Building Interdisciplinary Approaches within Management.

The Case of Quality and Logistics

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Στην Μάνα μου και στον Πατέρα μου. Ό,τι έχω κάνει και όπου έχω φτάσει είναι λόγω της δική σας αγάπης και συμπαράστασης.

Till Louise. Utan dig skulle denna resa aldrig ha blivit av. Jag är så glad att den fortfarande pågår.
Abstract

This research attempt, as its title witnesses, aims to build interdisciplinary approaches and to bridge gaps within management. Management and more specific, management of industrial organizations is a scientific discipline that consists of many different fields of interest. In industrial organizations, different parties of people, such as managers, engineers and workers are asked to communicate and collaborate towards common organizational targets and goals. This is where this research finds fertile ground, and tries to bridge the gaps between the quality management philosophy and corporate culture and the evolving, value adding functions and processes of logistics.

In particular, the gaps between quality management and logistics were bridged by a demonstration of the applicability of quality management practices –tools and methodologies- in a logistics context. This was conducted by an extensive exploratory research by means literature analysis of both management disciplines. The present situation, put in academic literature, was investigated and thoughtful reflections and suggestions for further use of quality management practices within logistics were provided.

All the quality management tools and methodologies examined were found, with one or another way, to be employed in logistics processes. Numerous examples demonstrating the universality of quality management concepts and techniques were identified. When it comes to the specific management area of logistics, eight quality management practices were found particularly useful, with three of them, namely Service Quality, SPC and Benchmarking to be well known, and to some extent, mature within logistics. However, empirical research, of qualitative and quantitative nature, is needed to confirm the trends recognized here.

The suggestions and reflections provided throughout this work indicate actions to be taken by logistics managers, in order to apply well known and widely accepted, cost saving and quality improvement, practices to their operations. In addition, these suggestions and their potential, constitute a challenging field for further research were new, applicable to logistics, quality management tools and methodologies can be found and ones that already exist can be enhanced.

The originality of this work can be found in that it thesis tries to bring conceptually closer two management areas that although have many values in common are not perceived as working on the same track, towards the same goals. This research adds value in the way that illustrates, in an extensive and formal way, that there should be no barriers within management.

Keywords: Quality Management, Logistics, Tools and Methodologies, Applicability, Exploratory Research, Literature Review
Acknowledgements

It is not easy to conduct such a daunting task as the writing of a master’s thesis. And it is makes it much more difficult the fact that nobody is around to help and accommodate you. However, in writing this thesis this was not the case. On the contrary, a number of people helped and stood by me. At this point, a futile attempt to put on paper the expression of my enormous gratitude to them will be carried out.

Initially, I will like to thank everyone in the Quality Technology and Management division. They instantly welcomed me in their family, and showed interest to my early, draft ideas about this thesis.

My special appreciation is given to my supervisor, Jostein Pettersen. He was to me more than a mere supervisor. He was my mentor and my friend. By his recommendations, he delighted my thoughts and attributed to my hunger for more knowledge. It is not an exaggeration to say that this thesis is a product of a team work, and is as much as mine as his.

It is not possible to squeeze in a few lines my gratitude to my parents and to my entire family; however a word of notice will be put here. Although away from them all this time, we were at the same time really close. By their true love and compassion I managed to get through this program and to reach my goals.

The last lines of this section were intentionally left to thank Louise. Without her and her love, the fact that I am now graduating from such an institution would have never been true. She did everything she could to provide me a convenient and joyful stay in Linköping. By far the most important contribution of her is the smile she had in her face and was instantaneously transferred to mine, when I was coming home late and tired during the long nights of the Swedish winter. Finally, I will like to thank her for presenting this city and this country as my home and to apologize for making her spend one and a half year with a man full of stress and anxiety.

Linköping, 4th of June 2008
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Part I
This is the opening part of the thesis. As in every academic text, this part will establish a first contact with the thesis contents. Its goal is to introduce the reader to the question this thesis is seeking an answer for, and why this undertaking is important. The approach to the problem will also be provided, as well as delimitations that the author faces in this endeavor.

After reading this part the reader will be able to understand why this thesis was undertaken, why this thesis is important, what went before in the thesis’ subject, and the way the thesis’ question will be addressed in the following part.

The contents of this part are:
Chapter 1 – Introduction
Chapter 2 – Background
Chapter 3 – Conceptualization of the Thesis’ Question
1 Introduction

In this opening paragraph, the area the thesis is concerned with will be discussed. The reader will be introduced to the particular question this thesis is seeking to answer. This paragraph is not intended to be a summary of what follows, but a preface to the main body of the thesis. An attempt is done to inform the reader of what the question is why this specific question is important and finally, how an answer will be provided.

1.1 A Thesis of an Interdisciplinary Subject

In any research effort, as well as in a master’s thesis, the ultimate goal is to track down a question or a problem and try to solve it. This is mainly done by applying various theories and techniques, which have been acquired during the author’s previous education; these are then put down in a form of a research paper. When it comes to the research attempt at hand, the area that is concentrated on is interdisciplinary.

The necessity for an interdisciplinary approach derives from the fact that yesterday’s trend for high specialization in education and research is challenged more and more day by day. Old practices of fragmentation among divisions such as finance, marketing, engineering, manufacturing etc. is left behind (Clark and Wheelwright, 1992). Nowadays, in professional as well as in academic environments, work is carried out in the form of either permanent cross functional collaboration among different departments and functional areas, or temporary project teams (Clark and Wheelwright, 1992). People that form those teams come from different educational backgrounds, and at the same time, have different career aspirations. On the other hand, these people are employed by the same company and share common goals and the responsibility for reaching them (Dahlgaard et al., 1992). Thus, in order to achieve a better integration and cooperation between the members of those teams, a common language must be established.

1.2 Purpose and Research Issues

Taken the recent trends in professional and academic life into account, this thesis tries to mingle the total quality management company philosophy and culture (Dahlgaard et al., 1998) with the value added perspective of supply chain management and logistics (Fawcett and Fawcett, 1995). Towards this direction, an explanatory research is conducted. The aim of this research is to demonstrate the applicability of quality management practices, i.e. tools and methodologies, to a logistics context. This will be conducted by means of a literature review that will highlight how quality management techniques are used in logistics. Furthermore a conceptual discussion of potential expansion of its use will be provided. More specifically, these practices will be classified according to their employment in logistics. In addition, a study of the way these practices are used in logistics will be conducted and finally, some suggestions regarding the further promotion and endowment of these applications will be provided.
The quality movement has received considerable attention internationally. In 1992, a vast survey was conducted by Ernst & Young and the American Quality Foundation, where 580 organizations in four countries were asked to indicate if they implement any quality management practice. 945 quality management practices were assessed (Ernst & Young and The American Quality Foundation, 1992). In addition, the number of surveys, examining the quality management practices implemented in various industry types and geographical regions (Ismail and Maling 2002; Khanna, 2006; Mellat-Parast et al., 2007), has been increased rapidly. But these practices, which were born in the manufacturing and operation functions of firms, have not yet taken their full potential when it comes to logistics.

To highlight the need for such a study, a reference to the way companies compete on the marketplace must be done first. On a strategic level, a company must understand its markets in the way its products or services qualify and win orders. This is done by mainly four means of differentiation: price, quality, delivery and flexibility (Hill, 2000). Recent studies indicate that delivery and flexibility are no longer secondary attributes placed in the shadow of price and quality when it comes to winning orders (DeMeyer et al., 1989). A low price and a standard quality level are nowadays taken for granted by customers (Kano et al., 1984). Achieving those will only allow an offer to be considered in the eyes of the customer. Orders are won nowadays through the complete alignment with the customers’ evolving needs and expectations. This alignment can only be achieved with the development of such a company culture and management philosophy that facilitates the focus on the customer.

The flexibility to adapt effectively and efficiently to the customer’s requests and the ability to deliver the order, with the right product, at the right time and in the right quantity will distinguish a firm from its competitors (Lambert et al., 1998). This is where the logistics function of a firm can contribute, and this is why examining the quality management practices implemented on this function is important.

### 1.3 Delimitations

The way the thesis question will be answered is as mentioned before through an exploratory research. The research is exploratory in the way that the area of investigation is not clearly defined and preliminary information can gathered that will help to better define problems and suggest hypotheses for their solutions (Kotler and Armstrong, 1997). There is much research done on how quality practices are implemented in manufacturing, but little on logistics. The six steps to Six sigma and the DMAIC process, lean production, standardization are just a few of the roadmaps to be followed to achieve and maintain excellence in production and manufacturing operations (Dahlgaard and Dahlgaard-Park, 2006), but what about logistics?

The specific exploratory technique that is employed is secondary data analysis. Studies by other researchers and practitioners are examined, providing significant amount of historical data that can identify methodologies that proved successful and unsuccessful (Blumberg et al., 2005). Further investigation can be build up on those historical data and supplementary knowledge can be achieved. On the

---

1. get and keep companies to markets (Hill, 2000)
other hand, it is seldom the case that more than a fraction of the existing knowledge of that field is put into writing, giving such research methods little space for additional generalizations (Blumberg et al., 2005). Hence, generalization will be left outside form the thesis’ purpose. The main contribution of this thesis will be given through a presentation of the improvement potential of the way quality management practices are utilized in logistics and through suggestion for the further employment of these practices in a logistics context.

1.4 Structure

The thesis consists of fourteen chapters that in turn form three parts. These three parts are related to each other and together shape the body of this thesis. The first part, as well as the third part, is structured in a serial manner and the reader should go through it sequentially. On the other hand, the second part consists of rather independent chapters. It is possible for the reader to study each chapter in a random order or to concentrate on a specific chapter of interest. However, it is the author’s suggestion to read this part in a sequential manner as well, since its succession is designed according to the Deming’s quality cycle Plan-Do-Study-Act, (PDSA), one of the cornerstones of total quality management. Browsing, the second part serially, and according to the PDSA cycle, will also further illustrate another application of quality management to logistics.

Part one is employed as an opening and preparatory division of the thesis. It consists of three chapters, namely, introduction, background and conceptualization of the thesis’ question. The starting chapter introduces the reader to the purpose of the thesis and the research delimitation the thesis faces. The successive background chapter provides information to the reader with respect to the history and terminology of quality management as well as logistics. The reader is benefited by the awareness of earlier and current research on these areas. The third and last chapter of this part articulates and analyzes extensively the research question stated previously. Through the use of numerous figures, the research question of the thesis is made clear and the reader is familiarized with the viewpoint and structure of the subsequent chapters.

