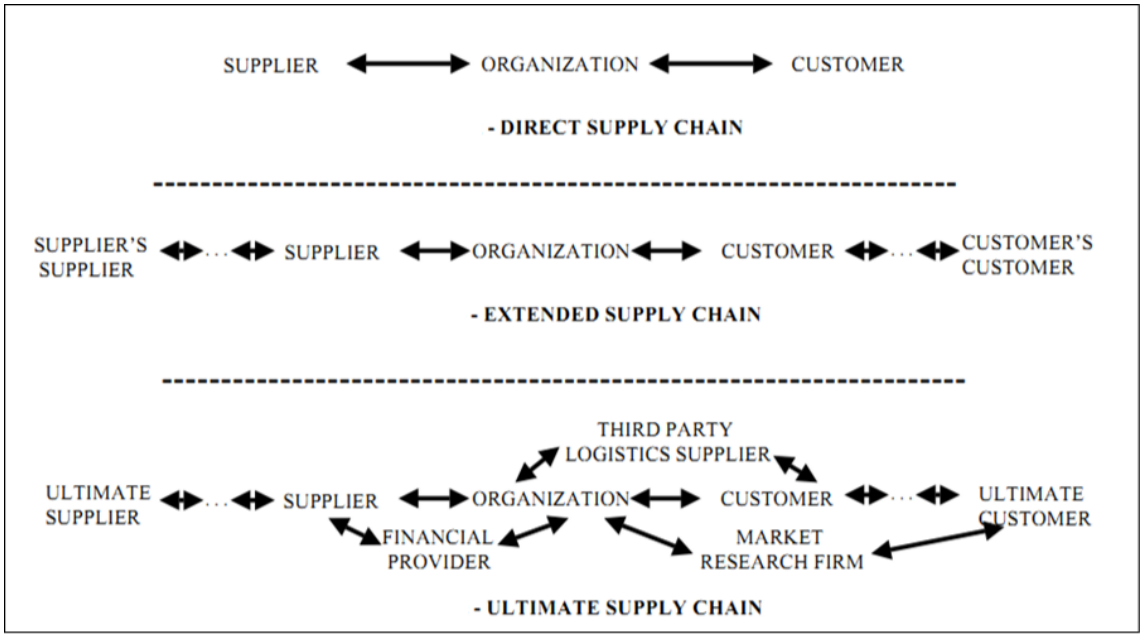


Figure 2 – Types of Channel Relationships – Source: MENTZER et al., 2001.

### 2.2. Supply Chain Management: Definition

The manufacturing industry must aim to create wealth by adding value and selling products. In all manufacturing companies, there is a need to control the flow of material from suppliers to customers, creating and adding value throughout processes and distribution channels. Thus, it becomes a necessity for a better planning, coordinating and controlling of all the process involved in a Supply Chain (STEVENS, 1989).

Nevertheless, Ballou (2006) explains that the concept of Supply Chain Management (SCM) and its theory experienced a long and progressive process of evolution, as Figure 3 shows. Before the 1950s, logistics was thought of in military terms and it was fragmented in activities such as transportation and purchasing, with low attempt to integrate and balance them.

In the 1960s, the logistics costs were high and represented an expressive portion of the national product. As consequence, two managerial areas received more attention: Physical Distribution and Business Logistics. Whereas the first had an outbound orientation (product flow), the second had an inbound orientation (management). However, with the limitations of theoretical basis and information systems, the focus was on coordinating the activities *within* the function and not among other functions or external focus. As result, in 1970s Logistics became a new field of study (BALLOU, 2006).

In the early 1980s, the term Supply Chain Management was introduced, creating a lot of discussion about its role and the Logistics role. Even so, as Cooper *et al.* (1997) argue, in the supply chain the business integration goes beyond the logistics field. A clear example of this is the product development that involves all the business aspects, such as Marketing, Research & Development, Manufacturing, Finance and Logistics of course.

As result, Logistics became a subset of SCM (Figure 3). Thus, the Council of Supply Chain Management Professionals (CSCMP) defines logistics to be:

> *"Logistics Management is that part of SCM that plans, implements, and controls the efficient forward and reverse flow and storage of goods, services, and related information between the point of origin and point of consumption in order to meet customer requirements."*

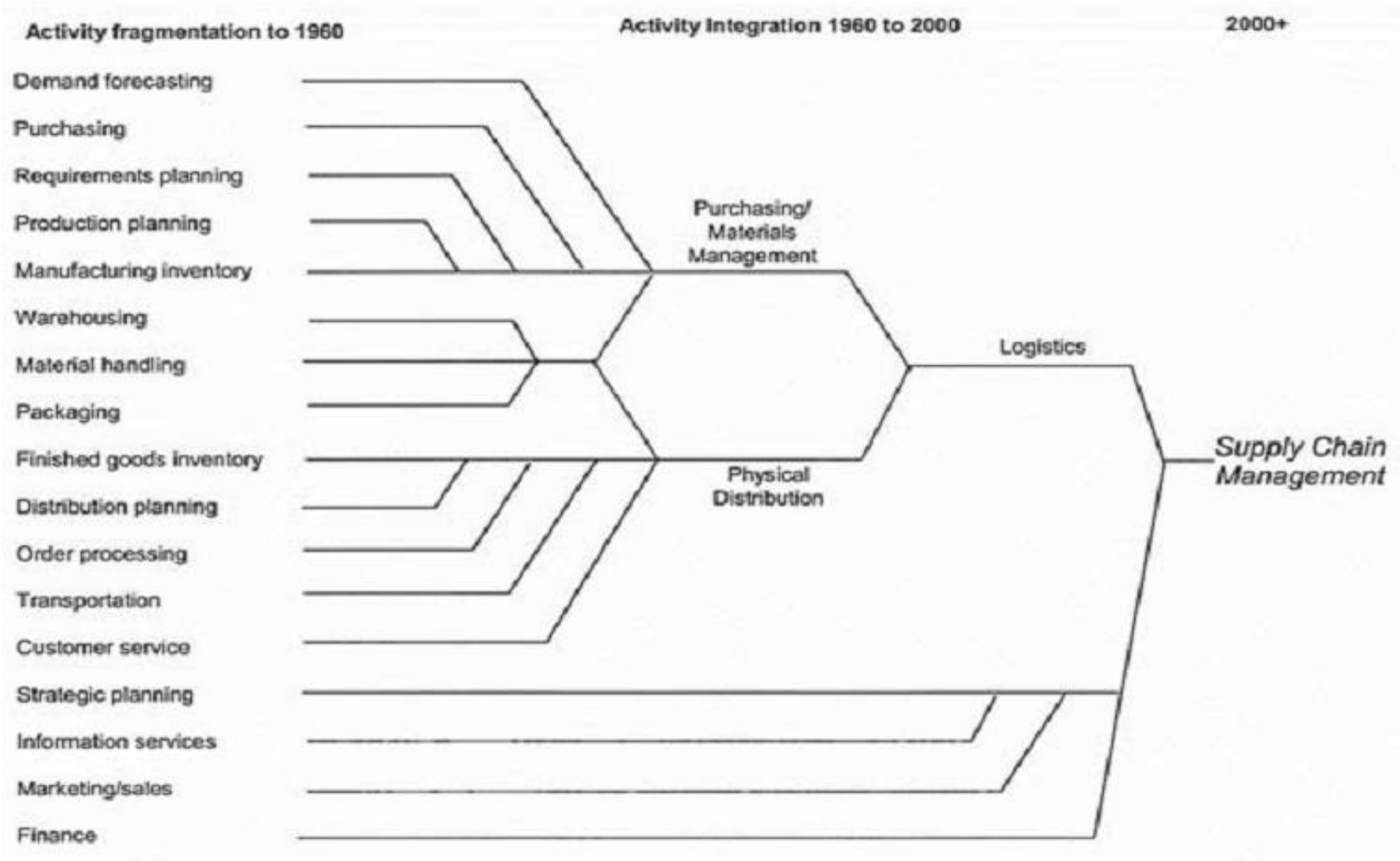


Figure 3 – Evolution of Supply Chain Management – Source: BALLOU, 2006.

On the other hand, there are many different definitions for Supply Chain Management and each one has a particular point of view (Table 1).

**Table 1 -DEFINITIONS OF SUPPLY CHAIN MANAGEMENT**

| | |
|---|---|
| Monczka, Trent, and Handfield (1998) | SCM requires traditionally separate materials functions to report to an executive responsible for coordinating the entire materials process, and also requires joint relationships with suppliers across multiple tiers. SCM is a concept, "whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers." |
| La Londe and Masters (1994) | Supply chain strategy includes: "... two or more firms in a supply chain entering into a long-term agreement; ... the development of trust and commitment to the relationship; ... the integration of logistics activities involving the sharing of demand and sales data; ... the potential for a shift in the locus of control of the logistics process." |
| Stevens (1989) | "The objective of managing the supply chain is to synchronize the requirements of the customer with the flow of materials from supplier." |
| Houlihan (1988) | Differences between supply chain management and classical materials and manufacturing control: "1) The supply chain is viewed as a single process. Responsibility for the various segments in the chain is not fragmented and relegated to functional areas such as manufacturing, purchasing, distribution, and sales. 2) Supply chain management calls for, and in the end depends on, strategic decision making. "Supply" is a shared objective of practically every function in the chain and is of particular strategic significance because of its impact on overall costs and market share. 3) Supply chain management calls for a different perspective on inventories which are used as a balancing mechanism of last, not first, resort. 4) Integration rather than interfacing." |
| Jones and Riley (1985) | "Supply chain management deals with the total flow of materials from suppliers through end users..." |
| Cooper et al. (1997) | Supply chain management is "... an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user." |

Table 1 - Definitions of Supply Chain Management – Source: MENTZER et al., 2001.

Mentzer *et al.* (2001) reviewed the Literature involving these definitions and proposed a broader definition that will be the reference for this essay:

> *"Supply Chain Management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole."*

### 2.3. Supply Chain Management: Implementation

Yet, Lambert, Cooper and Janus (1998) remember us that "It is a lot of easier to write a definition of Logistics or Supply Chain Management than it is to implement that definition".

Regarding the fundamental role of strategic coordination in SCM, Mentzer *et al.* (2001) examined the antecedents and consequences of SCM at the strategic level (Figure 4). They recognized the factors that enhance or impede the companies to achieve the Supply Chain Orientation, so called Antecedents. There are eight Antecedents highlighted by them:

- **Trust**, a willingness to rely on an exchange partner in whom one has confidence;
- **Commitment** of all partners is essential for a successful long-term relationship;
- **Interdependence**, to maintain a trust and sharing relationship with the partner to achieve the same goal;
- **Organizational compatibility**, complementary goals and objectives with the partner;
- **Vision**, management vision by the whole supply chain;
- **Key processes** defined in the whole supply chain;
- **Leader**, one company must assume this position to lead the supply chain;
- **Top management support** to shape the organization's values, orientation, and direction;

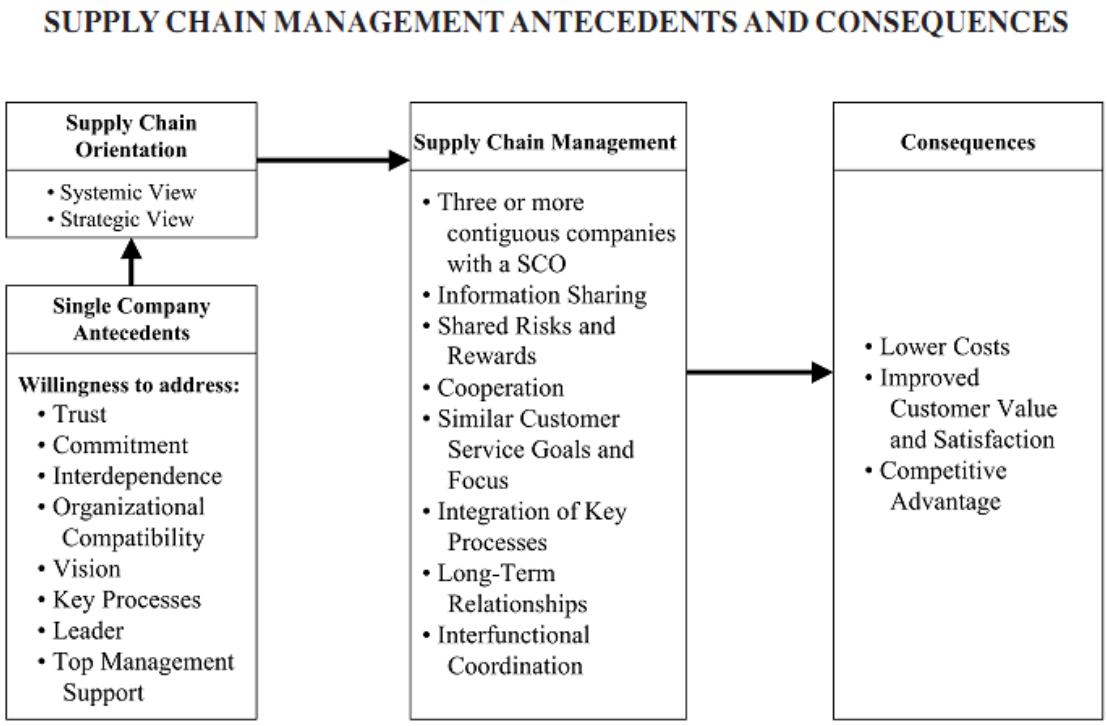


Figure 4 - Supply Chain Management Antecedents and Consequences – Source: MENTZER et al., 2001.

The Supply Chain Orientation (SCO) is developed by the organization that achieves a systemic and a strategic view of the implications of the tactical activities involved in managing the various flows in a supply chain. In other words, the organization can see the management and coordination of a supply chain from an overall system and strategic perspective.

If just the focal/leader enterprise has a SCO, we have an internal integration. But when not just the leader but all the key companies involved in a supply chain share the same willingness to fulfill these antecedents, then the supply chain has a SCO (a management philosophy). Finally, the implementation of all the principles ot the SCO, through management actions, across suppliers and customers is called supply chain management. And some of the consequences of SCM are lower costs and improved customer value and satisfaction to achieve competitive advantage (MENTZER *et al.*, 2001).

However, the implementation of this philosophy (SCO) is not an easy step. Therefore, the use of a reference model becomes as an interesting solution. So, in this essay, the Supply Chain Management framework developed by Cooper, Lambert and Pagh (1997) will be the reference. In their article, the three inter-related highlighted elements of SCM are: Supply Chain Network Structure; Business Processes; and Management Components (Figure 5).

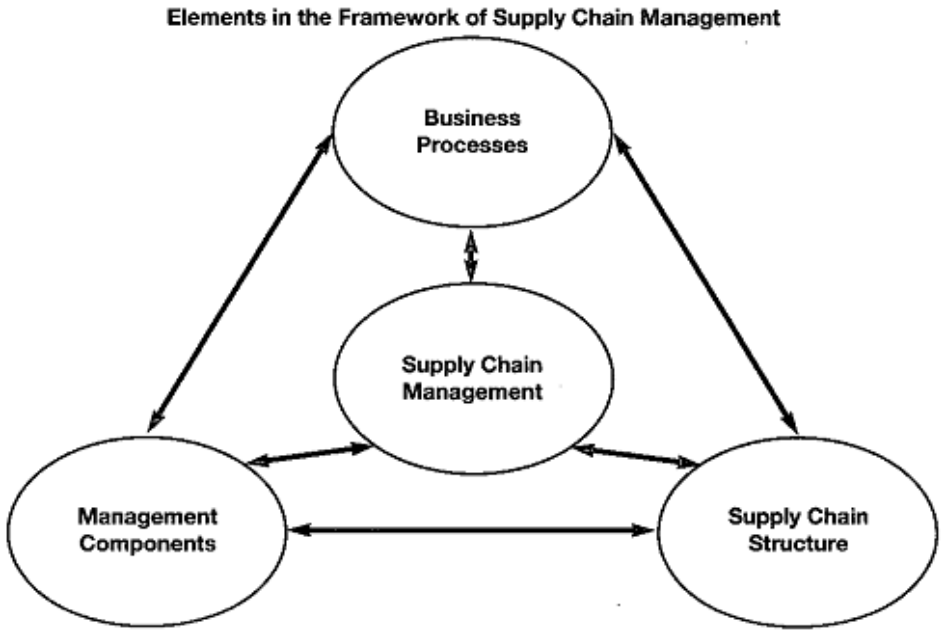


Figure 5 – Elements in the Framework of SCM – Source: COOPER, LAMBERT and PAGH, 1997.

The **Supply Chain Network Structure** is comprised of the firm members and the links between these firms (Figure 1). The organizations can be primary members, when they manage strategic activities or processes. Or supportive members, when just provide resources and knowledge to the SC. The links and the relationships vary according to the processes within the SC. Critical processes must be managed and monitored. Besides, the length and width in a Supply Chain Structure has direct relation with the number of tiers, suppliers and customers. (COOPER *et al.*, 1997; LAMBERT, 1998)

According to Davenport and Short (1990), the **Business Process** is a "set of logically related tasks performed to achieve a defined business outcome." This activity has clear inputs and outputs. It occurs intra and inter companies.

Thus, eight key business processes were identified that must be managed and implemented in a supply chain: Customer Relationship Management, Customer Service Management, Demand Management, Order Fulfillment, Manufacturing Flow Management, Supplier Relationship Management, Product Development and Commercialization, and Returns Management.

There are organizations designed "inside-out" to provide products and services. The *Customer Relationship Management* (CRM) changes the supply chain to have a clear focus on the customer, providing a new "outside-in" design. It identifies key customers and markets and involves the management of a long-term relationship of all SC with the customers,

providing the necessary information to maintain the focus on their requirements and needs. (LAMBERT, 1998; HOOTS, 2005)

With the outside-in CRM the "departments first understand the customer, and then move inward to operations. Within the context of customer-driven values, the systems and infrastructure capabilities needed to serve customers are developed." (HOOTS, 2005)

According to Lambert (1998) *Customer Service Management* is the "firm's face to the customer". It develops the necessary infrastructure and coordination for implementing the requirements defined in the CRM. The on-line information system is a fundamental tool. (BOLUMOLE *et al.*, 2003; LAMBERT, 1998)

*Demand Management* is the business process responsible for align and balance the customers' requirements with the capabilities in the supply chain. It synchronizes demand with production, procurement, and distribution capabilities in all supply chain, from the first key supplier to the point-of-sale. It requires a solid forecast and partners data that results in a more flexible and re- and pro-active SCM. (CROXTON *et al.*, 2002; COOPER *et al.*, 1997)

The *Order Fulfillment* is related with all the activities and processes involved to achieve the customers' requirements. It has a direct relation with the process's network and involves generating, filling, delivering and serving customers orders. The internal and external integration is pivotal for a smooth and seamless execution in all supply chain. (CROXTON *et al.*, 2003; LAMBERT, 1998)

As the other business processes, the *Manufacturing Flow Management* is concerned with the customers' requirements. It involves the management of the manufacturing activities aiming a more flexible manufacturing and the right mix of products, in order to have a fast response to the market. Again, the internal and external integration is pivotal. (GOLDSBY *et al.*, 2003; LAMBERT, 1998; COOPER *et al.*, 1997)

The *Supplier Relationship Management* (SRM) seeks a strategic collaboration with the suppliers, so that the company can develop new competitive products and efficient goods. Define the key suppliers and keep a close, long-term and strategic alliance with them is vital in SRM. The desired outcome is not a master-servant relationship, but a win-win relationship. (PARK *et al.*, 2003; LAMBERT, 1998)

According with Lambert (1998) "The *Product Development and Commercialization* is the supply chain management process that provides the structure for developing and bringing to market products jointly with customers and suppliers." It embraces Customer Relationship Management and Supplier Relationship Management in the research and development

department creating and promoting better, fast and responsiveness products, which are aligned with supplier, manufactory and customers. (COOPER *et al.*, 1997; LAMBERT, 1998)

Rogers *et al.* (2002) defined that "*Returns Managements* is that part of supply chain management that includes returns, reverse logistics, gatekeeping, and avoidance." It enables efficient flow management and creates opportunities to control and reduce returns and re-use elements, achieving a sustainable competitive advantage. The Returns Management must be considered in the R&D department. (ROGERS *et al.*, 2002; LAMBERT, 1998)

After identifying the Supply Chain Network Structure with its key members and links, and determining the key business processes that must be linked among companies, the next step is to determine the **Management Components** that is the third element of the SCM framework. They are critical and fundamental for the successful SCM, because they essentially integrate and manage each key business process link defined in the second element of the SCM framework. (MOBERG *et al.*, 2004; COOPER *et al.*, 1997; LAMBERT *et al.*, 1998)

According to Moberg *et al.* (2004), "the key element of SCM implementation is the set of management components that facilitate and manage integration among firms." Therefore, nine SCM management components were identified, which have been categorized into two groups: Physical & Technical and Managerial & Behavioral. The first one is composed by Planning and Control Methods, Work Flow/Activity Structure, Organization Structure, Communication and Information Flow Facility Structure, and Product Flow Facility Structure. The second is composed by Management Methods, Power and Leadership Structure, Risk and Reward Structure, and Culture and Attitude (Figure 6)

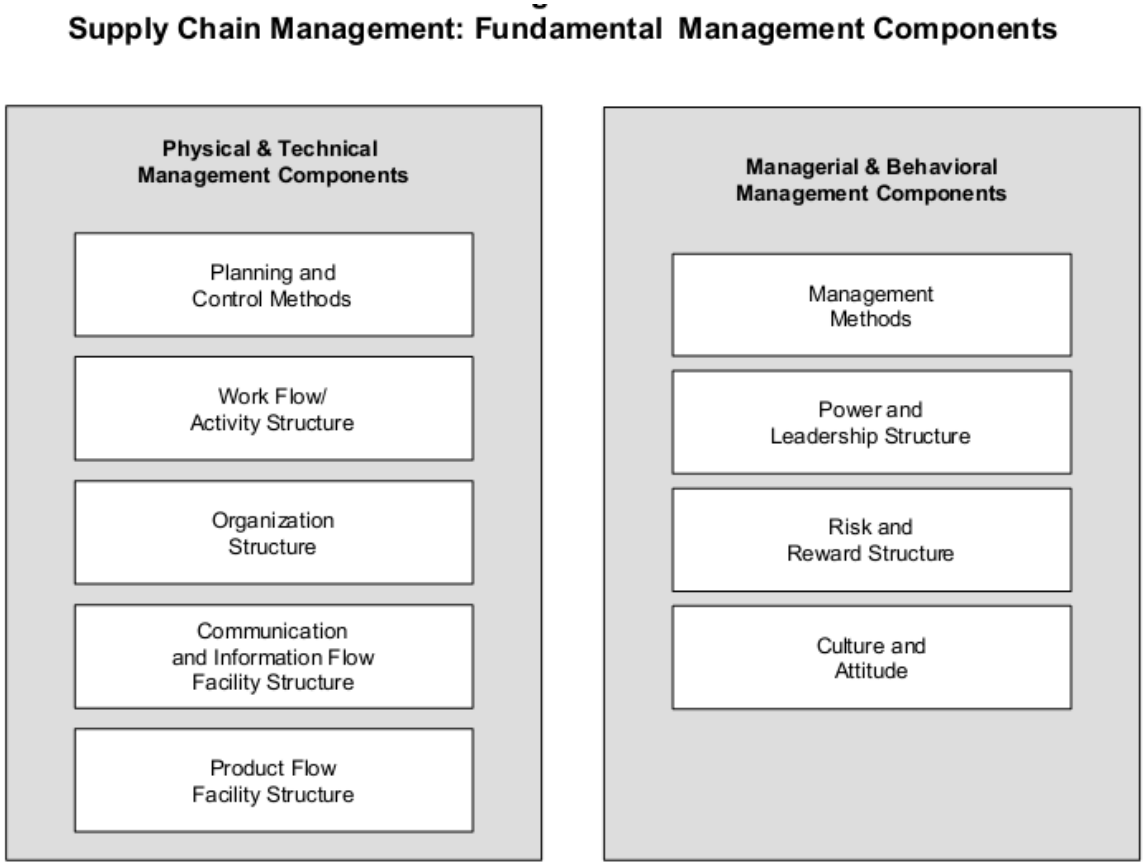


Figure 6 – Supply Chain Management: Fundamental Management Components – Source: LAMBERT, COOPER and JANUS (1998).

According to Lambert (1998), while Physical & Technical Management Components are visible, tangible, measurable and easy-to-change, and so are well understood and managed in the SCM. The second group, the Managerial & Behavioral Management Components is less tangible and visible, with a clear difficulty to be assessed and alter. And thus, difficultly understood and managed across the SC.

Finally, putting all the three elements of SCM framework together Cooper, Lambert and Janus obtained an illustration of how would be the Supply Chain Management (Figure 7). It simplifies the structure, the information and product flows, and the key business processes and also included the management components as the management tools.