Part two, which is the largest part and the main body of this thesis, consists of six fairly independent chapters. In each of these chapters, a specific quality management tool or methodology is examined with respect to its applicability on logistics. A presentation of each tool or methodology opens each chapter, which is then followed by an examination and review of literature. The selected literature, utilizes each specific quality management practices on a logistics context. Each chapter then closes by a reflection paragraph that addresses the thesis question. The tools and methodologies of quality management studied throughout this thesis work are namely, the service quality concept of perceived quality, the Kano model for customer satisfaction, the quality function deployment technique, the Taguchi’s robust design methods, the statistical process control techniques, the capability measures, the six sigma improvement methodology and the benchmarking studies, which roughly correspond on two tools and methodologies for each step of the PDSA cycle.
Part three, finally has a closing role and is employed to conclude the work done in the previous part of the thesis. It is comprised of three chapters. In the first chapter of this part, namely, bringing all together in a conceptual framework, an analogy with the last chapter of the first part, i.e. conceptualization of the thesis question, is attempted. Again, numerous figures are utilized to refine and sum up the work carried in the previous part. The second chapter of this part is established to draw some conclusions and give some directions for future research. Finally, the last chapter of this part and of the thesis in general provides the references of the literature used previously.
2 Background

In this section some measure of background information will be provided. A reference to the history, together with some terminology of the two areas under examination – quality management and logistics – will be given. Due to the interdisciplinary subject of this thesis, it is expected that the reader will benefit from a section that states the previous and current research on quality and logistics management respectively.

2.1 Brief History and Terminology of Quality Management

There is a vast research work on the history of quality. Many researchers have studied how the quality issue has evolved (Juran, 1995; Kruger, 1999; Dahlgaard-Park, 2000). From the ancient civilizations, with the construction of temples and roads, to the medieval times and the modern industrial society, the journey of quality still attracts more and more attention (Juran, 1995). In this section, a brief history of quality will be given, within a framework of three quality eras. In particular, the history of mankind when it comes to quality will be divided in the era of craftsmanship, the era of industrialization and the post World War II era.

2.1.1 The Era of Craftsmanship

To be able to understand the status of quality, one has to go back to the formulation of professions. By the time people started to gather into communities and establish cities the need to address the growing and specialized desires of the society led to the formulation of professions. Each art was employed by an artisan. This artisan was the only one capable for this art and was passing the skill to his successor, usually, from father to son. Around the twelfth century, when cities expanded, free artisans joined together in associations of each product (Spraul, 1957). These, “guilds” controlled the professional behavior of their members, in terms of obligatory membership in order to follow a profession, and also obligatory training and examination from masters to junior workers. In addition, craftsmen were only allowed to practice their profession if they performed exactly to its agreed and detailed set of directions, which was an early form of quality control policy. In that way, the interests of the craftsmen (having a safe protection from competition) and of the consumers (the guarantee of the product’s quality, directed by the association) were protected (Spraul, 1957). These associations were mostly found in Europe, and especially in central Europe (Kruger, 1999). In addition, this form of professional organization was also found; although in a less extend, in East Asia (Dahlgaard-Park et al., 2001). In Britain, on the other hand, these guilds lost their strength when the state seized their properties in the sixteenth century (Kruger, 1999). The following years, quality control was making progress, in particular, through technical innovations (Kruger, 1999), which ultimately led to the industrial revolution.
2.1.2 The Era of Industrialization

During the eighteenth and nineteenth century, in central Europe, guilds were still influencing the professional life in the form of chambers of handicrafts; the basic structures of the guilds which were developed for many years, offered a firm and solid basis for the expansion of industrialization in Europe (Kruger, 1999). Coming to the beginning of the twentieth century, on the other side of the Atlantic Ocean, following the industrial revolution craftsmen in United States become factory workers and masters became work supervisors. The Americans, by following the Frederic Taylor’s approach of scientific management and Henry Ford’s main concept of productivity, managed to achieve economic growth by enhancing quantity in expense of quality (Juran, 1988). Quality was regarded as responsibility of specialists, and was placed in the end of the production process in the form of inspection of finished goods. This productivity approach was unquestioned until the 1970’s, when this approach was not enough to deal with the fierce competition and dominance of the higher quality and lower cost products from Japan (Kruger, 1999).

Going back to Europe and to Britain, concurrently with the rise of productivity, the research interest in applied statistical techniques grew bigger. It was then that the statistician Gosset laid the mathematical foundations for the development of statistical quality control. The English school of statisticians, established at the beginning of the twentieth century, stimulated at the further development of the statistical quality control (Morrison, 1990). In 1932, Shewhart was invited to the University of London to give lectures in statistics and it was then that he suggested the first tools for statistical quality control, the control charts (Morrison, 1990). This can be said that is the first systematic approach of quality, or the birth of the modern quality control (Dahlgaard-Park et al., 2001). Although the (following) World War II acted as a stimulus towards statistics and the quality control, by providing applications for control charts, these concepts did not have the proper attention during peacetime in the Europe and USA as in Japan.

2.1.3 The post World War II Era

By the prevalence of peace in the world, the West and East found themselves in completely different positions. In America, the economic environment was dominated by a ‘command economy’, where any product was sold as soon as it was produced. The productivity approach and the promotion of quantity in expense of quality was a fine tuned machine and there was no reason for anxiety. Thus, there was no motivation for the Americans to implement quality control methods (Dahlgaard-Park et al., 2001).

On the other side of the world the situation was much different. All Japanese industries were destroyed. The economy was in ruins. In addition, the lack of natural resources made things worse. In this urgent task for survival, Japan answered with a will to produce superior industrial products, which will be exported to, foreign countries (Fukukawa, 1990; Dahlgaard-Park et al., 2001). For this purpose, American scientists like W. E. Deming and J. M. Juran were invited to Japan to teach quality methods and ideas (Ishikawa, 1986). By the late 1950’s, the words of Deming and Juran found interested ears in Japan. In addition, the Japanese scientific community launched vast training programs in quality techniques, not only to engineers and senior management, but also to the
shop floor workers and high school students. To highlight the extent of this absorption of knowledge effort, it should be mentioned that even means of public communication, like radio and television, were used for that purpose (Dahlgaard-Park et al., 2001).

In the beginning of the 1960’s, the concept that helped the Japanese to surpass the westerners was the concept of everyone’s involvement in quality control. This is when the foundation of Company Wide Quality Control or Total Quality Control was established. Especially in the automotive industry (Japan’s most profound victory over the West), this Company Wide Quality Control philosophy was combined with everybody’s effort for the reduction of Waste (Muda), i.e. everything that increases cost without adding value to the customer, (Dahlgaard et al., 2000). This effort gave birth to the Lean Production System (Krafcik, 1988) and Just In Time or Kanban systems (Udagawa et al., 1995). These production philosophies can be summed up to the continuous effort to use fewer resources (e.g. power, inventory, transport), the exact time that is needed, to produce the same or even bigger amount of products (Dahlgaard al. 2001). By applying these philosophies the Japanese products managed to prevail in the world markets by the 1970’s.

With the loss of market shares, Americans and Europeans noticed the significance of quality methods. Until that time, quality was seen as an engineering procedure. It was at the 1980’s that western management realized the vital importance of total quality, company wide quality control and the need for active and total participation of management as well as employees (Kruger, 1999). In this business context, every department manager and every employee is now responsible for his results and deliverables (Mangelsdorf, 1999). In this period, there was an attempt by many theoreticians to develop a holistic or synthetic theory of quality management. The relevant theories and practices taken from Japan were combined and the term Total Quality Management was then used instead of Total Quality Control (Dahlgaard-Park et al., 2001). In addition, during that period quality awards were established in the United States and Europe, to further promote the employment of quality movement across the western industry.

### 2.1.4 The Shift from “hard” to “soft” Quality and the Direction towards Business Excellence

While attaining a deeper understanding, the applications of quality management further expanded and transformed. From the ‘hard’ engineering concept of statistical quality control performed by technicians and mostly applied in manufacturing industries, quality management evolved to the total quality management philosophy and culture where the ‘soft’ managerial side of quality is more emphasized and all functional groups within a company are involved (Dahlgaard-Park et al., 2001). In today’s trend to achieve ‘Business Excellence’, the need to incorporate the impact on the wider society became an explicit and important element of the quality movement, making quality management even ‘softer’ (Dahlgaard-Park et al., 2001).

The shift to a more ‘soft’ perspective of quality management can be seen more explicitly in the shift of the viewpoint of the gurus of quality. When Deming started to teach quality in Japan, in the early 1950’s, he taught ‘hard’ statistics, but in the 1990’s he switched to a more ‘soft’ approach with ‘The System of

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Part I

Profound Knowledge’ (Deming, 1993). Moreover, Juran’s early definition of quality cost, in 1951, was a more engineering definition about the production of defects, while his definition in late 1980’s was a more holistic definition about the sum of all costs that could be avoided by the use of quality management (Juran, 1988).

Figure 2.1: The evolution of quality management. Modified from Dahlgaard-Park et al. (2001)

2.2 What is Logistics? The CLM Definition

There are many definitions of logistics as there are logisticians (logistics practitioners). Logistics has been called by many names, Business logistics, Logistics Management, Distribution, Physical Distribution, Supply chain management to mention a few. What the above terms have in common is that they deal with the management of the flow of materials from the point of origin to the point of consumption (Lambert et al., 1998). According to Kent and Flint (1997) definitions for logistics have evolved during the twentieth century. In the early 1990s, definitions of logistics were focused on merely transportation and physical distribution within the marketing domain, to become the contemporary concept logistics, focused on conforming to customer requirements.

The world’s most prominent organization for logistics professionals, the Council of Logistics Management (CLM), on an attempt to give a clear description on what logistics is, defines logistics as follows:

*Logistics is the part of the supply chain process that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet the customer’s requirements.* (Murphy and Wood, 2004: p. 6)
2.2.1 Analysis of the CLM Definition

In this section a brief analysis of the CLM definition of logistics will be given, excluding the relationship between logistics and supply chain management which will be discussed later. The general terms of effectiveness and efficiency are used in the context of how well the company do what they say they are going to do (e.g. percentage of orders shipped on time or customer service), and of how well the company used its resources to do that (e.g. monetary units per shipment or cost leadership) respectively (Mentzer et al., 2004; Murphy and Wood, 2004).