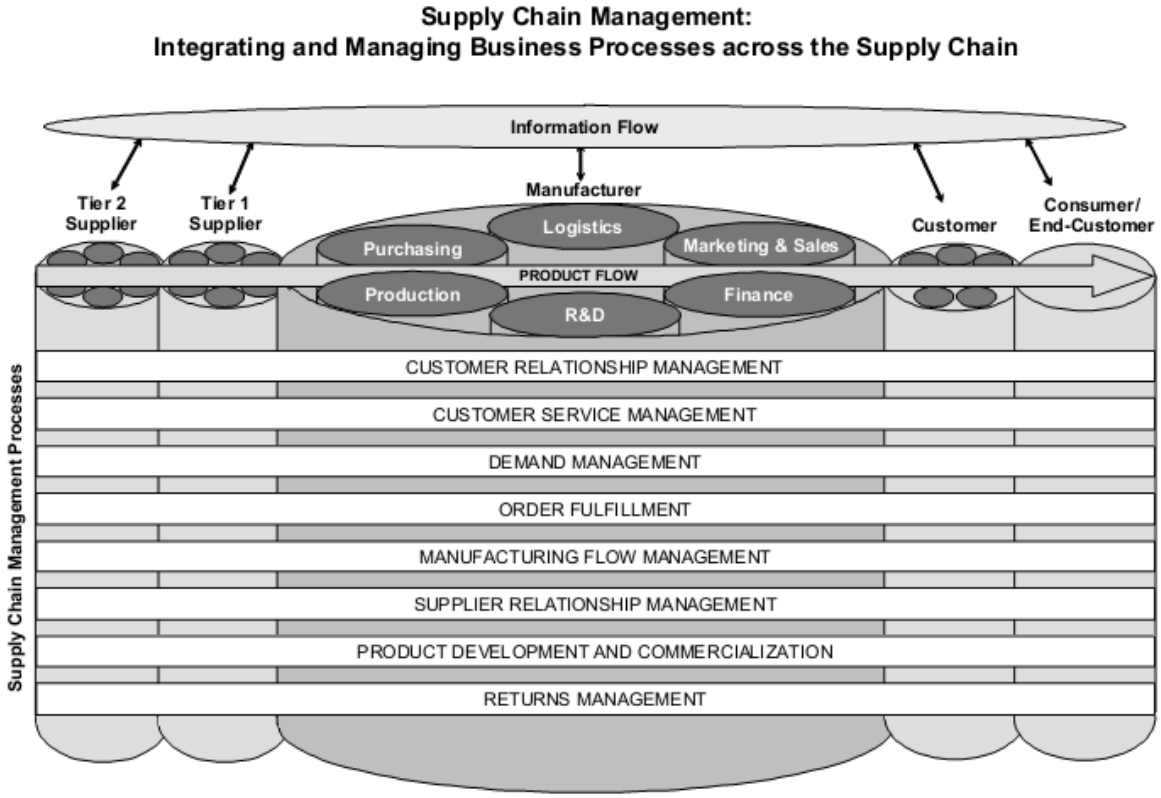


Figure 7 – Supply Chain Management: Overview – Source: Adapted from COOPER, LAMBERT and PAGH, (1997).

### 2.4. Final Considerations of the Chapter

The chapter 2 presents the necessary theoretical basis of Supply Chain Management through a literature review in 3 steps: definition of Supply Chain, definition of Supply Chain Management and implementation of Supply Chain Management (requirements and implementation). The following Table 2 synthesizes the Chapter 2.

Menzet *et al.* (2001) and Cooper, Lambert and Pagh (1997) were the great reference for this literature review. The first regards the definition and structure of both, SC and SCM. The second focus on the implementation of SCM.

After a well succeeded structuration and implementation of the SCM by the companies, it is possible to manage it through different methods or manner. According to the financial goal, customer target or final product will be defined the management approach for the Supply Chain. The following chapters show two of the main used approaches on the field of SCM, the Lean and Agile.

| Summary Table – Chapter 2 | |
|---|---|
| **Definition Supply Chain** | |
| *"A set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"* (MENTZER *et al*., 2001). | |
| **Definition Supply Chain Management** | |
| *"Supply Chain Management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole."*(MENTZER *et al.*, 2001) | |
| **Steps of Supply Chain Management Implementation** | |
| **Requirements:** | |
| Necessary Antecedents | Trust, Commitment, Interdependence, Organizational Compatibility, Vision, Key Processes, Leader, Top Management Support |
| Supply Chain Orientation | Systemic and strategic view of the implications of the tactical activities involved in managing the various flows in a supply chain. |
| **Implementation:** | |
| SC Network Structure | Identification of member firms and the links between these firms. |
| Business Processes | Eight key business processes performed to achieve a defined business outcome. (See Figure 7) |
| Management Components | Nine Management Components that essentially integrate and manage each key business process. (See Figure 6) |

Table 2 – Summary Table - Chapter 2

# 3. Lean Supply Chain

## 3.1. Introduction

The “birth of lean”, as Melton (2005) said, was in the 1940s in Japan with Toyota. In that decade the world confronted the Second World War and Toyota faced many difficulties with the local market dominated by the local subsidiaries of Ford and General Motors and from the war e.g. financial problems, disrupted production and pitiful labor (HOLWEG, 2007; MELTON 2005).

In this time the mass production philosophies were adopted in Western, with high volume production. Womack *et al.* (1990) argue that, following the ideas of Henry Ford, it was possible to maintain long production runs using standard designs. As result, it was ensured to the customer a lower cost, but also low variety and a lot of waste.

However, these philosophies were not compatible with the Japanese environment of constrains capital, physical space and labor, with a small market. In response to that, under the leadership of two Japanese executives from Toyota, Eiji Toyoda and Taiichi Ohno, it was started the implementation and development of the Toyota System Production (TSP). They achieved a ‘lean’ supply base by the 1970s and a ‘lean’ distribution by 1980s (HOLWEG, 2007; MELTON 2005).

Finally in *The Machine that Changed the World* (Womack *et al.*, 1990) the Lean Production became internationally recognized with a comparison of the two production systems. According to Womack *et al.* (1990), Lean Production “combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the later.” Besides, when compared to mass production, it takes "half the human effort in the factory, half the manufacturing space, half the investment in tools, half engineering hours to develop a new product in half the time." For a better view of the differences between these two manufacturing systems Melton (2005) developed a table based on the notes of Womack and his colleges in their book of 1990 (Table 3).

| | Mass Production | Lean Production |
|---|---|---|
| Basis | Henry Ford | Toyota |
| People-design | Narrowly skilled professionals | Teams of multi-skilled workers at all levels in the organization |
| People-production | Unskilled or semi-skilled workers | Teams of multi-skilled workers at all levels in the organization |
| Equipment | Expensive, single-purpose machines | Manual and automated systems which can produce large volumes with large product variety |
| Production methods | Make high volumes of standardized products | Make products which that customer has ordered |
| Organizational Philosophy | Hierarchical – management take responsibility | Value streams using appropriate levels of empowerment – pushing responsibility further down the organization |
| Philosophy | Aim for 'good enough' | Aim for perfection |

Table 3 – Product Systems Compared – Source: MELTON 2005.

In 1996 Womack and Jones (1996), in an attempt to clarify the Lean Production, presented in their bestseller *Lean Thinking* five principles of lean: *Value*, *Value Stream*, *Flow*, *Pull* and *Perfection*.

The first principle was the necessity that an organization has to define *Value* precisely from the perspective of the end costumer for a specific product, with specific capabilities, offered at a specific price and time. It is very important the focus on the costumer's view, because otherwise the company may be investing and putting efforts in processes that do not create value, and therefore are waste (WOMACK and JONES, 1996).

The second step is the *Value Stream identification*. The Value stream is a technique applied to each product or product family and it is used to analyze and design the flow of materials and information required to bring a product or service to a consumer. Through this technique is possible to identify the main value adding stages and the key multi-functional teams involved. And mainly, it also enables us to identify the steps that can be removed; the waste in the production. (WOMACK and JONES, 1996; PAEZ *et al.*, 2004).

The third principle and step is about creating *Flow* with the activities responsible for creating value. In the pursue of eliminating waste, creating Flow means working on each design, order, and product continuously from beginning to end so that there is no waiting, downtime, or waste, within or between the steps. It may require a change in the way of production, from batch production to work-cell production, in order to achieve capability and availability. (WOMACK and JONES, 1996; PAEZ *et al.*, 2004; MELTON 2005)

The forth is about creating *Pull* in the value stream. The target with flow is to minimize the through put time of a value stream, so that most activities and processes are based on firm customer orders and not forecasting. Melton (2005) argue that a 'push' system production works following the forecasting – "works as much as it can to fill a warehouse". While the 'pull' system production works according the customer's needs.

It is important to design and provide what the customer wants only when the customer wants the product. Therefore, techniques such as Just-in-time and Information Technologies are very important and applied in a Lean Production. (WOMACK and JONES, 1996)

The fifth principle is the pursuit of *Perfection*. As Paez *et al*. (2004) said, even in a "fully synchronized flow is likely to break down every time something goes wrong." In a mass-production the natural answer and concern is not stop the production, so they postpone the corrections and work with a big inventory for the eventualities. Nevertheless, in the lean production the answer for the problem is effective and immediate, and if necessary they stop the production. It is obvious that, it requires a culture change and a lot of patience and effort. In the beginning, it will be difficult. However, with time it will bring high reliability and quality. Every day the company will be closer to achieve the Zero Defects. (WOMACK and JONES, 1996; PAEZ *et al.*, 2004; MELTON 2005)

After comprehending the five principles of lean production and specially the fifth principle it is clear that to become 'lean' the organization must always work in the continuous improvement of the production (Figure 8).

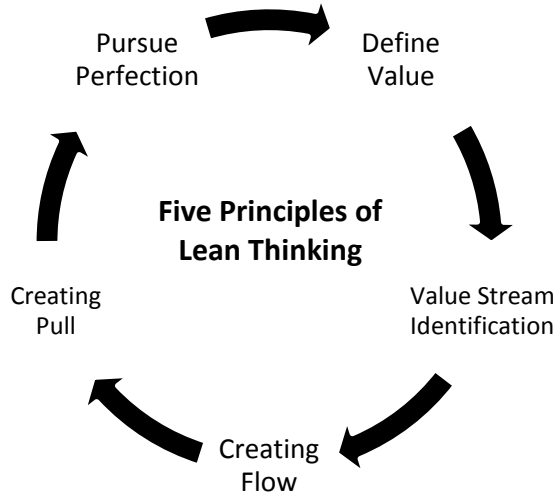


Figure 8 – Five Principles of Lean Thinking – Source: WOMACK and JONES 1996.

Over the years there were a lot of articles and studies about lean production or lean thinking. Boyle *et al*. (2011) argue that Lean can be considered from two perspectives: The philosophical perspective and the practical perspective. The first one is about applying the five principles of lean production, above discussed. It focuses on the interrelationship of these principles in order to improve overall levels of quality, productivity, integration and waste reduction (WOMACK and JONES, 1996; BOYLE *et al.*, 2011).

The practical perspective of lean production is about the operational level and is related with the tools and techniques used to aim better results. Included in these tools and techniques are: Value Stream Mapping, Quick Changeover/Setup Reduction, Single Minutes Exchange of Dies (SMED), Kaizen, Cellular/Flow Manufacturing, Visual Workplace/5S Good Housekeeping, Total Productive Maintenance (TPM), and Pull/Kanban Systems and others (WOMACK and JONES, 1996; BOYLE *et al.*, 2011; MELTON 2005).

### 3.2. Definition of Lean Supply Chain Management

It is really common in the literature the use of the term Lean Supply Chain. But we must be clear of which definition will be the basis for this essay. It is very usual to find a definition to Lean Supply Chain that follows some sort of generalization of concepts. Such as the definition that says that it is every supply chain that uses the Lean tools and techniques in order to achieve better results including agility. However, as Gattorna *et al.* (2009) said, "*there is no doubt that the application of lean principles brings the elimination of waste in materials, processes, time and information. But sometimes this is achieved at the expense of agility and flexibility."*

Gattorna *et al.* (2009) argue that the Lean Thinking is really important and must be present at the supply chain. But there are some principles that do not apply overall supply chain. The problem reside in the fact that the Japanese automotive environment, where the lean manufacturing was born, does not reproduce the wider supply chain operating environment, especially in volatile markets. He argues that supply chain exists in different markets with different necessities and for each one a different paradigm of management. In the classification proposed by Gattorna one of them is the Lean Supply Chain Management. Therefore, we will use as reference the definition that was developed by Gattorna (GATTORNA *et al.*, 2009).