Logistics has traditionally been focused on the forward flows and storage, i.e. from the point of origin towards the point of consumption. Lately, the interest on reverse flows, or reverse logistics, i.e. those that originate at the point of consumption (Murphy and Wood, 2004) is increasing. Higher product return rates (due to new ways of purchasing, e.g. internet shopping), attractive profits from remanufacturing of technical products, materials recycling and governmental waste management directives are only some of reasons for the increasing importance of reverse flows (Guide, 2000; Rogers and Tibben-Lembke, 2001).

Logistics is also as much about flow and storage of information as it is about storage an flows of goods. With the advances in information technology on hand and the implementation of electronic data interchange (EDI) systems, it is less costly and easy for a company to substitute information for inventory (Murphy and Wood, 2004).

Finally, the definition indicates that the purpose of logistics is to meet the customer requirements. Logistics strategies and activities should be based upon each individual customer’s wants and needs, and companies should communicate with their customers in order to learn about their wants and needs (Murphy and Wood, 2004).

2.2.2 Logistics and Supply Chain Management

The CLM definition of logistics states that logistics is part of the supply chain. These two terms are often confused and viewed as overlapping. In an attempt to clarify their differences Cooper et al. (1997) defined supply chain management as:

Supply chain management includes the integration of business processes from end use through original suppliers that provides products, services and information that add value for customers. Supply chain management is not just another name for logistics and includes elements that are not typically included in a definition of logistics, such as information systems integration and coordination of planning and control activities. (Cooper et al., 1997: p. 2)

By adopting this framework, logistics takes place within supply chain and seems to be more tactical or operational. Logistics is a function which is performed within a given supply chain at multiple locations (e.g. supplier to manufacturer, manufacturer to distributor, etc) involves mainly the flow of physical goods and information. Thus, logistics could be considered as the implementation and execution of supply chain activities. Supply chain management, on the other hand, might be viewed as more strategic in nature, and includes the integration and coordination of planning and control activities among the participating firms (Lummus et al., 2001).
2.2.3 Logistics History

Logistics’ history can be tracked down to the first days of commerce and transportation of goods between ancient nations and the movement of army troops during peacetime and wartime respectively. According to Kent and Flint (1997), the contemporary logistics thought started to evolve at the beginning of the twentieth century. Logistics thought (here the military logistics part is excluded), initially was focused on transportation based primarily on agricultural economics (Crowell, 1901). During the past decade logistics importance increased to a key component of business strategy, differentiation and link to customers (Kent and Flint, 1997). The view of logistics as an integral part of collaboration between members of supply chains is up to date dominant (Lummus et al., 2001; Murphy and Wood, 2004).

In an exploratory field study conducted by Kent and Flint (1997), seven leading academics in the field of logistics were interviewed. The finding of this research was a time classification of the key concepts of logistics thought. The figure below summarizes this taxonomy.

<table>
<thead>
<tr>
<th>Major Characteristics</th>
<th>Major Influences</th>
<th>Eras</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>-Agricultural Economics</td>
<td>Farm to Market</td>
</tr>
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<td>-Farm to Market</td>
<td>-Military Operations</td>
<td>1916-1940</td>
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<td>Physical Distribution</td>
<td>-Industrial Economics</td>
<td>Segmented Functions</td>
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<td>-Independent Functional Areas</td>
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<td>1940-1960</td>
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<td>-Systems Approach</td>
<td>-Management Science</td>
<td>Integrated Functions</td>
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<td>-Integration of Logistics Functions</td>
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<td>1960-1970</td>
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<tr>
<td>Customer Service</td>
<td>-Information Technology</td>
<td>Customer Focus</td>
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<td>-Productivity</td>
<td>-Management Strategy</td>
<td>1970-mid 1980s</td>
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<tr>
<td>Integrated Supply</td>
<td>-Marketing</td>
<td>Logistics as Differentiator</td>
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<td>-Globalization</td>
<td>-Social Science</td>
<td>mid 1980s-late 1990’s</td>
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<td>-Reverse Logistics</td>
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<td>Behavioral, Boundary Spanning</td>
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<td>Service Response</td>
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<td>late 1990’s-present</td>
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<td>Logistics</td>
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<td>-Theory Development</td>
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*Figure 2.2: The evolution of Logistics. Modified from Kent and Flint (1997).*
2.2.4 Logistics components

In this section the key components of logistics management will be discussed and will be placed in the context of supply chain management. As stated previously the terms of supply chain management and logistics are usually confused. The main difference between these two terms is that supply chain management incorporates the strategic decisions among the member firms of the materials and information flow channel (Lummus et al., 2001). The main management actions that take place at this level are planning and controlling of the goods and information flows between the members (Murphy and Wood, 2004). On the other hand, logistics includes the tactical and operational decisions regarding these flows mainly on the span of a single member of the network. These actions however, involve different functions within a firm and have boundaries spanning across firm aspects (Mentzer et al., 2004).

Logistics is commonly examined as a system. As the case with every system, logistics has inputs, processes and outputs. Logistics is depended upon natural (land, facilities and equipment), human, financial and information resources as inputs. Suppliers provide the material, which logistics manages their forward and reverse flow, in the form of raw material, in process inventory and finished goods. In addition, logistics manages and distributes properly all the relevant information. The effective and efficient performance of the logistics activities, which are seen as the core logistics processes, make it possible to produce the key logistics outcomes, effective (customer service) and efficient (cost-leadership) movement, time and place utility (logistics added value) and proprietary asset (competitive advantage).

The outputs of the logistics system are what make logistics significant. While effective and efficient movement of goods and information are of well known significance for the survival of any firm operating in a supply chain context, the thing that differentiates logistics from the other functions of an organization is the utility and proprietary asset logistics outputs.

One of the fundamental ways logistics add value is by creating utility. From an economic standpoint, utility represents the value of usefulness that a product or service has in fulfilling a want or need (Murphy and Wood, 2004). There are four types of utility: form, possession, time and place (Murphy and Wood, 2004). While form and possession utility are regarded as not affected by logistics (affect most by production and financing respectively), time and place utility is where logistics contributes. Neither the value added by having a product or service when is needed (time utility), nor the value added by having a product or service where it is needed (place utility) would be possible without getting the right amount of the right product, or service needed for consumption or production, to the right place at the right time in the right condition at the right price with right information (Stock and Lambert, 1987; Lambert et al., 1998). These “seven rights of logistics” credited to E. Grosvenor Plowman (Gecowets, 1979) are the essence of the value addition provided by logistics (Stock and Lambert, 1987; Kent and Flint, 1997; Lambert et al., 1998).
Maybe the most remarkable thing about logistics is that is itself a competitive advantage for a firm, in a way, it could be said that logistics is a proprietary asset of the organization (Lambert et al., 1998). Logistics resources (Olavarrieta and Ellinger, 1997) can be tangible (e.g. distribution centers, transportation equipment) and intangible (e.g. management skills, corporate culture and expertise) (Mentzer et al., 2004). This heterogeneity of resources together with the knowledge accumulated in a company (collective memory of past problems and solutions) form a unique logistics service mix. This mix constitutes an advantage that cannot be transfer from one firm to another, even with the transfer of an employee from one firm to another (Mentzer et al., 2004). Thus, this advantage is inimitable and it could be say that is a proprietary asset of a firm.

**Figure 2.3:** The logistics components in a supply chain context. Modified from Lambert et al. (1998).
3 Conceptualization of the Thesis’ Question

After the provision of some background information in the two research areas of quality management and logistics, the question stated in the introductory paragraph will be further articulated and conceptualized. The reason for doing the previous is that the reader will be better able to understand and follow the pages that come after, in the main body of the thesis.

3.1 Quality and Logistics Entities

As stated in the introductory paragraph, quality management practices although well known and understood among managers and engineers have not reached their full potential when it comes to logistics operations. Compared with manufacturing and production operations, logistics is not perceived as a field of challenge for new management philosophies, such as quality management, although it should be.

In this thesis, quality management is seen as a radiation source which spreads out principles and methods that have changed, and still change the way business is done today (Ernst & Young and The American Quality Foundation, 1992; Khanna, 2006; Mellat-Parast et al., 2007). The view of total quality management as a management system, proposed by Hellsten and Klefsjö (2000), will be utilized to carry out this thesis’ analysis. According to this view, quality management is a management system consisting of three independent and at the same time interrelated components, namely, values, methodologies and tools. These values, methodologies and tools are widely accepted and successfully implemented in almost every field of contemporary business (Ismail and Maling, 2002).

3.2 Quality as a Management System

In an attempt to present total quality management as a management system, Hellsten and Klefsjö (2000), influenced by Deming’s definition of a system,

A system is a network of interdependent components that work together to try to accomplish the aim of the system. (Deming, 1994: p. 50)

developed a conceptual representation of total quality management as a system consisting of three interdependent and interrelated components:

- **Core Values**, which are the basis for the culture of the organization.
- **Methodologies**, which are ways to work within the organization to reach the values.
- **Tools**, which are concrete and well defined means for decision making and data analysis support.
To ensure a successful quality management implementation, total quality management must be seen at its whole entity. Hellsten and Klefsjö (2000) conclude that fragmental implementation of total quality management, (e.g. few tools or methodologies) will ultimately lead to failure. To ensure a successful quality management implementation and development, Hellsten and Klefsjö (2000) suggested that an organization must establish its quality management strategy. Top management should determine which core values should characterize the organization. After the core values are established the methodologies that support these values should be identified and finally, the tools that support those methodologies should be used effectively in order to achieve the aim of increased external and internal customer satisfaction with a reduced amount of resources.

**Figure 3.1:** Total Quality Management as a management system consisting of values, methodologies and tools. It is important to note that the values, methodologies and tools in the figure are just examples and not a complete list. From Hellsten and Klefsjö (2000).

**Figure 3.2:** Role of core values, methodologies and tools. From Hellsten and Klefsjö (2000)
3.3 Logistics in an Attempt towards its Unified Theory

On the contrary to quality management, logistics is seen as a business function and an academic research area that is in the process of absorbing ideas and techniques from other research disciplines, such as economics and marketing, in an attempt to develop its own unified theory, i.e. a theory of the role of logistics in an organization, (Mentzer et al., 2004). Logistics has throughout its evolution process been influenced by other research disciplines, in the way its major characteristics and focus were formed (Kent and Flint, 1997).