In Gattorna's classification the *buying behavior* is paramount. For him it is important to configure the supply chain management according to this behavior. And in the Lean Supply

Chain what defines the *buying behavior* is the 'efficiency/consistency' that is characterized by the low sharing information and price dispute. He emphasizes it in *Dynamic supply chains: delivering value through people* (2010) stating that:

> *"Customers in the lean market will often shop around and use multiple sources in the search for steady supply and lowest prices. But in doing so, they can be impersonal or even adversarial, with few if any loyalties developing.* […] *if you are looking to compete under these conditions, you must strive to be the lowest-cost producer, and sustain this advantage over time, using whatever techniques at your disposal."*

Thus, the Lean Supply Chain Management seeks to serve at a low-cost with reliability and not over-service. So, despite the low share information with the suppliers, the lean supply chain still works in a more predictable market conditions, usually with functional products (Table 4). Thereby it works using a business production strategy of Make-To-Forecast (MTF) consisted of efficient operations management (use of Lean tools and techniques) in a high volume, a low-cost production and high utilization of capacity. On the other hand it has reduced agility, responsiveness and resilience (GATTORNA *et al.*, 2009; GATTORNA 2010; FISHER 1997).

| **Functional Versus Innovative Products: Differences in Demand** | | |
|---|---|---|
| Type of Product | Functional (Predictable Demand) | Innovative (Unpredictable Demand) |
| Product life cycle | more than 2 years | 3months to 1 year |
| Contribution margin* | 5% to 20% | 20% to 60% |
| Product variety | Low (10 to 20 variants per category) | High (often millions of variants per category) |
| Average margin of error in the forecast at the time production is committed | 10% | 40% to 100% |
| Average stock-out rate | 1% to 2% | 10% to 40% |
| Average forced end-of-season markdown as percentage of full price | 0% | 10% to 25% |
| Lead time required for made-to-order products | 6 months to 1 year | 1 day to 2 weeks |
| * the contribution margin equals price minus variable cost divided by price and is expressed as a percentage. | | |

Table 4 – Functional Versus Innovative Products: Differences in Demand – Source: adapted from FISHER 1997

### 3.3. Final Considerations of the Chapter

The chapter 3 shows a literature review of Lean Management and the approach lean on Supply Chain Management. The following Table 5 synthesizes the chapter.

| Summary Table – Chapter 3 | |
|---|---|
| **Lean Management** | |
| Philosophical Perspective | Five principles: Define Value, Value Stream Identification, Creating Flow, Creating Pull, Pursue Perfection |
| Practical Perspective | Tools and Techniques: Value Stream Mapping, Quick Changeover/Setup Reduction, Single Minutes Exchange of Dies (SMED), Kaizen, Cellular/Flow Manufacturing, Kanban and others |
| **Lean Supply Chain Management** | |
| Buying Behavior | Efficiency/Consistency |
| Focus | High volume; Low variety; Low costs; MTF |
| Value Proposition | • Seek economies of scale<br>• Low-cost production & distribution<br>• Forecast demand; mature (functional) products; predictable lead times<br>• High reliability |

Table 5 – Summary Table - Chapter 3 – Source: Adapted from GATTORNA et al., 2009.

# 4. Agile Supply Chain

## 4.1. Introduction

Hoek *et al.* (2001) argue that the Agility is the new challenge to the international business world that requires responsiveness and mastering the uncertainty. It is an integrating part of the Agile Supply Chain, which is inserted in volatile markets and requires increasing dynamic performance.

Thus Goldman *et al*. (1995) define the four basic dimensions of agility:

- Enriching the customer;
- Cooperation to enhance competitiveness;
- Organizing to master change and uncertainty;
- Leveraging the impact of people and information.

In the first dimension, *enriching the customer*, the relationships between company and customers are based on mutual dependence and inevitable interactions arise when the manufacturer and the customer understand each other well enough to create solutions together. Thus, solutions are developed over time, at the same rate of customer's problems evolution. Involving the client in the production process or setting interactively the mix of products, services and information for optimum value to each client, is a fundamental task of Agility (GOLDMAN *et al.*, 1995).

Every business relationships that promote internal and external *cooperation to enhance competitiveness* can focus their efforts on activities in which their human and technological resources are better suited. Alliances between companies with complementary skills and resources can reduce costs and risks embedded, also reducing development time. The alliance promotes the meeting of human and physical resources available in all partners. They increase the chances of success and create relationships of interdependence on which are designed future collaborations and continued participation in the creation of multiple generations of a families of successful products. (GOLDMAN *et al.*, 1995)

In the third dimension, *organization to master change and uncertainty*, the agile enterprise is organized to allow it to thrive surrounded by constant changes and uncertainty. The goal of a fast concept of simultaneity of time implies innovative and flexible

organizational structures to take quick decisions by the distribution of authority. The staff should be motivated and sufficiently open to new knowledge so that you can transform changes and uncertainties in new opportunities for business growth. And they should have the power and the necessary support to do so routinely and quickly. (GOLDMAN *et al.*, 1995)

The last dimension, *leveraging the impact of people and information*, the agile enterprise nurtures an enterprising culture that leverages the impact of people and information in the operations. There is a tendency that competition between companies is not only in prices but in the products and services that are rich of information and based on customer appreciation. One of the main differentiation factors is the people in the organization, their knowledge and information and initiative. What customers are really paying for is the access to people capable of synthesizing profitable products, which achieve the customer's needs through their knowledge, information and technology that the company makes available to them. (GOLDMAN *et al.*, 1995)

Therefore, Christopher (2000) defines agility "as the ability of an organization to respond rapidly to changes in demand, both in terms of volume and variety." And Goldman *et al.* (1995) add that to an organization "be agile is to be capable of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities."

### 4.2. Definition of Agile Supply Chain Management

Hoek *et al.* (2001) and Christopher (2000) – in harmony and conformity with the agility dimensions – proposed the elements of the Agile Supply Chain Management in Figure 9. As Hoek *et al.* (2001) said these elements "reflect the more general aspects of agility applied to the supply chain operating environment."

The first element is *Customer Sensitivity*, which seeks to understand the needs and requirements of the market, to ensure that the processes add value on the point of view of the Customer (the Customer "Enrichment"). Thus, the organization should be geared to read and respond to real demand, hearing the information from point-of-sale or point-of-use using information technology. In addition, initiatives such as Customization and Postponement now have great value in Agile Management. (CHRISTOPHER, 2000; HOEK *et al.*, 2001)

Another element is *Virtual Integration*, which refers to the use of information technology to share data internally and externally, i.e. with suppliers, customers and other partners. It allows a broader view of supply chain and tries to make the data be collected,

interpreted and responded from the point-of-origin to point-of-use in a quickly and efficiently way, avoiding distortions. Tools such as Electronic Data Interchange (EDI), Internet and others are essential. (CHRISTOPHER, 2000; HOEK *et al.*, 2001)

The *Process Integration* is the next element and it means a collaborative work between companies in the supply chain, whether in product development, or systems used and the information shared. This requires a relationship where there is trust, transparency, commitment and strategies aligned and should be done with strategic suppliers and customers. As a consequence it is possible that each company in the chain specializes in what it does best and also allows answers and solutions faster and more efficiently. Internally it is suggested more autonomy for strategic managers of the company. (CHRISTOPHER, 2000; HOEK *et al.*, 2001)

Other element is the *Network* that as proposed by Hoek (2001, p.139), it is essential the "Cooperation for Competition." There is a growing recognition that individual businesses no longer compete as autonomous entities, but rather as supply chains. And they should prioritize a better structure, coordination and management of the relationships with its partners in a network committed to a better, closer and more responsive relationship with their end customers. (CHRISTOPHER, 2000; HOEK *et al.*, 2001)

In addition, the *Measurement* is the tools used to measure performance of the Supply Chain. These tools must not only be towards quality, efficiency and productivity, but also to evaluate other elements of the supply chain, such as exchange of information, integration and consumer response. It is an essential element because it gives direct answers to the management that is been applied. (CHRISTOPHER, 2000; HOEK *et al.*, 2001)

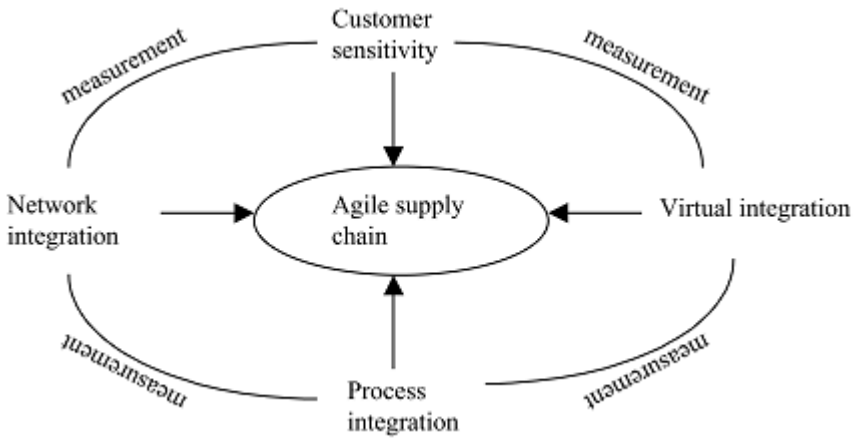


Figure 9 – Elements of the Agile Supply Chain – Source: HOEK et al., 2001.

Putting all these elements together it is possible to provide a supply chain that is agile and ensure speed – the paramount characteristic of an Agile Supply Chain. But, as Gattorna (2010) argues it is pivotal deliver speed "in a cost-effective way; otherwise we will find ourselves careering off the track in a high-cost, high-speed wreck." In other words, the Agile Supply Chain must provide speed according to the customer's needs. However, the organization must first select him or her and then direct the strategies to the specific needs of this specific customer. Otherwise the supply chain will try to respond to all demands and fail.

Gattorna (2010) asserts that "We need to work out when the demand is genuine and therefore absolutely necessary, and if so, respond in quick time. And we need to know when the customer does not need the product immediately, or if they do, there is a price premium involved."

Thus, the responsiveness is fundamental in the Agile Supply Chain and therefore the number of products or families of products trying to achieve costumer's requirements increase and the time of life-cycles decrease. Now the product tends to be more innovative and it is embedded in an unstable and sometimes unpredictable environment. (See above Table 4) (GATTORNA 2010; FISHER 1997)

As the Lean Supply Chain, the Agile Supply Chain follows the classification of Gattorna and has a 'demanding/quick response' costumer *buying behavior*. In this case there is more sharing of information because of the common focus in high-performance responsiveness with quality, and low priority to the price. The business production strategy of Make-To-Order (MTO) or even Engineering-To-Order (ETO) is inserted in a high variety market of unstable or unpredictable demand, hence is necessary available capacity. (GATTORNA *et al.*, 2009; GATTORNA 2010)

### 4.3. Final Considerations of the Chapter

The chapter 4 shows a literature review of Lean Management and the approach lean on Supply Chain Management. The following Table 6 synthesizes the chapter.

| Summary Table – Chapter 4 | |
|---|---|
| **Agility** | |
| *"An agile organization is capable of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities."* (GOLDMAN *et al.*, 1995). | |
| **Agile Supply Chain Management** | |
| **Elements** | |
| Customer Sensitivity | seeks to understand the needs and requirements of the market |
| Virtual Integration | use of information technology to share data internally and externally |
| Process Integration | collaborative work between companies in the supply chain |
| Network | network committed to a better, closer and more responsive relationship with their end customers |
| Measurement | measure performance over all aspects of the Supply Chain |
| **Technical Features** | |
| Buying Behavior | Demanding/quick response |
| Focus | Manage enterprise for responsiveness; quick reaction; MTO or even ETO |
| Value Proposition | • Fast decision-making<br>• Fast delivery; flexible scheduling<br>• Rapid Response in unpredictable conditions<br>• Available Capacity |

Table 6 – Summary Table - Chapter 4 – Source: Adapted from GATTORNA et al., 2009.

## 5. Framework for Performance Evaluation of Supply Chain Management

Gunasekaran *et al.* (2001) assert that "most of the companies realize that, in order to evolve an efficient and effective supply chain, SCM needs to be assessed for its performance." Thus, the performance evaluation must be present in all Supply Chains and involves gathering formal and informal data to help suppliers, manufactures and customers to define and achieve overall supply chain goals and the continuous improvement of the SCM. Besides, it is important to highlight that this is a complex undertaking process that involves several actors and a lot of cooperation. (GUNASEKARAN *et al.* 2001; ESTAMPE *et al.* 2010)

To give a clear picture of the SCM performance, Gunasekaran *et al.* (2001) developed a framework for measuring the performance of a supply chain. Displayed below in Table 7, you may see the metrics that must be assessed are classified in the three levels:

- Strategic – it gives the forward orientation overall the supply chain. The metrics are global and long-term applied throughout all supply chain;
- Tactical – it involves the establishment of key initiatives to achieve the overall strategy. The metrics are medium-term in specific units or departments or organization of the supply chain;
- Operational – it involves the activities that are actually done. The applied metrics are short-term and implemented in tasks and operations of the supply chain.

These elements or metrics can measure in both financial and non-financial approaches. Because, it is important consider that "while financial performance measurements are important for strategic decisions and external reporting, day-to-day control of manufacturing and distribution operations is better handled with non-financial measures." (GUNASEKARAN *et al.* 2001)

Gunasekaran *et al.* (2001) still disposed in Figure 10 the metrics according to the supply chain structure, aligning the metrics in 5 fields or links of the SCM: *Plan Performance*, *Source Performance*, *Production Performance*, *Delivery Performance* and *Customer Service and Satisfaction*.