![Figure 3.3: Input and influences to logistics](image)

3.4 Quality and Logistics put together

In this thesis these two entities\(^2\), quality and logistics, are put close to each other in an attempt to examine and understand if one affects the other and the way this is done; see figure 3.4.

![Figure 3.4: Quality and Logistics entities put together](image)

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\(^2\) From now on, the general term entity will be used instead of the terms business function and academic research area
3.5 First Level Analysis, Classification

At this initial level of analysis, the purpose is to examine if a tool or methodology which is part of the quality management entity and is transmitted across the academia and practice, is adopted or not in logistics. A secondary data analysis, by means of textbooks and academic journals review, will be conducted to classify a number of tools and methodologies of the quality entity regarding the utilization of these in logistics. For this purpose, a binomial approach will be utilized; tools and methodologies of the quality entity will be seen as either used or not used in the logistics entity. A tool or methodology will be considered as used if it is adopted in the logistics context, either in its original form or modified. On the other hand, a tool or methodology will be considered as not used if it is not adopted in logistics. At this level, there will be no examination with respect to the reasons why these tools and methodologies are not implemented. This analysis will be conducted further, in a lower level of the analysis hierarchy.

![Figure 3.6: Adoption and Non Adoption](image)

3.6 Second Level Analysis, Investigation

After examining whether a tool or methodology has found a fertile ground in the logistics entity or not, the next level of analysis is a deeper investigation. In case a tool or methodology is used, an examination of how that tool or methodology is used to support the values of quality management in logistics will be carried out. On the other hand, when a tool or methodology is found not used in logistics, a possible interpretation of the reasons why it is not used will be presented. Articles and textbooks that deal with the implementation of these quality components into logistics will be thoroughly studied and reflections and insights on these will be provided.
3.7 Third Level analysis, Suggestion

At the third and final level of analysis, suggestions for the further implementation of quality management practices to logistics will be provided. Regarding the tools and methodologies that were found to be used in logistics, ideas for a better and more extensive implementation will be offered. Concerning the tools and methodologies that were found not to be used in logistics, thoughts and reflections for the enhancement of the merge of those with logistics will be proposed.

3.8 Thesis’ Contribution

The contribution this thesis is going to give can be summed up as a demonstration of the applicability of quality management practices in logistics. More specifically, tools as methodologies of quality management will be classified as used or not used in the logistics context. In addition, an investigation of the way these practices are used, or not will be carried out in the second level. Detailed description of the practices found in literature will be presented and analyzed. Furthermore, some insights and reflections on the potential endorsement of quality management practices in logistics will finally, be provided in the third and last level analysis.

The outcome of this thesis will aid future research efforts to further promote the use of quality management practices to a business area as important and vital for every organization as logistics (Murphy and Wood, 2004). Specifically, in the quality management tools and methodologies which found to be used in logistics, suggestions and possibilities for their further and more extensive application will be given. As a final point, the quality management tools and methodologies which found to be not used in logistics a conceptual bridge between the two entities will be offered.

Figure 3.5: Illustration of the thesis’ contribution
Part II
This is the largest and main part of the thesis. Its goal is to satisfy the purpose of the thesis, i.e. to demonstrate the applicability of quality management practices –tools and methodologies– to a logistics context.

After reading this part the reader will acquire a deeper understanding of a number of quality management practices and their applications in logistics. In addition, critical reflection on the previous will be provided that will benefit the reader on his or hers future research.

The structure of this part follows the PDSA improvement cycle, with roughly two chapters for each cycle step.

The continents of this part are:

Chapter 4 – Service Quality in Logistics, Plan
Chapter 5 – The Kano Model in Logistics, Plan
Chapter 6 – Quality Function Deployment in Logistics, Do
Chapter 7 – Robust Design in Logistics, Do
Chapter 8 – Statistical Process Control in Logistics, Study
Chapter 9 – Capability Measures in Logistics, Study
Chapter 10 – Six Sigma in Logistics, Act
Chapter 11 – Benchmarking in Logistics, Act
4 Service Quality in Logistics

As stated before, this chapter, together with the next one, corresponds to the Plan step of the PDSA cycle. The Plan step roughly, deals with understanding and defining the problem and its potential for improvement. This step is perhaps the most important step of the improvement cycle, since it is futile, if not silly, to try to improve something that you do not understand (Dahlgaard et al., 1998). Thus, failing in understanding the subject of improvement will ultimately lead to the failure of the improvement attempt itself. Taking the above into account, this and the following chapter is an attempt to understand and define where and how quality management and logistics meet.

More specifically, in the following pages, a general and conceptual attempt to provide a definition of logistics quality and to examine how the philosophy of quality management has been interpreted by logistics academics and practitioners will be made. Logistics is a business area and academic research field which centers mostly on the provision of intangible services, such as transportation, distribution and warehousing, rather than on the mere production of physical articles. In a similar, the context on logistics quality should be based on service quality rather than product quality (Bergman and Klefsjö, 2003).

4.1 Service Quality

In the rapid changing and extremely competitive, contemporary business environment, the focus of organizations has changed from profit maximization to maximizing the profits through increased customer satisfaction (Seth et al., 2005). According to Bergman and Klefsjö (2003), customer satisfaction has been traditionally studied within the market functions of organizations and it was rarely the case that the information acquired by marketeners reached the people that designed the products or the services and the processes that produce or provide them. Lately, the pressures of competition have not only forced organizations to look on the processes but also to look on the way these processes are delivered to the customer, ultimately, leading to the concepts of service quality.

Since the early 1980s, when the service quality concept first appeared in literature, service quality has become a major area of attention, with a strong impact on business performance through its associated customer satisfaction and customer loyalty concepts (Seth et al., 2005). The continued attempt towards the definition, modeling and measurement of service quality highlights the importance researchers gave on this fundamental thought.

Perhaps, the most important and influential idea behind service quality is the statement that Grönroos (1984) initially acknowledged, that the perceived quality of a given service is the outcome of the comparison between the consumer’s expectations about the service and the perception about the actual service he or she received. Hence, the quality of the service is dependent on two variables, the expected and perceived service, and when these services are projected on a comparative manner they result in the service quality. Taking the above into

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3 see chapter 2 - Background
4 more on customer satisfaction and customer loyalty can be found in Reinheld (1993) and Johnsson and Gustafsson (2000)
account, Parasuraman et al. (1985), developed their gap model which is based on the premise that perceived service quality is a function of the magnitude and direction of the gap between expected service and perceived service. In the following paragraphs we will take a closer look on these two exploratory models, as these models have greatly influenced the work on the service quality research area.

4.2 Logistics Service Quality

Excellence in logistics has been recognized by many researchers and practitioners as a fundamental concept (Lambert et al., 1998; Murphy and Wood, 2004). Logistics is an improvement area in which firms cannot only establish benefits associated with cost reductions, but also through the creation of competitive advantage (Mentzer et al., 2004). The visible service impact of logistics on customers (Bienstock et al., 1997) can be used as a driving force towards total customer satisfaction. Thus, the quality of the logistics services is of great importance when it comes to customer satisfaction creation.

The understanding of the way logistics create customer satisfaction has been evolved throughout the existence of logistics. This evolution took place in parallel with the evolution of logistics itself (Kent and Flint, 1997). The traditional view of how logistics create customer satisfaction is based on the creation of value through time and place utility, the so called “seven rights of logistics”\(^5\). As the business environment that surrounds logistics changed, the view on how logistics adds value also changed and expanded to include logistics operations which also encompass the form utility, i.e. production of physical products. Despite the broadening in its perspective, the way logistics create customer satisfaction still failed to be based on operational measures, such as items in stock and percent of orders delivered on time. Moreover the focus on the service provider, i.e. how logistics executives can quantify the value they create for customers, was dominant (Mentzer et al., 2001).

Following the publication of articles dealing with the perceptions of customers on the service they receive (Grönroos, 1984; Parasuraman et al., 1985 and 1988), logistics academics realized of a necessity to develop a process to measure customers’ perceptions of the value created for them by logistics services. As pointed by Mentzer et al. (2001), is the customer’s perspective of service quality that determines their satisfaction level. This led to numerous publications dealing with logistics service quality (LSQ) based on customers’ definitions. This movement added to logistics’ performance measurement a more qualitative, intangible nature of customer satisfaction to complement the traditional set of operational service attributes.

\(^5\) see chapter 2 - Background
4.3 The Grönroos Model of Technical and Functional Quality

Grönroos (1984) was among the first to state that a firm, in order to compete successfully, must have an understanding of its service quality and the way this quality is influenced. Managing service quality means that the firm has to match the expected service and the perceived service to each other so that consumer satisfaction is achieved. Service quality, the author concludes, consists of three components, technical quality, functional quality and corporate image.

Technical quality is the quality of what the consumer actually receives as a result of his or her interaction with the service firm and is important to him or her and to the evaluation of the quality of service. Technical quality can usually be measured by the consumer in a rather objective manner. An example of technical service quality from a logistics standpoint could be the actual transportation of goods from the supplier’s inventory to the retailer’s warehouse.

Functional quality is the quality of how the consumer receives the technical quality, i.e. the way he or she receives the outcome of the service. An example of a functional quality from a logistics standpoint could be the friendly and accurate communication with the order processing personnel during a transportation of goods or an additional thanks giving letter accompanying the invoice after the transaction. Following some empirical investigation, Grönroos (1984) concluded that functional quality is more important to the perceived service than the technical quality at least as long as the latter quality dimension is on a satisfactory level.

Corporate image is of utmost importance to service firms, due to the fact that expectations of the consumers are influenced by their view of the company. The corporate image is how the consumers perceive the firm, and since consumers interfere and interact with a firm’s services, corporate image is based on the perception of a firm’s services. Therefore, the corporate image can be build up mainly by the technical and functional quality of its services.

![Figure 4.1: The Grönroos model of service quality. From Grönroos (1984)](image-url)
4.4 The Gap Model

Probably the most influential and significant of all service quality exploratory models is the model proposed by Parasuraman et al. (1985). In line with the thoughts of Grönroos, Parasuraman et al. (1985) suggested that there are three underlying themes with respect to service quality. Service quality is more difficult to evaluate than product quality, service quality is a comparison between expectations and performance, and quality evaluations involve outcomes and processes. While the first theme is a general statement which derives from the fact that there are fewer tangibles in services than in products, the latter two themes are completely aligned with the technical and functional quality model of Grönroos (1984).