The main goal of this five link classification is to create a clearer picture of where and how each metric should be used for a better performance assessment, and also who will be responsible for applying and analyzing them.

| Level | Performance metrics | Financial | Non-financial |
|---|---|---|---|
| Strategic | Total supply chain cycle time | | X |
| | Total cash flow time | X | X |
| | Customer query time | X | X |
| | Level of customer perceived value of product | | X |
| | Net profit vs. productivity ratio | X | |
| | Rate of return on investment | X | |
| | Range of product and services | | X |
| | Variations against budget | X | |
| | Order lead time | | X |
| | Flexibility of service systems to meet particular customer needs | | X |
| | Buyer-supplier partnership level | X | X |
| | Supplier lead time against industry norm | | X |
| | Level of supplier's defect free deliveries | | X |
| | Delivery lead time | | X |
| Tactical | Delivery performance | X | X |
| | Accuracy of forecasting techniques | | X |
| | Product development cycle time | | X |
| | Order entry methods | | X |
| | Effectiveness of delivery invoice methods | | X |
| | Purchase order cycle time | | X |
| | Planned process cycle time | | X |
| | Effectiveness of master production schedule | | X |
| | Supplier assistance in solving technical problems | | X |
| | Supplier ability to respond to quality problems | | X |
| | Supplier cost saving initiatives | X | |
| | Supplier's booking in procedures | | X |
| | Delivery reliability | X | X |
| | Responsiveness to urgent deliveries | | X |
| | Effectiveness of distribution planning schedule | | X |
| Operational | Cost per operation hour | X | |
| | Information carrying cost | X | X |
| | Capacity utilization | | X |
| | Total inventory as: | X | |
| | * Incoming stock level | | |
| | * Work-in-progress | | |
| | * Scrap level | | |
| | * Finished goods in transit | | |
| | Supplier rejection rate | X | X |
| | Quality of delivery documentation | | X |
| | Efficiency of purchase order cycle time | | X |
| | Frequency of delivery | | X |
| | Driver reliability for performance | | X |
| | Quality of delivered goods | | X |
| | Achievement of defect free deliveries | | X |

Table 7 – Metrics to evaluate performance of a SCM. – Source: GUNASEKARAN et al., 2001.

Gunasekaran *et al.* (2001) assert that it is important to analyze the SCM in a *balanced approach* using a good few metrics for the specifics performance measurements. Equilibrating financial with non-financial measures and classifying according to the levels and/or to the supply chain structure.

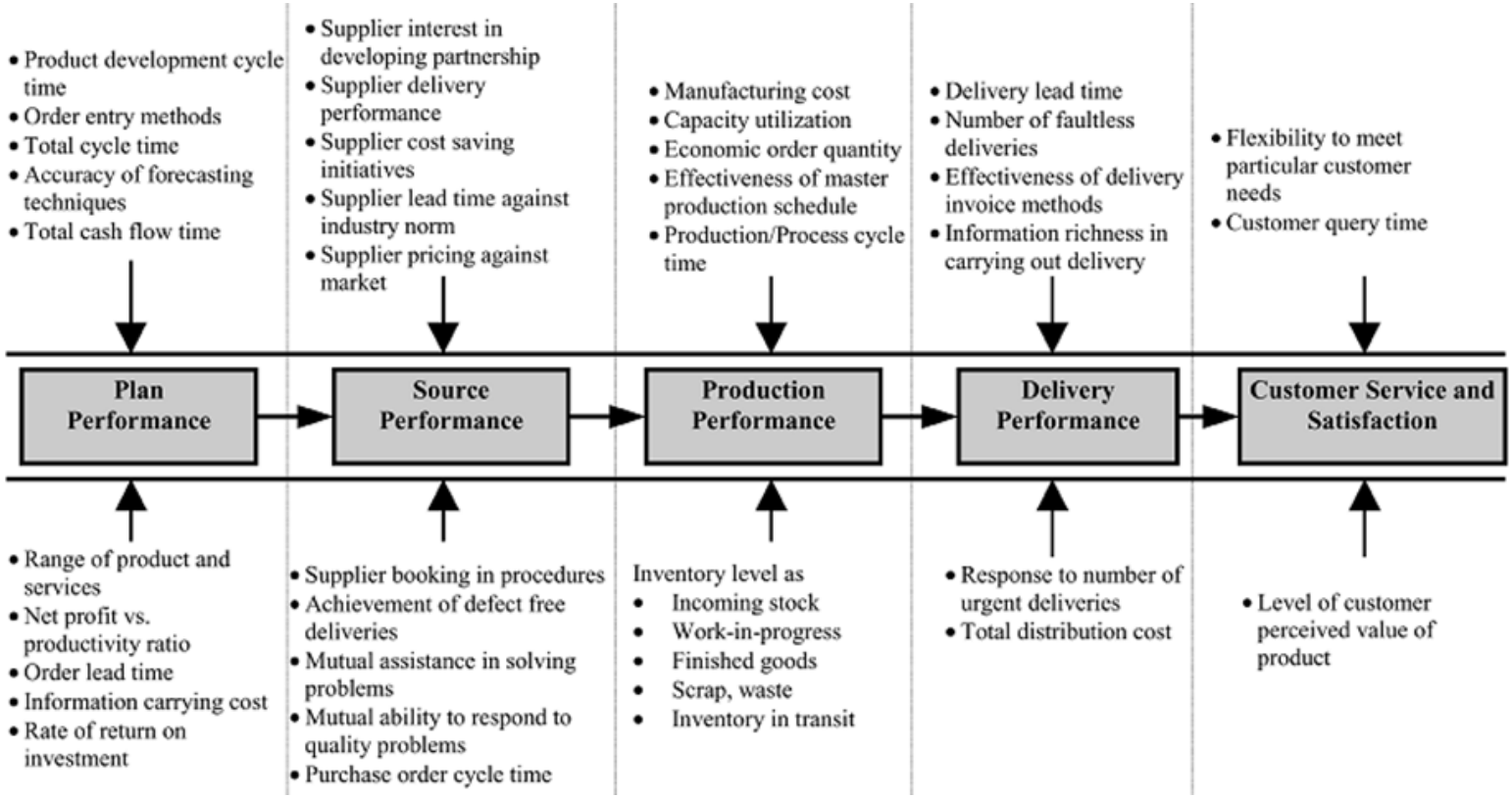


Figure 10 – Measures and metrics at five basic links in a supply chain: plan, source, make/assemble, deliver and customer. – Source: GUNASEKARAN et al., 2001.

This essay will not use business data. Hence, the focus is in non-financial performance metrics and most of them come from the article of Gunasekaran *et al.* (2001). Therefore, the selected performance metrics shown in Figure 11 to 15 were applied in the evaluation, which are using the supply chain structure classification proposed in Figure 10.

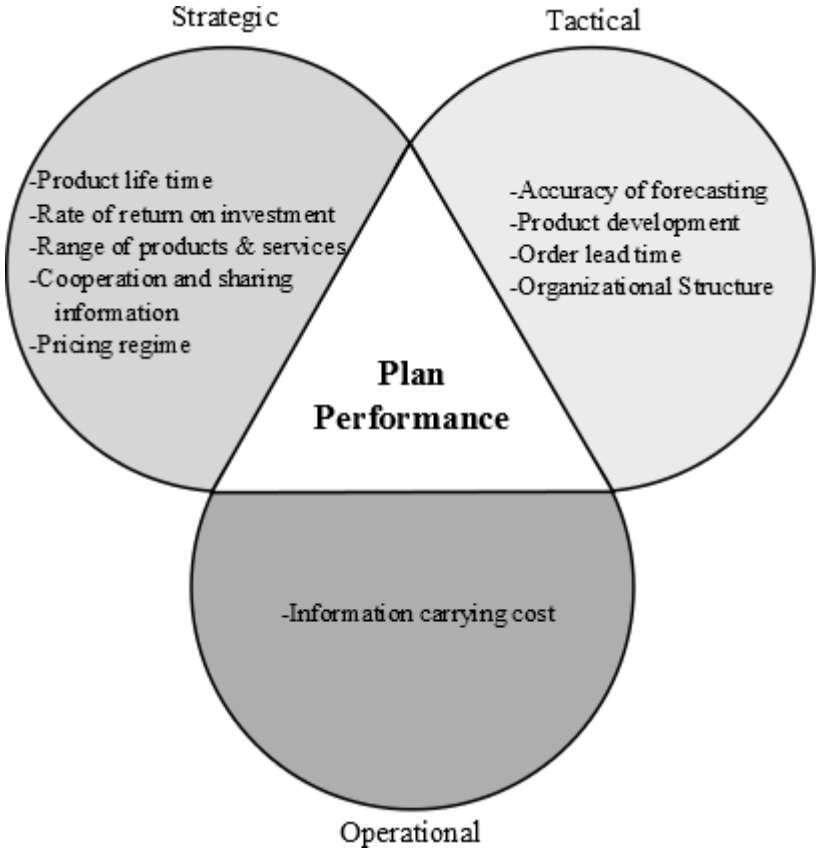


Figure 11 – Measures of Plan Performance– Source: Based on Figure 10 and Table 7.

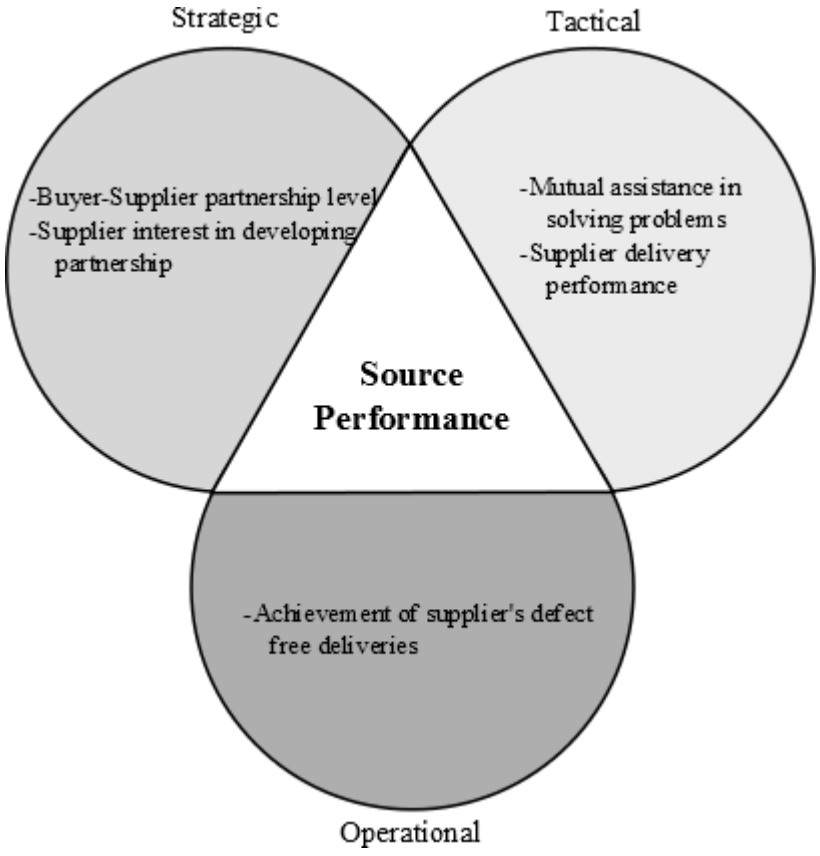


Figure 12 – Measures of Source Performance– Source: Based on Figure 10 and Table 7.

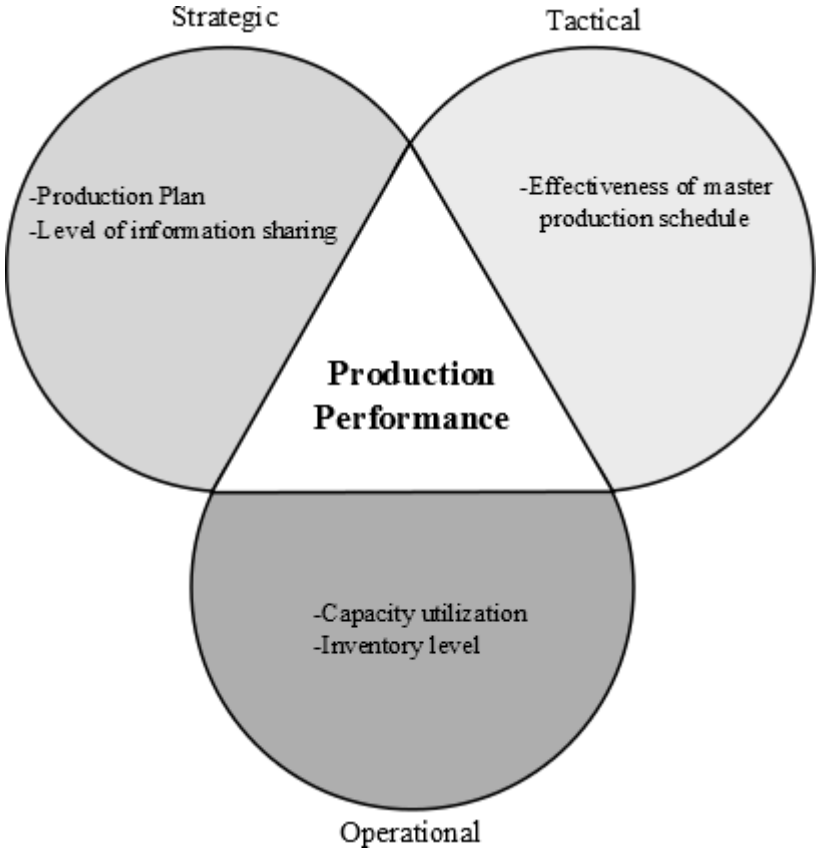


Figure 13 – Measures of Production Performance– Source: Based on Figure 10 and Table 7.

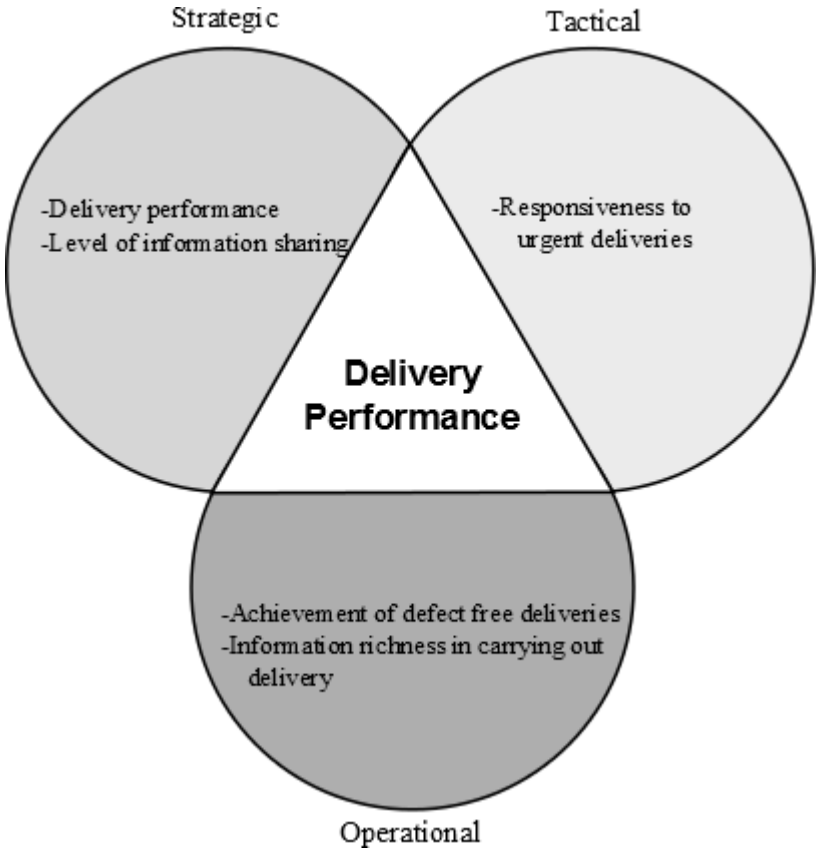


Figure 14 – Measures of Delivery Performance– Source: Based on Figure 10 and Table 7.

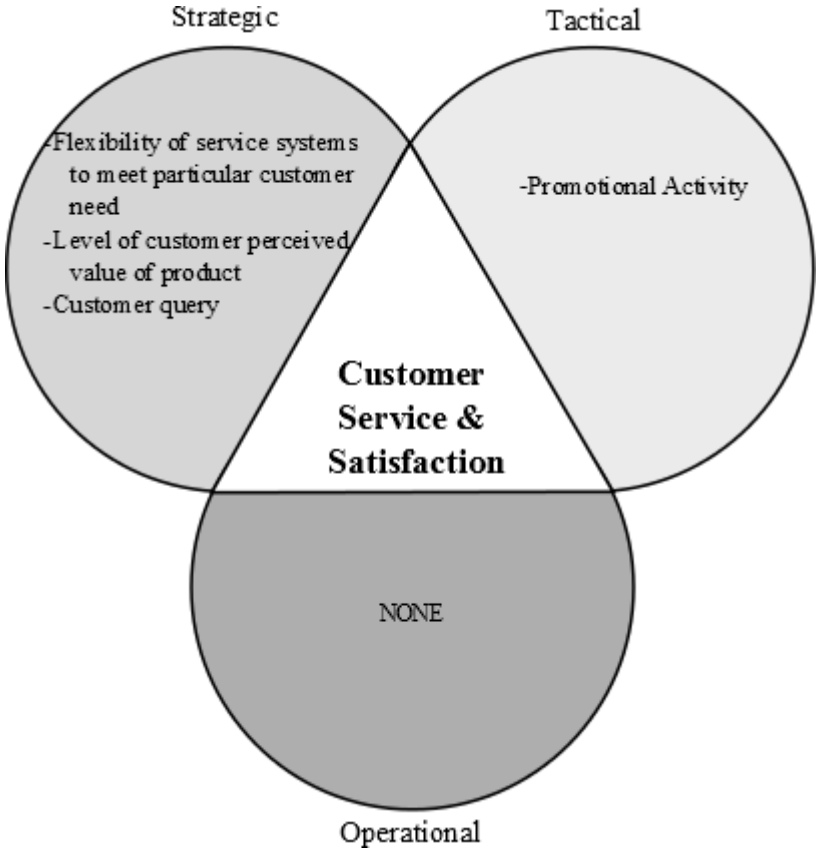


Figure 15 – Measures of Customer Service & Satisfaction – Source: Based on Figure 10 and Table 7.

## 6. Performance Evaluation of Lean Supply Chain Management

This Section presents the performance analysis for Lean Supply Chain Management. The performance evaluation will use the framework proposed by Gunasekaran *et al.* (2001) and also use the metrics selected in the Figures 11 to 15. Because it is a theoretical essay, we will seek to demonstrate the possible results for each of the selected metrics without the use of values or business data.

### 6.1. Plan Performance Evaluation

Following the classification proposed by Gunasekaran *et al.* (2001), the first of the five fields of performance evaluation to be analyzed is *Plan Performance.* The metrics are showed in Figure 11.

The buying behavior that Lean Supply Chain (LSC) seeks to serve is 'efficiency/consistency'. Gattorna *et al.* (2009) made a clear statement about these relentless customers: "They are innately conservative and slow to change. In essence this type of customer is a 'laggard' and just wants the same product-service experience repeated on a consistent basis and they will shop around to get it." So, services and products must be standard and reliable and must be driven by a lean mentality of low-costs.

Thus, to achieve this reliability the LSC deals with mature products. It means that the managed product in the LSC stays longer in the Maturity Stage of the Product Life Cycle (Figure 16). Consequently, it has a stable and predictable demand which enables a big advantage of a high *Accuracy of Forecasting* of demand with a margin of error of less than 10%. Thereafter it becomes possible to apply lean tools in order to minimize physical cost and reach a predictable lead time. The final result is a long *Life Time* of more than 2 years. (GATTORNA 2010; FISHER 1997; DAY 1981)

At the same time the customers' necessity for the "same product experience" allows minimal variations in the product. It reflects in the *Range of Products and Services* of a LSC that becomes narrow (10 to 20 variants per category). Therefore, this Supply Chain is not prepared for a Make-to-Order production. That results in a long *Order Lead Time* for MTO products of 6 months to 1 year. However, for mature products the *Order Lead Time* is short, taking weeks or even hours. (GATTORNA *et al.*, 2009; GATTORNA 2010; FISHER 1997)

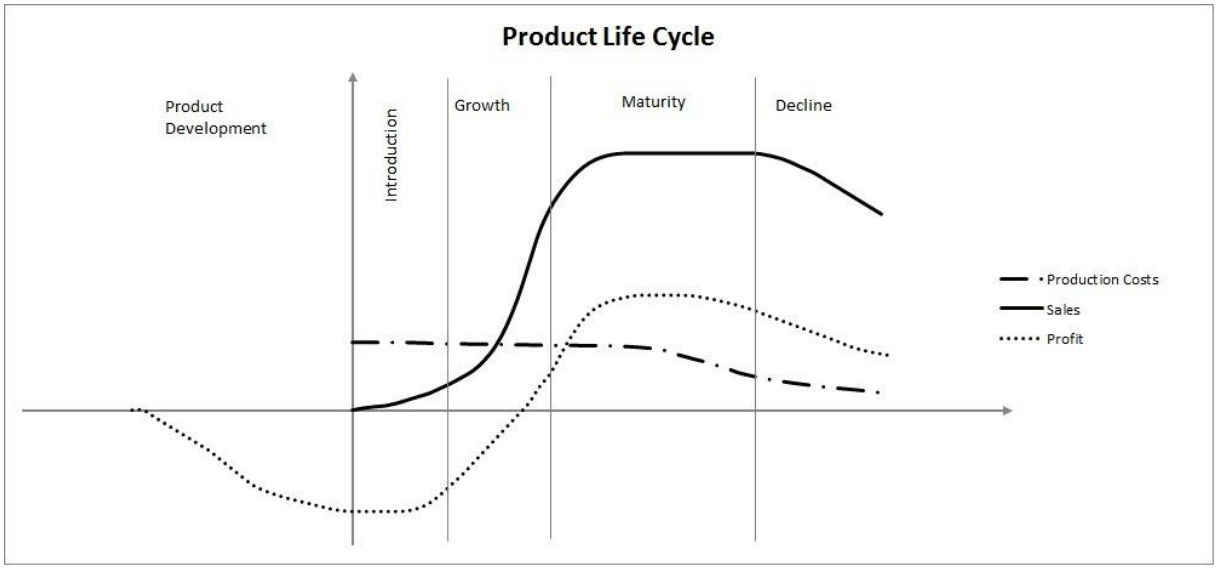

Figure 16 – The Product Life Cycle of a Mature Product – Source: Based on Vernon, 1966.

The *Product Development* of the LSC must ensure that the product meets the customers' buying behavior of reliability and low-price. Therefore, the products rarely suffer changes. When it happens, the changes are minimal innovations and little differentiation just to ensure a longer life time. Besides, the LSC is not accustomed to develop new products. Thereby, the *Product Development Cycle Time* usually takes years, because it faces high difficulties, such as high bureaucracy and personnel not prepared for pro-active actions and for sharing information. (GATTORNA *et al.*, 2009; GATTORNA 2010)

Another necessity to satisfy this sensitive price customer is to promote a *Pricing Regime* that seeks to produce at the lowest cost and ensure it to the costumer. Thus, the selection of the supplier on price basis and the use of Economies of Scale are normally used in the LSC - that occurs when the expansion of the production capacity of a company or industry causes an increase in the total amount produced without a proportional increase in production cost. As a result, the average cost of the product tends to be smaller with increased production. (GATTORNA 2010)

Besides, this Pricing Regime means a low profit by product and it also means a low *Rate of Return on Investment* (RRI). However the investments made in the Product Development Stage and in the Product Introduction Stage will generate return in the Maturity Stage and the longer this stage, the greater the RRI, especially because the mature product needs low investments. (GATTORNA *et al.*, 2009; FISHER 1997)

Gattorna (2010) noted that the *Organizational Structure* follows the LSC mentality that seeks security and predictability and flees of flashy and risky. Thereby the LSC presents a

Hierarchical Organizational Structure organized in clusters around several core processes, such as departments. Teamwork is embedded, mainly in the cluster, but to avoid risks, the decision-making processes and responsibilities are centralized and usually not open to suggestions. Rules, procedures and pre-set policies are strong partners with low space to creativity and innovation. Keeping the standard is the goal. (GATTORNA *et al.*, 2009; GATTORNA 2010)

The *Cooperation and Sharing Information* can be analyzed by two ways: external and internal communications. Externally there is a low cooperation or sharing information, especially with the customer. This relentless customer does not want a close relationship. He is predictable and prefers that the supply chain direct its efforts to reduce the costs. As consequence, the LSC does not need to implement a sophisticated information system connecting all the supply chain, from the first supplier to the last customer, especially on the customers' side. This means a low to medium *Information Carrying Cost*. Internally the cooperation and sharing information is higher than externally. But in this hierarchical structure the 'information is power' so it tends to be concentrated. Besides, the internal communications is formal and regular, it follows a more directive process. (GATTORNA *et al.*, 2009)

### 6.2. Source Performance Evaluation

The next field of performance to be evaluated is *Source Performance*. The metrics are showed in Figure 12. Gattorna (2010) argued that "to work most effectively, the Lean Supply Chain requires collaboration with suppliers on the supply-side." After all, the consumer has known characteristics and he will choose the product according to them. Thus, there is a necessity for a good *Buyer-Supplier Partnership Level* to fulfill these customers' necessities. Nevertheless, this partnership is not focused on developing a new product, project or technology. Their focus is to ensure that the consumer gets a lower cost product with high reliability. Therefore the shared information in this partnership usually is: data of production, inventory, delivery and quality. These enable a better applicability of lean's tools satisfying the buyer-behavior. (GATTORNA *et al.*, 2009; GATTORNA 2010; STEWART 1995)

In the LSC the *Supplier Interest in Developing a Partnership* is high, because a supplier usually competes with others suppliers by price and reliability and he can easily be discarded for a cheaper one, especially when the partner is powerful. In this case the *Mutual*

*Assistance in Solving Problems* is low, and the supplier must deal with them alone. More rarely, there are cases of a partnership not so dependent on prices, as when the product requires greater reliability rather than low prices. In these cases there is a greater exchange of information with a high *Mutual Assistance in Solving Problems*. This type of partnership tends to last. (GATTORNA 2010)

Another important item in the supplier-side to be analyzed is the *Supplier Delivery Performance*. The supplier does not need to be the fastest or the most creative, but it must attend a delivery with high punctuality and consistency with a low price. It means that the LSC looks for suppliers that seek the *Achievement of Defect Free Delivery*. In this supply chain not only the final customer is relentless but also the intermediaries. Consecutive failures result in penalties or even the discard as a supplier. (GATTORNA 2010; STEWART 1995)

### 6.3. Production Performance Evaluation

The third field of performance to be evaluated is *Production Performance*. The metrics are showed in Figure 13. As the others evaluated fields, it is paramount to ensure the achievement of the LSC buying-behavior. Thus, the supply chain "must strive to be the lowest-cost producer and use whatever strategies and techniques at your disposal to do so" (GATTORNA 2010).