Following the analysis of an empirical investigation, involving executives of service organization and consumers of services, Parasuraman et al. (1985) found that key discrepancies or gaps occur in various service process levels between executive perceptions and customer experiences of the service quality and proposed a conceptual model to represent the relationships among these gaps.

Explanatory research conducted by Parasuraman et al. (1985; 1988) through extended interviews and focus groups with experts and customer surveys, resulted in the identification of various service quality criteria that can be used to measure the gap between perceived and expected service and thus, measure service quality.

**Figure 4.2**: A fraction of the service quality model of Parasuraman et al., (1985). It is mostly known as the Gap analysis model.
4.5 Physical Distribution Service Quality

An early attempt to combine and measure logistics with respect to its service quality was given by Bienstock et al. (1997). As a basis for their analysis, Bienstock et al. (1997) utilized the framework proposed by Williamson et al. (1990), which states that physical distribution is the outbound part of logistics, with materials and conversion management being the inbound and internal part of logistics respectively. Bienstock et al. (1997) proposed the first specialized model that strives to measure, a part of logistics service quality. The most interesting observation on the physical distribution service quality model is that it is an extension of service quality research from retail or end customer (Grönroos, 1984; Parasuraman et al., 1985 and 1988) to an industrial marketing context.

Physical distribution is a combination of a number of services such as transportation and inventory management, in which service transactions take place while the service provider and the service receiver are separated, and the service activities are directed to things rather than to people. Thus, Bienstock et al. (1997) argued that traditional service quality emphasis on functional dimensions may not be adequate in a physical distribution context. Thus, they based their model on the work of Mentzer et al. (1989) who constructed a preliminary set of physical distribution quality dimensions, comprised of the technical ideas of physical distribution service timeliness and availability, and delivered products condition.

In a similar fashion as Parasuraman et al. (1988), Bienstock et al. (1997) initially reviewed the relevant literature, and subsequently conducted numerous extended interviews with practitioners and focus groups to come up with the specific tangible objects that form the quality of the physical distribution service. Analysis of the responses of an industry wide survey resulted in a valid and reliable instrument for measuring and assessing industrial customers’ perception of the physical distribution service quality they receive from their suppliers.
4.6 Logistics Service Quality Process Model

Subsequent to the physical distribution service quality model of Bienstock et al. (1997), Mentzer et al. (1999) viewed physical distribution service quality as a component of the broader concept of logistics service quality. By investigating a particular organization, Mentzer et al. (1999) expanded the service quality field in a logistics context. In this way, the physical distribution service quality model which examined the customers’ perception across a number of firms and industry sections was focused on the logistics customer service environment faced by one focal organization.

In a similar manner as in Parasuraman et al. (1988), eight logistics service quality dimensions were formed through extended focus group discussions and interviews with executives of the focal company. These dimension were later refined in a set of specific tangible objects that in turn shaped the survey instrument proposed to the logisticians of the focal company in order to assess and quantify their customers’ perceptions on the logistics services they receive.

Building on the work of Mentzer et al. (1999), Mentzer et al. (2001) extended the model of logistics service quality in a process direction that takes into account various customer segments. An important limitation of the previous model was that all logistics service quality dimensions were seen as occurring simultaneously and in a weighted manner; therefore, the ordering of these quality components with respect to time had been neglected. Thus, Mentzer et al. (2001) conceptualized logistics service quality as a process of timely interrelated quality constructs. In addition, the different meaning of logistics service quality might have on separate customer segments had also been ignored. Whether or not the desires and the values of separate customer segments are different on the various aspects of logistics service quality was not previously examined.

The investigation on the potential diverse preferences on logistics service quality of different market segments has a significant implication for an organization. In case a difference in preferences exists, the logistics programs should be customized to meet the unique needs of each segment and thus, improve efficiency and effectiveness. On the other hand, in case no difference exists in the preferences of each segment, identical logistics services should be designed to gain competence through economies of scale.

Once more, the methodology of qualitative interviews and focus groups research followed by a survey and quantitative analysis proposed by Parasuraman et al. (1985) and also followed by Parasuraman et al. (1988), Bienstock et al. (1997), centered on a particular focal company as in Mentzer et al. (1999), provided nine logistics service quality constructs; see figure 44.

Following the identification of the logistics service quality components these dimensions were plotted on a process map manner to study their interaction, dependencies and their sequential nature. This resulted in a three stage categorization of order placement, order receipt and satisfaction.
The first stage, order placement, includes dimensions that deal with the perceptions of the interactions with the logistics personnel when customers place orders. At the second stage of order receipt, the customer starts to have perceptions about the tangible products. In this stage dimensions that deal with the order completeness, timeliness and the way potential discrepancies are handled are included. Finally, the last stage includes the satisfaction that the customer gets from the service he or she received and is driven by the timeliness of the received orders the way discrepancies were handled, the initial interaction with the service provider personnel and the efficiency and effectiveness of the ordering procedures.

**Figure 4.4**: The process adapted Logistics Service Quality model for a general customer segment. Adapted from Mentzer et al. (2001).
4.7 Quality of Service in various Interfaces of a Supply Chain

It is well established among researchers that in the contemporary business environment, individual firms no longer compete as independent entities, but rather as an integral part of supply chain links (Kent and Flint, 1997; Lambert et al., 1998; Murphy and Wood, 2004). On the other hand, the focus of the previous logistics service quality studies centered on a specific logistics service encounter. To overcome the delimitations of the previous models, which investigate only a part of a supply chain, Seth et al. (2006) proposed a conceptual model for assessing the quality of service at various interfaces of the whole span of a supply chain. Seth et al. (2006) moreover, included third party logistics service providers in their analysis.

Furthermore, while Seth et al. (2006) employed the gap analysis (Parasuraman et al., 1985) for assessing discrepancies in the service quality of the various supply chain interfaces, they introduced the concept of bi-directional gaps, which together with the perception of the service receiver, about the service itself, takes into consideration the perception of the service supplier.

By following the methodology of exploratory qualitative interviews as in Parasuraman et al. (1985), Seth et al. (2006) proposed a model for assessing the quality of service in the various interfaces of a supply chain comprised of supplier, third party logistics, manufacturer (or focal company), third party logistics, distributor, third party logistics and customer, based on gap analysis. The model is depicted in figure 34. A satisfactory level of service quality is the level of logistics services delivered, when the difference between perception and expectation of the end customer towards the products, processes, services and organizations is zero or positive. The gap between the perception and expectation of the end customer is a function of the various interface gaps. These various interface gaps are further analyzed in additional sub models.

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Figure 4.5: The principle idea behind Seth et al. (2006) conceptual model for the quality of service in a supply chain. The service quality of the whole supply chain consists of six independent interface gaps.

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6 Third party logistics providers (3PL) are external companies, usually specialized on logistics operations, which take over the logistics functions of an organization. 3PL helps an organization to concentrate on its core activities and thus may result in lower costs and better customer service. More on 3PL can be found in Larsen, (2000).
4.8 Reflection

Even though lately, logistics operations are perceived as incorporating functions that are dealing with the value creation of form utility, such as manufacturing, are mostly centered on functions that deal with the storage and transportation of goods between places. Thus, it is widely acknowledged that logistics operations provide services rather than products (Mentzer et al., 2004). Many researchers have pointed out the difficulty of measuring quality of services (Parasuraman et al., 1985; Bergman and Klefsjö, 2003), it is thus difficult to quantify and measure the quality of logistics.

As seen as service, logistics is intangible and with its activities directing to products rather than to people. In addition, despite the fact that in almost every service transaction the service provider and the service receiver are both at the same place and at the same time, making the service transaction inseparable, in logistics this is not the case. In logistics services, the transaction players are organizations, and the service orders take place electronically and from a distance that may be spanning across national boarders. Hence, the frameworks proposed by marketing service researches like Grönroos (1984) and Parasuraman et al. (1985; 1988), although constructive are not on their own adequate to assess and model aspects of logistics service quality, since are concentrated on the functional nature of service quality and on end users of retail services.

Subsequent to the flourish period, with respect to quality of service, of the late 1980s numerous logistics researchers adopted the thoughts and concepts of service quality, from marketers and attempted to implement them in a logistics context. Three service quality models in a logistics context were presented in this chapter. Starting from the narrow purchasing and physical distribution interpretation of service quality in logistics, Bienstock et al. (1997) for the first time transferred the concepts of service quality in an industrial organizations level, where the transaction players are instead of people organizations and the technical nature of service perception is more significant. Consecutively, Mentzer et al. (1999; 2001) expanded the scope of service quality in logistics to include the functional dimensions of service perception. In addition a process oriented approach and a customization of the impotencies with respect to different market segments was introduced. Finally, Seth et al. (2006) integrated service quality into a supply chain framework by proposing a conceptual model based on gap analysis of various interfaces of a supply chain.

A suggestion for the further use of the service quality in a logistics context would be to breakdown the various functions and activities of logistics and to create scale instrument which will incorporate items to quantify and assess gaps associated to each specific logistics interface. In this way, the overall gap between expectations and perceptions of logistics services could be easier identified, articulated and handled, through this division. Additionally, service provider attributes, such as price, and service related attributes, such as word of mount and loyalty, should be incorporated together with the technical and functional aspects of services. In this way, the abstract and vague nature of logistics quality service can be easier and better assessed.
Creation of various conceptual and survey instruments that assess service quality of specific logistics activities, overall logistics and whole supply chains.

Service attributes such as price and word of mouth together with the functional and technical service attributes will facilitate to the understanding of the vague nature of logistics service quality.

Survey instruments that assess the service quality of each specific logistics function/activity and then aggregate to get the overall logistics service quality.

**Figure 4.6**: Service quality and logistics classification, investigation and suggestion
5 The Kano Model in Logistics

In this chapter, a conceptual model for understanding and classifying customer needs and expectations of product and service characteristics will be presented, and its usefulness will be analyzed in a logistics context.

As it was the case with the previous chapter, the Kano model is a quality management methodology that can be employed towards the understanding of the elements logistics customers expect from logistics services. Thus, as is the case with the service quality models, Kano model is placed in the Plan step of the PDSA improvement cycle of logistics.