The *Production Plan* is characterized by an efficient operations focus, high volume production and low variety. The LSC works with mature products, it allows a Make-to-Forecast production and a high applicability of lean tools. The innovation that is not present in the development of the product is welcome in the production area in order to smooth the product flow, refine the process and reduce the costs. Besides, with the high forecasting's accuracy it is possible to have a high *Capacity Utilization*. And it is also common the use of economies of scale to reduce costs. (GATTORNA *et al.*, 2009; GATTORNA 2010)

The *Inventory Level* also deserves special attention, because it is a fast way to grow the profit margin. Therefore, techniques to reduce the inventory are fairly applied, like Just-in-Time and Enterprise Resource Planning (ERP). For the use of these techniques, it is clearly necessary a high *Level of Information Sharing* in the supplier-side of the supply chain. Thus it is possible and commonly achieved a high *Effectiveness of Master Production Schedule*

fulfilling, at the end, the production of a low-cost and reliable product. (GATTORNA 2010; STEWART 1995)

### 6.4. Delivery Performance Evaluation

The *Delivery Performance* is the fourth field to be analyzed and the metrics are shown in Figure 14. The customer in LSC is relentless and since he can easily find another product with the same characteristics, he can also easily change to a rival. Thus, the *Delivery Performance* must have reliability. Procedures and rules are fairly used to fulfill with punctuality the delivery schedule and to ensure the *Achievement of Defect Free Deliveries*.

It is clear that the final customer shares little information and does not want a close relationship. However the intermediate customers in the supplier side, such as warehouses and retailers, may seek a closer relationship through online information systems with high *Level of Information Sharing* and also high *Information Richness in Carrying out Deliveries*, although it is not a rule. At the same time, the LSC has problems to delivery an unexpected demand that is out of the schedule and requires fast and pro-active answer. Therefore, the *Responsiveness to Urgent Deliveries* is low. (GATTORNA 2010)

### 6.5. Customer & Service Satisfaction Evaluation

The last field to be evaluated is *Customer & Service Satisfaction*. The metrics are showed in Figure 15. As said before, in the LSC the customer is clear about its wishes and wills: the emphasis must be in low price with high reliability. So, the loyalty in this market is low as well as the *Level of Customer Perceived Value of Product*, which not rarely is seen as a commodity. (GATTORNA 2010)

At the same time, the *Flexibility of Service Systems to Meet Particular Customer Need* becomes low because all the organizational structure and the management plan of all LSC are focused on attending the buying behavior. The relationship is distant and attempts to develop a close relationship, such as *Promotional Activities* and *Customer Query* are commonly seen as distraction and waste of money. It is preferable to direct the investments in improving production and logistics processes of the supply chain. (GATTORNA *et al.*, 2009; GATTORNA 2010; HOOTS 2005)

### 6.6. Final Considerations of the Chapter

The chapter 6 presents the performance analysis of Lean Management Supply Chain Management. The following Table 8 synthesizes the chapter.

| Summary Table – Chapter 6 | | |
|---|---|---|
| **Performance Analysis of Lean Supply Chain Management** | | |
| **Plan Performance** | Product life time | Long (more than 2 years) |
| | Rate of return on investment | Low (return in the Maturity Stage of Product) |
| | Range of products & services | Narrow (10 to 20 variants per category) |
| | Cooperation and sharing information | Low (information tends to be concentrated) |
| | Pricing regime | Low-cost (sensitive price customer) |
| | Accuracy of forecasting | High (error margin is less than 10%) |
| | Product development | Minimal innovations for longer life time<br>High difficulties to develop a new product |
| | Order lead time | Short for mature products (weeks or hours) |
| | Organizational structure | clusters around core processes; avoid risks |
| | Information carrying cost | Low to medium (focus on reduce costs) |
| **Source Performance** | Buyer-Supplier partnership level | Medium (focus on reduce costs) |
| | Supplier interest in developing partnership | High (due to the relentless competition) |
| | Mutual assistance in solving problems | Low (especially when the partner is powerful) |
| | Supplier delivery performance | Punctuality and consistency with a low price |
| | Achievement of supplier's defect free deliveries | High (failures result in penalties or even the discard) |
| **Production Performance** | Production Plan | High volume, low variety and low cost |
| | Level of sharing information | High (use lean technics, mainly supplier side) |
| | Effectiveness of master production schedule | High (excellent efficiency) |
| | Capacity utilization | High (use of economies of scale) |
| | Inventory level | Low (avoid tied up money) |
| **Delivery Performance** | Delivery Performance | Reliable (use of procedures and rules) |
| | Level of sharing information | Medium (in some cases high) |
| | Responsiveness to urgent deliveries | Low (not prepared) |
| | Achievement of defect free deliveries | High (failures may result in loss of customers) |
| | Information richness in carrying out delivery | Medium (in some cases high) |
| **Customer Service & Satisfaction** | Flexibility of service systems to meet particular customer need | Low (not prepared) |
| | Level of customer perceived value of product | Low (product may be seen as commodity) |
| | Customer query | Low (may be seen as waste) |
| | Promotional Activity | Low (may be seen as waste) |

Table 8 – Summary Table - Chapter 6

## 7. Performance Evaluation of Agile Supply Chain Management

This Section presents the performance analysis for Agile Supply Chain Management. The performance evaluation will use the framework proposed by Gunasekaran et al. (2001) and also use the metrics selected in the Figures 11 to 15. Because it is a theoretical essay, we will seek to demonstrate the possible results for each of the selected metrics without the use of values or business data.

### 7.1. Plan Performance Evaluation

As before, the classification proposed by Gunasekaran *et al.* (2001) will be used at the performance analysis of Agile Supply Chain Management. The first field to be evaluated is *Plan Performance*. The metrics are showed in Figure 11.

When talking about Agile Supply Chain (ASC) Gattorna (2010) is pragmatic to state that "the winners in this environment are those that can respond urgently and effectively". Now, the dominant buying-behavior of customers is 'demanding/quick response' and responsiveness is the keyword to this universe where unexpected solutions or demands are commonly sought by them.

Often, this customer requires unpredictable products configurations or differentiated products and services. To meet these requests the ASC deals with innovative products which have short *Life Time* of 3 months up to 1 year. For the innovative product, the Product Life Cycle is quite different from the mature product (see below Figure 17). The Maturity Stage is no longer the most profitable. Now, the Maturity Stage is short because as the product has a specific applicability, when it reaches this stage the demand tends to be no longer so high. Consequently, the Growth Stage stands out as the most profitable with a high demand – or even the higher, as in the fashion-apparel market. (GATTORNA 2010; FISHER 1997; DAY 1981)

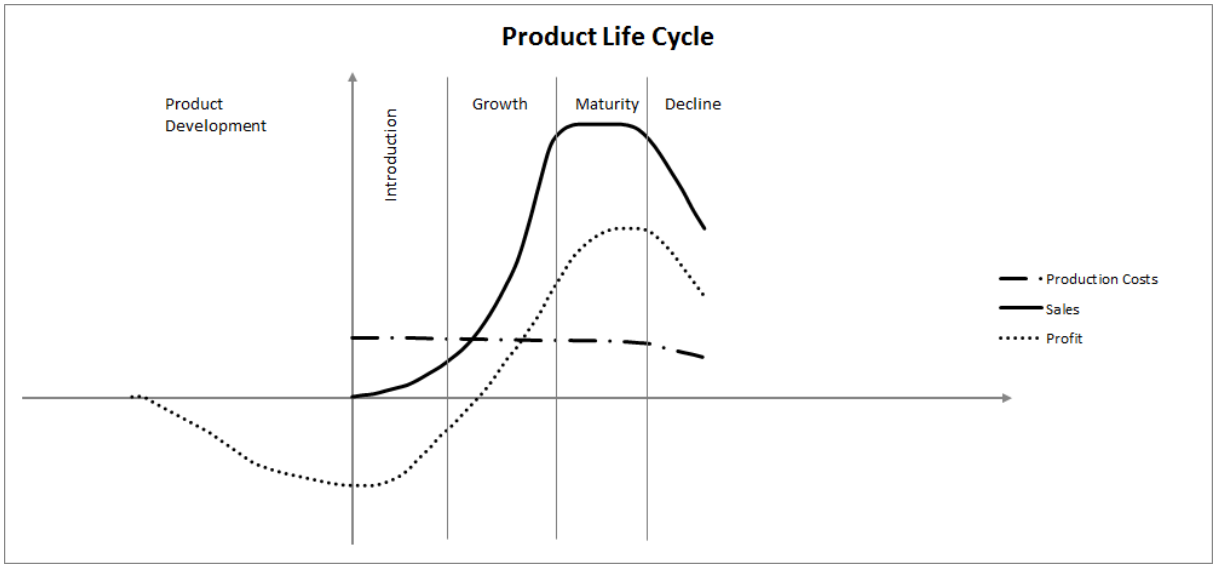


Figure 17 – The Product Life Cycle of an Innovative Product – Source: Based on Vernon, 1966.

However the necessity for specifics products makes the *Range of Products & Services* greater than in the LSC with millions of variants per category. And it also raises big problems for the forecasting area. The innovative products create unpredictable demands resulting in a low *Accuracy of Forecasting* of demand with errors of 40% up to 100% in extreme cases. As a solution, the forecasting must focus not on demand, but on the capacity required at different points along the supply chain. (GATTORNA *et al.*, 2009; GATTORNA 2010; FISHER 1997)

Gattorna (2010) asserts that the Agile Supply Chain "needs to focus on embedding responsiveness in the extended enterprise to match uncertain business conditions into the future." Working in this type of environment the innovation can come through different paths: natural evolution (adding value to an existing product), fast adaptation (adapting to stay ahead of competitors), forced adaptation (adapting to new market forces and conditions) or new product. (GATTORNA 2010)

Therefore, a strong branch of the ASC is the *Product Development* characterized by pro-active staff, fast and centralized decision-making, low bureaucracy and high cooperation (especially inside), ensuring innovation and quick responses to the market. Thus, this supply chain is well prepared for a Make-to-Order production with an *Order Lead Time* of 1 day to weeks and also for Make-to-Engineering with a *Product Development Cycle Time* that usually takes less than one year, or even a few months in low technological products. (GATTORNA *et al.*, 2009; GATTORNA 2010; FISHER 1997)

Of course, dealing with unpredictable products and high responsiveness involves a greater risk than dealing with mature products. So, to avoid the erosion of the margin, the

*Price Regime* must add incremental costs and/or a premium price, depending on the urgency or innovation involved. Thus, the *Rate of Return on Investment* by product is high and the profit comes soon, usually in the Growth Stage of Product Life Cycle (See Figure 17). However, with the short Maturity Stage, this supply chain must be prepared and mindful regarding the market in order to quickly answer when necessary, with an adaptation or even a new product. (GATTORNA 2010; FISHER 1997; DAY 1981)

Just like the LSC, the *Organizational Structure* of an ASC is molded on the customer's buying-behavior. The Hierarchical Organizational Structure is organized in clusters designed for speed, action-oriented and focused on the customer. The rules and procedures are seen as guidelines, and if necessary, for a better and fast response can be change or replaced. The working environment is pro-active, creative and embedded changes. It is common sharing responsibilities. The decision-making process is centralized to assure high and fast responsiveness, and it also embraces suggestions. It is normal teamwork and turnover of members between different groups to receive additional training. The key here is to be reactive either with speed and/or creativity. (GATTORNA *et al.*, 2009; GATTORNA 2010)

The *Cooperation and Sharing Information* follows the same mindset of the organizational structure. The communications are formal, regular and very action-oriented, but they are also totally open and it is preferable an impersonal tone or a face-to-face talk. Besides, to have a high responsiveness, the level of sharing information and cooperation inside the focal firma or with the strategic members of the supply chain is high and fast. The use of high technological software or equipment is normal to make the information flow through all supply chain. Thereby the *Information Carrying Cost* is high. (GATTORNA *et al.*, 2009; GATTORNA 2010)

### 7.2. Source Performance Evaluation

The metrics for the next field, *Source Performance*, are showed in Figure 12. The buying behavior of an ASC requires high responsiveness and needs pro-active attitudes and cooperation. So, to fulfill it the *Buyer-Supplier Partnership Level* must be high. In the Agile Supply Chain long-term partnerships between the firms with high sharing information and turnover of staff are common, especially when the focus is on developing new products, projects or technologies in a fast and creative way. And of course, at these strategic

partnerships the *Mutual Assistance in Solving Problems* are extremely high. There is an open communication channel between the key members. Speed is not just pivotal but also the innovation and creativity for the products or services have a paramount role. (GATTORNA *et al.*, 2009; GATTORNA 2010; STEWART 1995)

Nevertheless, when the supplier has no strategic advantage and is required from him fast responses with low innovation then the *Buyer-Supplier Partnership Level* is low and he may easily be substituted at an eventual problem or inconsistency. Thereby, the *Supplier Interest in Developing Partnership* is high. (GATTORNA *et al.*, 2009; GATTORNA 2010)