Although the Kano model is generic in nature and mostly directed to product quality dimension, as can be seen from the following, is found to be particularly useful when it comes to the planning of logistics operations.

5.1 The Importance of Customer Satisfaction

Customer satisfaction is a strategic source of competitive advantage, for many companies throughout the world (Porter, 1985). More and more companies utilize customer satisfaction as performance measurement of their products or services as well as for developing their business strategy.

Customer satisfaction has substituted market share as a mean for promoting business strategy (Porter, 1985). This is based on the premise that customer satisfaction constitutes a better future performance index. High customer satisfaction leads to high level of customer loyalty, which in turn leads to a stable stream of cash flow for the company, moreover a high level of customer satisfaction leads to various process and customer attraction cost savings.

In addition, customer satisfaction decreases price elasticity, i.e. a customer is willing to pay more for products and services of high quality and leads to a strong brand name, with all the relevant benefits for the company (Reichheld, 1993). Thus, the ultimate goal of every company is to satisfy its customers.
5.2 The Kano Model

Kano et al. (1984) proposed a model which classifies the needs of a customer for a product or service for the satisfaction of his or her needs into three categories, basic or must-be needs, expected or one-dimensional needs and excitement or attractive needs (Bergman and Klefsjö, 2003).

Must-be needs. Must-be needs are so obvious that the customer would not even mention these needs if asked. However if these needs are not fulfilled, the customer will be dissatisfied. On the other hand we cannot get a satisfied customer by just fulfilling these needs, because these needs are considered as prerequisites and are taken for granted.

One-dimensional needs. The customer is fully aware of these quantifiable needs and will mention them if asked. Customer satisfaction is proportional to the fulfillment of these needs. With respect to the One-dimensional needs a company can win or lose customers by doing far better or worse respectively, than its competitors.

Attractive needs. These needs are unconscious, and are described by the characteristics of the product or service that have the highest influence when it comes to the customer satisfaction. By finding such characteristics and dimensions of the product or service a company can gain a considerable competitive advantage over its competitors.

![Figure 5.1](image-url)  
*Figure 5.1: The Kano model of customer satisfaction. Adapted from Bergman and Klefsjö (2003).*
5.3 Logistics Customer Service planning by using the Kano Model

Utilizing the Kano model’s categorization for the quality dimensions of products and services to classify logistics customer service elements is a way to ensure the grading of logistics services according to customer’s needs and expectations. Huiskonen and Pirttilä (1998), found this approach particularly useful in identifying and distinguishing the important customer service elements of logistics operations.

In addition, each customer segment perceives different value in each logistics customer service element, thus a categorization of those elements in Kano terms is a very useful methodology when it comes to the logistics customer service planning process.

Huiskonen and Pirttilä, (1998), argue that traditional customer service analysis and planning processes are inadequate to truly identify the exact nature of logistics customer services and the associated customer satisfaction. By dividing the overall service into various service elements and then conducting surveys, which address and measure of these elements as of being of the same nature, can lead to misinterpretations with a significant impact on an organization’s performance. For example a Likert scale\(^2\) of 1 to 7 implies a presumption of linearity of the effect of service elements on customer satisfaction, which is not always true in logistics services.

Potential benefits of the use of Kano’s classification could be the precise description of the different types of services elements, with a result of being able to more efficiently recognize advantages and disadvantages of the current logistics customer services offered. Moreover, the Kano’s classification provides an easier way to recognize different customer requirements, which in turn is a prerequisite to a customer service differentiation strategy, which sequentially leads to a source of competitive advantage.

Huiskonen and Pirttilä, (1998), acknowledged that only the one-dimensional logistics customer service elements can be recognized by the traditional customer service assessment techniques, and proposed the use of the Kano questionnaire of positive and negative questions (Kano et al., 1984) to identify must-be and attractive logistics service elements, which are unspoken and unexpected by customers. Understanding the nature of the logistics service elements, can be proved to be a useful tool in effectively designing a customer service strategy, which will better address the situation of an organization’s logistic operations.

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\(^2\) An example of a survey utilizing a Likert scale of 1 to 7 can be found in Parasuraman et al. (1988)
A modification of the analytical tool of competitive position matrix (Lambert and Sharma, 1990) was presented by Huiskonen and Pirttilä (1998). In this tool, the logistics service types, in terms of the Kano’s classification, are projected against the position of the company with respect to the competition. An analogy with SWOT-analysis (Kotler, 1994) is then done, when comparing the company’s position with its competitors. The modified competitive position matrix together with examples of the different types of service elements are presented in figure 5.2.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{competitive_position_matrix.png}
\caption{The competitive position matrix, modified in Kano’s classification terms. Adapted from Huiskonen and Pirttilä (1998).}
\end{figure}
5.4 Reflection

The Kano model of quality elements classification of products and services has found a fertile ground in logistics. As with customers of other types of services, customers of logistics services elements can also be classified in accordance with the Kano model.

The framework proposed by Huiskonen and Pirttilä (1998) can be very useful when it comes to developing competitive strategies based on logistics services. When competing by means of differentiation, which is often the case supported by logistics, the Kano model and the Kano questionnaire, are useful methodologies to identify the logistics service attributes that a company should focus on and thus, create opportunities for improvement.

A suggestion for the further endorsement of the simple and straightforward methodology proposed by Kano in a logistics context could be to further combine the classification of logistics service quality elements with policy deployment techniques.

An example could be that balanced scorecards for performance measurement are used for defining and communicating the mission, vision and goals of an organization, based on the explicit understanding of its customer’s needs and expectations.

Moreover quality management methodologies such as the quality function deployment can be easily enhanced by and combined with the Kano methodology on a logistics context.8

Furthermore, statistical process control monitoring techniques can be properly concentrated on the monitoring and supervision on logistics quality elements which are particularly found to be important through the Kano needs identification and classification methodology.

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8 see chapter 6 – The quality function deployment in logistics
Figure 5.3: Kano Model and logistics, classification investigation and suggestion for further improvement.
6 The Quality Function Deployment in Logistics

In this chapter, a methodology for understanding customer needs and translating them into product characteristics will be presented, analyzed and then projected in relation to logistics operations in the supply chain context. The Quality Function Deployment methodology, originally used in new product development processes, is also found to be particularly useful and broadly used when it comes to logistics operations.

The purpose of this methodology in product development is to translate the customer needs into products that successfully address these needs. In a similar manner, this methodology is presented in this thesis as a way to design logistics services that successfully address the logistics customer needs. Thus, following the understanding and definition of quality in logistics, during the Plan step comprised of the two preceding paragraphs, this methodology that facilitates the design of quality logistics services is placed in the subsequent Do step of the PDSA cycle.

6.1 The Quality Function Deployment

Quality Function Deployment (QFD) originates in 1972 in Japan, as a methodology adopted to improve product quality in Japanese firms. This methodology was first introduced by Mizano and Akao at Mitsubishi shipyards in Japan (Akao, 1990). While employing this methodology, customer demands are systematically identified and projected on product features and design parameters. A definition of QFD provided by Slabey is:

\[\text{QFD is a system of translating consumer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing, sales and distribution.}\]

(Slabey, 1999, as cited in Bergman and Klefsjö, 2003: p 121)

The two main QFD approaches are namely the “matrix of matrices” and the “four phase model”, with the latter being more analyzed in literature and more implemented in industry. Four successive matrices, with each matrix corresponding to each step, are constructed. By this way, needs and expectations of customers are transferred from a higher level to a lower level. Such a sequence starts from product planning, continues to product design then to process and finally, to production design (Olhager, 2002; Bergman and Klefsjö, 2003).

To carry out and facilitate this transfer, QFD utilizes a tool which is an elaboration of a matrix chart, one of the seven management tools, or else the seven new quality tools (Bergman and Klefsjö, 2003). The most common matrix chart tool, which is applied in the first step –from customer attributes to engineering characteristics- is known as the House of Quality (Bergman and Klefsjö, 2003; Bottani and Rizzi, 2006).
The House of Quality (HOQ) is composed of mainly two parts, related to customer requirements and needs, “what’s”, and technical elements or product characteristics, “how’s”. The most prominent article which provides the systematic way of filling the HOQ is an article written by Hauser and Clausing (Hauser and Clausing, 1988).

The method of filling the HOQ matrix comprises of numerous steps (Hauser and Clausing, 1988). The first step is to identify the customer attributes, i.e. needs and requirements, usually through surveys and interviews. Then the relative importance is expressed through weights. It is worth to mention here, that in this the Kano model applies to QFD. After having defined the relative importance of the customer attributes an evaluation of the company’s products is taking place to determine the degree of fulfillment of the customer’s attributes. This evaluation is carried out by customers and not by the managers and engineers of the company. The next step is to identify measurable attributes concerning the products or services of the company. These attributes constitute the engineering characteristics or the how the product or service will address the customer attributes.

The core element of the HOQ is the relationships matrix, where the degree of strength of the relationship between customer attributes and engineering characteristics is expressed. In a similar manner the roof of the house, the correlation’s matrix expresses how the engineering characteristics affect each other. Benchmark analysis of the competitors’ engineering characteristics is then conducted. Finally target measures are introduced on each engineering characteristic which translate the customer’s expectations into numerical values, in order to quantitatively asses a company’s performance against customer’s requirements (Hauser and Clausing, 1988; Bottani and Rizzi, 2006).

Figure 6.1: The principle idea behind the House of Quality (HOQ) tool of the Quality Function Deployment (QFD).
6.2 The Voice of the final Customer

It is widely recognized by many authors (Christopher, 2005; Womack and Jones, 2005) that the contemporary thought of supply chain management in general and logistics in particular, is moving from management of the physical transportation of goods to the consumer driven value chain management. This approach recognizes the importance of the final rather than the direct customer needs in the supply chain network (Zokaei and Hines, 2007). In this context, not the product but the entire chain should be effectively managed continuously to deliver the end customer’s value requirements.

In the quest of achieving the end customer focus of the supply chain Zokaei and Hines (2007) developed a technique that utilizes two quality management methodologies, the Kano model of customer satisfaction and the Quality Function Deployment to capture and understand the end customer attributes and link those to the logistics attributes of the supply chain. Except from developing a generic methodology, Zokaei and Hines (2007), implemented their technique to a network of four business units performing in the milk industry in the UK.