Thus, for strategic or non-strategic partners the *Achievement of Defect Free Deliveries* has high priority. In such a responsive market, suppliers can quickly lose clients when fail in a basic item. Besides, the *Supplier Delivery Performance* will be evaluated on speed, quality and punctuality. Here, different from the LSC, the cost has not such an important role. None rarely, outsourcing will be used in order to achieve the customer's expectations. For the suppliers it can be a window for new business opportunities, so they must be alert and prepared. (GATTORNA *et al.*, 2009; GATTORNA 2010)

### 7.3. Production Performance Evaluation

The *Production Performance* is the third field of performance to be evaluated. The metrics are showed in Figure 13. On the production terms, the ASC has one keyword: flexibility. Essentially, the production is the basic Make-to-Order. But with the low Forecasting Accuracy, the supply chain must always be prepared. Several different strategies and tools can be used to manage it, such as: Assembling-to-Order, Postponement, Outsourcing or even multiple production locations near to the point of consumption. Clearly the use of these strategies promotes the need for high *Level of Information Sharing* in both sides of the supply chain, supplier and customer-side. And the information must always be up-to-date. The order is to be pro-active and if necessary creative to fulfill the buying behavior. (GATTORNA 2010)

The *Production Plan* is characterized by a quick reaction focus with low volume production and high variety. Changes seeking improvement are normal in the production and the processes are always being refined. Furthermore, the unpredictable demand and the necessity for speed push the *Capacity Utilization* and force it to be low. Spare capacity (when possible), use of buffers, increase of capacity or extra manpower are commonly used. Also the

*Inventory Level* is controlled to always have an additional inventory for unpredictable demands. Beyond that, the *Effectiveness of Master Production Schedule* is high, but flexible too. (GATTORNA *et al.*, 2009; GATTORNA 2010)

### 7.4. Delivery Performance Evaluation

The forth field of performance to be evaluated is *Delivery Performance*. The metrics are showed in Figure 14. All the Agile Supply Chain focus on responsiveness and speed and it includes the Delivery, which can be an order winner. Once a date is defined the *Delivery Performance* must attend it with punctuality and reliability. The *Achievement of Defect Free Deliveries* is extremely pursued. (GATTORNA *et al.*, 2009; GATTORNA 2010)

With all the Supply Chain adapted to that, the *Responsiveness to Urgent Deliveries* is fierce. The use of high technological communication system is natural in this environment of high *Level of Information Sharing* with elevated *Information Richness in Carrying out Deliveries*. In some cases, the customer can receive up-to-date information of the product and follow it online. (GATTORNA *et al.*, 2009; GATTORNA 2010)

### 7.5. Customer & Service Satisfaction Evaluation

Based on the metrics of Figure 15 the last field to be evaluated is *Customer & Service Satisfaction*. The Agile Supply Chain is totally designed to perform responsiveness with speed to the customer. Still, when talking about the ASC Gattorna (2010) comes up with an interesting question: "is such an extreme response necessary for all customers?" The answer is no. It is necessary to cull the customers that the supply chain will attend and cut the rest out. Otherwise the supply chain will derail.

In this supply chain the relationship with the customer is closer and a lot of time and money are spent understanding the customer and its desires. Therefore, the *Customer Query Time* is elevated and all these information is carried to the spots where it can be fruitful, such as product development and production. As a result, the *Flexibility of Service Systems to Meet Particular Customer Need* becomes extremely high. At the same time, the *Level of Customer Perceived Value of Product* is also elevated and the customer pays for it. Besides, *Promotional Activities* are important tools fairly used to attract customers (GATTORNA *et al.*, 2009; GATTORNA 2010; HOOTS 2005)

### 7.6. Final Considerations of the Chapter

The chapter 7 presents the performance analysis of Agile Management Supply Chain Management. The following Table 9 synthesizes the chapter.

| Summary Table – Chapter 7 | | |
|---|---|---|
| **Performance Analysis of Agile Supply Chain Management** | | |
| **Plan Performance** | Product life time | Short (3 months up to 1 year) |
| | Rate of return on investment | High (return in the Growth Stage of Product) |
| | Range of products & services | Large (can be millions of variants per category) |
| | Cooperation and sharing information | High (action-oriented) |
| | Pricing regime | Price Premium (mainly high-tech products) |
| | Accuracy of forecasting | Low (unpredictable demand) |
| | Product development | Prepared to ensure innovation and quick responses to the market |
| | Order lead time | Short for innovative products |
| | Organizational structure | clusters action-oriented, focus on the customer |
| | Information carrying cost | High (action-oriented, creative) |
| **Source Performance** | Buyer-Supplier partnership level | High (focus on responsiveness) |
| | Supplier interest in developing partnership | High (long-term partnership are common) |
| | Mutual assistance in solving problems | High to Extremely High (long-term partnership are common) |
| | Supplier delivery performance | Speed and quality with innovation |
| | Achievement of supplier's defect free deliveries | High to Extremely High (failures can tarnish the company's image) |
| **Production Performance** | Production Plan | High Flexibility, high variety and low volume |
| | Level of sharing information | High (up-to-date/ use lean tools on both sides) |
| | Effectiveness of master production schedule | High (but flexible) |
| | Capacity utilization | Low (necessity for flexibility) |
| | Inventory level | Medium to high (prepare for the unexpected) |
| **Delivery Performance** | Delivery Performance | Fast and reliable |
| | Level of sharing information | High (use of top technologies) |
| | Responsiveness to urgent deliveries | Extremely high ( the ASC is designed for it) |
| | Achievement of defect free deliveries | High (failures may result in loss of customers) |
| | Information richness in carrying out delivery | High (use of top technologies) |
| **Customer Service & Satisfaction** | Flexibility of service systems to meet particular customer need | Extremely high ( the ASC is designed for it) |
| | Level of customer perceived value of product | High (innovative and in most cases high-tech product) |
| | Customer query | High (seek to understand the customer) |
| | Promotional Activity | High (attract new customers) |

Table 9 – Summary Table - Chapter 7.

## 8. Conclusion

The present market environment shows the necessity of more adapted management systems and strategies. As discussed before, nowadays the companies must work together with the same goals. Thus, the Supply Chain Management has been fairly used as a good solution. Nevertheless, there is not just one paradigm of SCM, but several. And it is essential identify which is the correct SCM to be applied.

Two of the main discussed paradigms of SCM are lean and agile. Over the Literature Review was clear the mismatch and confusion across the Lean and Agile SCM. It is common think that Lean SCM is the evolution of Lean Management and thereby, for some authors there was no Lean approach and for others the Agile and Lean were the same. This confusion happens because, as shown, lean tools, technics and philosophy are used on both approaches. However, this essay follows the classification proposed by Gattorna *et al.* (2009) because it is based on the customer's buying behavior rather than management techniques used.

Besides, the choice of Gattorna *et al.* (2009) to name Lean SCM is just because the similarities how both, Lean SCM and Lean Management, pursue minimization of costs, elimination of wastes and improvement of efficiency. On the other hand, the reason for Gattorna *et al.* (2009) call Agile SCM is its pursuit for speed and responsiveness.

Therefore, this study gives a better understanding and a broader picture of lean and agile SCM. Its originality comes from the new way that the SCM was analyzed, through several metrics and over five fields of performance proposed by Gunasekaran *et al.* (2001): Plan, Source, Production, Delivery and Customer & Service Satisfaction. The following Table 10 presents a summary comparison of both approaches.

This analysis made possible to see how the customer is impactful on the equation. He no longer just receives the product. Now, its wishes and desires will be the compass of all supply chain and it is according to the customers buying behavior that the strategies and the correct approach in the management of the supply chain will be defined.

According to Gattorna et al. (2009) the Lean SCM has a customer's buying behavior of "efficiency and consistency". This is a relentless and price sensitive customer that wants the same product-service experience. Thus, this essay shows that the Lean SCM is characterized by a MTF production plan of high effectiveness, accuracy of forecasting and reliability. The organizational structure is designed to avoid risks and wastes. It is not prepared to respond to urgencies and the unpredictable.

| Comparison Table | | | |
|---|---|---|---|
| **Supply Chain Management:** | | **Lean Approach** | **Agile Approach** |
| **Technical Features** | Buying Behavior | Efficiency/Consistency | Demanding/quick response |
| | Focus | High volume; Low variety; Low costs; MTF | Responsiveness; quick reaction; MTO or ETO |
| | Value Propositions | • Economies of scale<br>• Low-cost production & distribution<br>• Forecast demand<br>• High reliability | • Fast decision-maker<br>• Flexible<br>• Prepared for the unpredictable<br>• Available Capacity |
| **Plan Performance** | Product life time | Long | Short |
| | Rate of return on investment | Low | High |
| | Range of products & services | Narrow | Large |
| | Cooperation and sharing information | Low (concentrated) | High (action-oriented) |
| | Pricing regime | Low-cost | Premium (innovation) |
| | Accuracy of forecasting | High | Low |
| | Product development | Minimal innovations | High innovations(fast) |
| | Order lead time | Short for mature p. | Short for innovative p. |
| | Organizational structure | Avoid risks | Action-oriented |
| | Information carrying cost | Low | High |
| **Source Performance** | Buyer-Supplier partnership level | Medium | High |
| | Supplier interest in partnership | High | High (long-term) |
| | Mutual assistance | Low | High |
| | Supplier delivery performance | Consistency/ low-price | Speed/ innovation |
| | Supplier's defect free deliveries | High | High (and fast) |
| **Production Performance** | Production Plan | MTF | MTO or ETO |
| | Level of sharing information | High (supplier side) | High (both sides) |
| | Effectiveness of Master production schedule | High (efficiency) | High (flexible) |
| | Capacity utilization | High | Low (available) |
| | Inventory level | Low | Medium |
| **Delivery Performance** | Delivery Performance | Reliable | Fast |
| | Level of sharing information | Medium | High |
| | Responsiveness to urgent deliveries | Low | Extremely High |
| | Achievement defect free deliveries | High | High |
| | Information richness | Medium | High |
| **Customer Service & Satisfaction** | Flexibility to meet particular customer need | Low | Extremely High |
| | Level of customer perceived value of product | Low (commodity) | High (innovative p.) |
| | Customer query | Low | High |
| | Promotional Activity | Low | High |

Table 10 – Comparison Table – Source: Based on Tables 3, 4, 8 and 9

The product development sector on Lean SCM makes minimal innovations for longer life time and has difficulties to develop a new product. It is prepared to do the basics and the usual the best way possible, and nothing else.

Thereby, the Lean SCM has a clear focus on a narrow range of functional products of low-cost, long life time and low level of perceived value by the customer. The supplier side is characterized by price competition and reliability, with low mutual assistance. On the other hand, the delivery is reliable and based on procedures and rules with a medium level of sharing of information.

The disposable plastic cup is a good example of mature product managed in a lean SCM. It presents minimal variations (size and color) over the years, an extremely low technological improvement, and it is a low cost product of low perceived value by the customer.

The other paradigm, the Agile SCM attends a market segment that demands innovation and creativity on a fast way. So, Gattorna et al. (2009) suggested the "demanding and quick response" as this customer's buying behavior. Based on this buying behavior, this study shows that the Agile SCM has a production plan of MTO or ETO and it pursues high flexibility and fast reaction to market changes and necessities.

Its organizational structure is designed to be action oriented and creative. The decision making process is flexible and fast, assuring responsiveness. The product development sector is always looking the market's tendencies and needs. It is designed and prepared to create innovations and even new products on a short time.

Moreover, Agile SCM works with a large range of innovative products of short life time and high level of perceived value by the customer. The supplier side is characterized by speed, long-term partnership and high mutual assistance. The delivery performance must have responsiveness and for that employs top technologies with a high level of sharing of information.

The high tech cell phone is an excellent example of innovative product managed by an agile supply chain. Every year a new and innovative model of high technological improvement is released in the market. In order to fulfill quickly the customer's requirements it not just follow tendencies, but also creates new ones. Becoming a product of high-perceived value by the customer.

Thus, it is surely a smart decision to deeply analyze the supply chain characteristics and the customer's buying behavior to define the better management and strategies to be adopted.

Finally, this essay reinforces and empowers ideas of Gattorna et al. (2009) with the deep evaluation of the five fields of a SCM performance. And this study also opens new perspectives for future researches, whether theoretical or practical. It can be used as a guide in the analysis a company's performance over the five fields proposed and to assure that the efforts are not wasted and also assure compatibility between the customer's necessities and the supply chain goals.

## 9. Final Considerations

This work was done according a partnership between the Department of Production Engineering - University of São Paulo (Departamento de Engenharia de Produção - Universidade de São Paulo) and the Institute of Production Systems and Logistics - University of Hannover (Institute für Fabrikanlage und Logistik – Gottfried Wilhelm Leibniz Universität Hannover), tutored by Prof. Dr. Fernando César Almada Santos, Dipl.-Wirtsch.-Ing. Sebastian Beck and Dipl.-Wirtsch.-Ing Sebastian Bertsch.

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