The methodology they went after is rather simple and straightforward. The authors acted as project leaders and coordinators. Initially, they built a team consisting of members from all the participating firms and launched an intensive training program to familiarize the team members with the mapping and analysis tools deployed during the project and the basic principles of supply chain management. After building the team, a large number of data, within a firm and throughout the value chain, was collected. Consecutively, the team worked towards the understanding and categorization of the end customer needs, which were provided by a third party customer survey, according to the Kano model.

<table>
<thead>
<tr>
<th>Customer Value</th>
<th>Kano Category</th>
<th>Supply Chain Objective</th>
<th>Supply Chain Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Safety</td>
<td>Must-be</td>
<td>Correct processor quality</td>
<td>Customer complaints</td>
</tr>
<tr>
<td>More than 3 days in</td>
<td>One-dimensional</td>
<td>Reduce end to end lead time</td>
<td>Lead time</td>
</tr>
<tr>
<td>the shelf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low food miles</td>
<td>Attractive</td>
<td>Reduce total transportation miles</td>
<td>Total food miles</td>
</tr>
</tbody>
</table>

Figure 6.2: Classification of customer needs for a milk supply chain according to the Kano Model. Adapted from Zokaei and Hines (2007).
Having gained a clear understanding of the needs and after reflecting on the current state activities of the network the team identified improvement opportunities towards a more effective and efficient future state for the logistics operations and the supply chain. Finally, an action plan was developed to transfer the supply chain from the current to the future target state, by promoting the milk’s origin and implementing clearer transportation efficiency measures.

6.3 Identifying and prioritizing Strategic Logistics Actions

Another interesting application of QFD in a logistics context is an approach proposed by Bottani and Rizzi (2006). In their paper they utilize QFD in a fuzzy logic framework (Zadeh, 1965) to identify and prioritize strategic actions a firm should take regarding its logistics operations. Their motivation lays in the fact that customer service, and thus the generation of competitive advantage, is perceived by customers as a result of logistics processes and activities.

By analyzing an Italian company performing in the mechanical industry and its necessity for strategic change, due to customer requirement shift, they developed a methodology to deal with the logistics service management through a QFD approach.
Initially, they identified the customer service requirements in terms of logistics performances, “what’s”, i.e. service factors that affect logistics service perception, through customer interviews and logistics management literature review. It is worth mentioning here that there was no reference or integration with the Kano’s perception on customer attributes.

Consecutively, strategic actions the firm could take to improve its service performance were identified, “how’s”, through literature and the firm’s characteristics analysis. Regarding the service factors weights, relationships and correlation matrix an innovative fuzzy logic approach was employed to deal with the linguistic judgments given by the project participants.

Finally, a linking and prioritization of the strategic actions the firm should take in order to improve its logistics related customer service and to eliminate the distance or the gap between the firm’s logistics performance and the service perceived by its customers was conducted.

**6.4 The Voice of the Business Environment**

QFD has also been utilized to ensure that the business dynamics and potential changes a company experiences are embedded in the process of configuring its supply chain focus and logistics operations. Since different companies, or network of companies, experience different changes and trends in their business environment, there is a need for a tool that facilitates the identification and implementation of the proper degree of agility and adaptation (Goldman et al., 1994).

Baramichai et al. (2007) proposed a tool based on the QFD, the Agile Supply Chain Transformation Matrix (ASCTM), to help companies improve their agility based on the evaluation and analysis of their business environment, capabilities and performances. By improving a firm’s agility Baramichai et al. (2007) mean the deploying of the right approaches as a response to the right changes. This approach is similar with the initial premise of the original QFD methodology in new product development, to deploy the right engineering characteristics of the product as a response to the right customer attributes (Hauser and Clausing, 1988), and this is where this methodology fits with the agility deployment in purchasing introduced by Baramichai et al. (2007).

The ASCTM methodology as introduced by Baramichai et al. (2007) consists of three phases, similar to the four stages of the QFD (Bergman and Klefsjö, 2003). Initially a HOQ is utilized to project and relate the business challenges a company faces, with the possible changes in the purchasing requirements. The final deliverable in this phase is the prioritization of the changes according to their importance.
Consequently, ways to accommodate these changes are identified through the appropriate mix of approaches for agility creation. Again in this phase, a HOQ is utilized to help the company determine the appropriate change response strategies and the ways used for accommodating changes under the proposed strategies.

In the final HOQ employed, in the last phase, the specific business practices and infrastructure that are necessary to support the use of internal and external agile capabilities in purchasing are identified and linked to the change accommodations and sequentially to the specific possible changes and particular business challenges.

By developing a structured QFD approach in deploying agility in purchasing operation, Baramichai et al. (2007) addressed the issue of devoting time and money to make changes that fail to be excessive and unnecessary. ASCTM transfers the voice of the business environment to the down floor business practices and infrastructure needed to accommodate the necessary changes.

**Figure 6.4**: The three phases of the ASCTM tool. From Baramichai et al., (2007).
6.5 Reflection

As can be seen by the previous paragraphs the Quality Function Deployment methodology has been implemented and is used in the logistics context. Its main applicability is mostly centered in an attempt to capture and transfer trends from the marketplace, e.g. voice of the customer and voice of the business environment, to the practices and actions of the logistics in operational level.

Some of the benefits that are associated with the implementation of the QFD methodology in logistics are the deeper understanding of the customer requirements; the effective management of the trade offs in the logistics configuration, the elimination of potential problems in the initial stages of the supply chain design. Moreover, the facilitation of the competition analysis and the better communication and collaboration of different functions within a firm and different firms within a supply chain network is of high significance.

A suggestion for the further promotion of the QFD methodology in logistics could be that these techniques can be auxiliary utilized in the process of designing supply chain networks, i.e. locating warehouses and distribution centers, at the same way as are used in designing products. Transferring the voice of the customer to the supply chain design process will allow supply chain to deploy structural logistics decisions that match with the needs and expectations of the customers of which they designed to serve.

Another contribution QFD could make in logistics is to convey messages across hierarchical levels, i.e. from strategic to tactical and operational planning implementing and control level of the supply chain. By this way, strengths and weaknesses will be highlighted and disseminated throughout the employees of an organization, but also, throughout the organization of the supply chain network.

Moreover, QFD is a methodology that facilitates the strategic change of organizations. As shown by the Agile Supply Chain Transformation Matrix before, the changes can be better spread across logistics operations. A step forward could be to use QFD to identify and recognize these changes, in a way that logistics operations will not lag, but on the other hand, lead in the organizational change process.
Figure 6.5: Quality Function Deployment and logistics classification, investigation and suggestion for further applications.
7 Robust Design in Logistics

In this chapter, issues related to Taguchi’s off-line quality control are examined with respect to their application in logistics. By the term off-line quality control, Taguchi refers to the activities related to a product or a process design and development (Bergman and Klefsjö, 2003).

These activities are interpreted in this thesis as activities that can be utilized towards the robust design of logistics services, thus as it was the case with the previous chapter, robust design in logistics deals with the configuration of logistics operations, and is placed in the Do step of the PDSA improvement cycle, following the Plan step which defined the quality in logistics.

Taguchi’s thoughts on quality have attracted a great deal of interest over the last decades and he is sometimes attributed as the man behind the success of the Japanese industry after the Second World War. Thus, in order one to get a complete view of the quality management methodologies and tools used in a logistics context, an investigation on Taguchi’s philosophy and methods is profound, if not mandatory.

7.1 Taguchi’s Philosophy

Taguchi’s philosophy is succinctly found in his definition of quality. He defined quality or rather the lack of quality as “… the total loss imparted to society caused by the product after delivery” (Roy, 1990). By referring to the loss to society Taguchi doesn’t restrict to the traditional consumer costs but rather he expands his view onto the costs to the manufacturer and all stakeholders in general; see paragraph 7.2. His early views on the impact to society are close to the contemporary discussion on sustainable development and a sustainable society (Bergman and Klefsjö, 2003).

In the core of his concepts, as to early thoughts of Shewhart, is variation. Taguchi, however, goes further to the causes of variation and bring them to discussion in the initial stages of product and process design and development.

According to Roy (1990), three fundamental concepts form the foundation of Taguchi’s philosophy. The quality should be designed into the product, the quality is best achieved by a design that minimizes the deviation from the target value and that the cost of quality and the associated cost should be measured system-wide.

An important role within the Taguchi’s philosophy is the role of disturbances, or noises. A product is exposed to disturbances which affect its quality throughout its lifetime, from the initial designs to the purchasing of the raw materials, to the production stages and to the final delivery to the end customer. What is common with these disturbances is that they are infeasible or impossible to control. Thus, Taguchi proposed that the design of the product or the process should be robust, i.e. insensitive to the disturbances that the product might be exposed throughout its lifespan (Bergman and Klefsjö, 2003).
Towards this direction, Taguchi provides methodologies for quality control already during the early stages of design and development, he refers to them as off-line, highlighting that no amount of inspection can put quality back into the product; it merely treats a symptom.

### 7.2 The Design Process

To achieve desirable product quality by design, Taguchi identified three stages in the design process. System, parameter and tolerance design (Bergman and Klefsjö, 2003).

In the process of system design, the actual frame of the product or process is set, based on the design team's judgment of the customer needs and the capability of the process. The final result of this stage is a prototype design of the product or the process that satisfies the customer needs, provided that it is not exposed to disturbances.

While system design determines the frameset of the product or process, the parameter design aims at making the design insensitive towards the various disturbances by determining the target values for the design parameters.

In the final design stage, the tolerance design stage, the tolerance limits are selected by balancing the loss to society due to deviations from the target value and the cost to the producer of making an adjustment in case of a situation out of tolerance.

### 7.3 The Loss Function

Taguchi defines quality using the following words "...the lack of quality is the total loss imparted to the society from the time a product is shipped to the society", thus he cannot accept the traditional view that as long as the parameter lies within the tolerance limits, the loss to the society is zero and as soon as the parameter value has exceeded one of the tolerance limits the financial cost is large but constant (Bergman and Klefsjö, 2003).

Taguchi quantified the financial loss when a parameter value deviates from it target value, to do so he used the squared loss function as an approximation (Roy, 1990). Together with the tolerance design, Taguchi took into consideration the customer's and the manufacturer's costs to conclude that the sum of customer's and manufacturer's costs, corresponding to the society's costs, that has to been minimized.
7.4 Experiment Design Strategy

Perhaps the most important message in Taguchi’s quality philosophy is to be found in design of experiments. While employed in the Electrical Communication Laboratories (ECL) in Japan during the 1950s, he observed that a great deal of time and money was expended in engineering experimentation and testing, what he called off-line quality. Little emphasis was given to the process of creative brainstorming and to minimize the expenditure of resources (Roy, 1990).

Taguchi viewed quality improvement as an ongoing effort and as a continuous strive to reduce variation\(^9\). Taguchi developed a design of experiments methodology that effectively and efficiently identifies and examines the deviation of a product’s or process’ quality indicator around a target value. Taguchi identified the weakness in the classic design of experiments\(^10\), which is principally that the fact that the classic design of experiments, merely describes the expected results of experiments and not their dispersions (Bergman and Klefsjö, 2003).

To achieve a design parameter as close to the target value as possible, Taguchi constructed a special set of experiments. In his experimental layout, controllable factors and uncontrollable disturbances, i.e. parameters that the experimenter can and can not influence during the experiment respectively, were combined in a unique manner. The experimental strategy proposed by Taguchi, can be summarized as to incorporate the disturbances within the experiment and not waiting for their effect to appear while the product is out to the society. This strategy results in the robust design of product or services, i.e. to the design of product or services that are insensitive to disturbances throughout their interaction with the environment and the society.

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\(^9\) For more on variation see chapter 8 – SPC in logistics and chapter 11 – The six sigma improvement methodology in logistics

\(^10\) Further on the classic design of experiments can be found in Box et al. (1978); Montgomery (2001)
Taguchi developed new methods to optimize the process of engineering experimentation and incorporated those in the design process presented before (Roy, 1990; Bergman and Klefsjö, 2003). In the system design face suitable working levels of the design factors are determined, further in the parameter design the levels of these factors that produce the best performance of the product or system are chosen and finally, in the tolerance design stage the results of the parameter design are fine tuned by tightening the tolerance of the factors that significantly influence the outcome of the experiment.

Taguchi established his set of fractional experiments to describe a large number of experimental situations. Taguchi’s experimental designs are attractive because of experimental efficiency, but there are some potential tradeoffs (Roy, 1990). Generally speaking, Taguchi’s experiments work well when there is minimal interaction among factors. If however, the factors interact with each other, there is still a good chance that the optimum condition will be identified accurately, but the estimate of performance at the optimum can deviate significantly. The degree of inaccuracy depends on the degree of complexity of interactions among all factors.

**Figure 7.2:** A simple input-output mental model for a transportation service. The principle behind Taguchi’s experimental strategy is that only if noise factors are taken into account early in the design phase the outcome will robust and insensitive to disturbances.
7.5 Adding Logistics Costs in the Loss Function

Taguchi’s loss function has been a receiver of criticism in the past. This criticism is been mostly based on the fact that the loss function is merely focused on manufacturing, intra-organizational concepts. Larson (1992) in an attempt to extend the concept of quality loss function to include inter-organizational impacts of a product quality proposed that logistics costs, such as storage and transportation costs, should be added to the calculation of the total cost. This addition would make the loss function even steeper.

While examining a product’s quality impact on a supplier-buyer logistics dyad basis, Larson (1992) developed analytical relationships between product quality and supplier, customer inventory within a total cost framework. Larsson (1992), identified that in supplier to buyer shipping, the quality indicator is the defect rate, and has a “The-Smaller-The-Better” loss function with an ideal value of zero (see figure 7.4). The quality loss can be, thus, estimated as the difference between the total cost of a given logistics system configuration under \( d \) percent defects and the total cost of the same system with zero defects.

**Figure 7.3:** An example of a fractional four factors at two levels transportation experimental design structure that includes noise. Although Taguchi’s strategy will provide a transportation service insensitive to the noise weather condition, the interactions among factors are not included.
To demonstrate the impact of product quality, i.e. the percentage of defects, to the quality loss of the logistics system, Larson (1992), developed three models that estimate the total cost of moving materials from origin to destination. He constructed his models to incorporate alternative percentage defects, i.e. zero and not zero, and inventory inspection policy configurations, i.e. no inspection, 100% inspection. After testing those models and utilizing a numerical example, he concluded that the percentage of defects is a very significant and expensive factor that forces the total cost, including the logistics costs to rise.

With his study, Larson (1992) advocated to the idea that producing, shipping, and receiving defective items leads to wasted logistics effort; defects are transported back and forth, and stored at origin, in transit and at destination, leading to unnecessary logistics costs, which add up to the total communal costs of a firm. However, his narrow view of quality as percentage of defects in questionable and his approach to quality improvement through en product inspection was, also at the time of the article’s publication, much questioned.

![Figure 7.4: An intra- (1) and an inter-organizational (2) “The-Smaller-The-Better” Loss function. The additional logistics costs, e.g. transportation, storage costs, contribute to an even steeper loss function. Based on Larson (1992).](image-url)
7.6 Utilizing Taguchi’s Experiments to configure Logistics Customer Service

In an attempt to find which logistics customer service offerings are important in realizing customer value, Holcomb (1994) developed a model based on Taguchi’s method of parameter design for designing, assessing and improving customer service offering of logistics operations, from the customer value determinants perspective, i.e. both quality and cost.

Holcomb (1994) argues that except from understanding the customer service quality\textsuperscript{11}, it is necessary, through the use of powerful quality techniques such as the Taguchi methods, to design processes that deliver the right mix of the service elements desired.

The methodology utilized by Holcomb (1994) is divided into two phases which roughly correspond to the system and parameter design of the Taguchi’s design process.

In the first phase, the logistics customer service factors were determined. Specifically, how their levels are perceived by customers in their role in creating value was studied. By means of a mail survey and the examination of existing customer service levels currently provided to customers of a consumer goods company, attributes were identified that offer the firm the best opportunity to improve its service delivery performance as perceived by customers.

The logistics customer service elements identified were the length of order cycle, on-time delivery and the completeness of shipments. Especially the length of order cycle was acknowledged as the best opportunity of a company to improve its perceived logistics quality. Additionally, the levels of these logistics customer service elements that were required were determined. Finally, a segmentation of the market was done with respect to the customer service attributes. In this way, the association among logistics customer service variables was highlighted.

In the second phase, the setting of the logistics customer service parameters to improve the quality of service delivery was identified. The goal of this phase was to determine the attribute values of the customer service delivery process so that the system consistently exhibits a high level of performance and is minimally sensitive to noise. Towards this direction, an experimental design was conducted which examined interactions between controllable and noise factors.

\textsuperscript{11} For more on logistics service quality see chapter 4
Three customer service delivery factors were tested, delivery method, order size and order lead time, to determine which if any, of these can be manipulated to reduce variation of performance within the current operating environment. It should be noted here, that although two noise factors were used in the experiment, the nature of this factors is not given by the author. To derive the experimental response variable “perfect order” score, three performance measurement statistics were employed, on-time delivery, shipment delivered time and billed accurately. As a final point, the level of effect of each logistics service attribute was evaluated.

The major findings of the experimental structure was that, with respect to a specific order type, the promotional order type, order size has a significant main effect on service delivery performance and contributes to the variability of conformance to requirements. On the other hand, compared to the brand introductions order type, order size was found to affect neither the average, nor the variability of the performance, were order lead time is a critical factor to the performance variability.

The contribution of the method introduced by Holcomb (1992) can be summed up as providing assistance in the process of identifying what customers value more, mostly attributed to the first or system design phase, and to how the service delivery process must be designed to deliver that value, mostly attributed to the second or parameter design phase.

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**Figure 7.5:** The design structure for a logistics service attribute experiment. Adapted from Holcomb (1994).
7.7 Sensitivity Analysis of Logistics Infrastructure Design through the Use of Taguchi’s Experiments

In the process of designing logistics networks, future state changes should be taken into account; factors that increase the risk of undue cost must be identified and corrected. Lalwani et al. (2006) proposed a method based on the Taguchi’s design of experiments that estimates the likely impact of uncertainty on a logistics network design. This method was applied on an automotive aftermarket operations European-wide logistics network to highlight the factors that the logistics network design is more sensitive to. The network under consideration consists of over 550 suppliers and 10,000 customers.

The application of the method on the aforementioned logistics network comprised of two parts. In the first part, three modeling techniques, i.e. inventory, transportation and optimization/ trade-off models, were employed to generate the future infrastructure design of the logistics network.

The modeling utilized information about the customers, suppliers and distribution centers details such as locations, distances and annual demands together with data of future anticipation derived from brainstorming sessions of business managers. After modeling the transport and inventory costs, i.e. distances between suppliers-distribution centers-customers and amount of stock in each distribution center respectively, a trade-off analysis of the number and location of the distribution centers led to a solution of two distribution centers with a level of demand reached within the desired order cycle of 92 per cent.

The second part of the method utilized the Taguchi method for design of experiments to conduct a simulation sensitivity analysis of the first part’s solution (see figure 7.6). Through the use of business managers brainstorming sessions, eight factors and their levels were identified that play a part in the future scenario risks. These factors have two main influences; first, on the optimum number of distribution centers, and second on the total logistics costs, i.e. inventory and transportation costs. These influences were used as response variables for the simulation experiments.

Successively, the percentage contribution of each factor to the response variables was determined through an Analysis of Variance (ANOVA)12. The Taguchi method suggests that the experiment is repeated with insignificant factors removed (Roy, 1990), i.e. the factors that ANOVA indicated to have a small contribution to the response. Thus, one more experiment was conducted that examines the influence of three significance factors.

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12 ANOVA is statistical technique which is used to provide a measure of confidence by determining the variability (variance) of the data. More on ANOVA can be found in any textbook on statistical analysis and quality control, as well as in Roy, (1990) and Montgomery (2001).
After removing the demand profile in different countries, as indicated by the ANOVA, a new set of experiments was constructed to thoroughly study the influence of the delivery frequency, transport and inventory cost factors.

The outcome of the above analysis can be summed up as that the transportation cost and the demand profile of the different market regions were relatively unimportant in terms of affecting the design. On the other hand, the inventory holding costs had the biggest effect on both the number of distribution center and logistics costs. In addition, higher customer expectations on delivery frequency have an impact on logistics costs and therefore should be charged accordingly. To conclude, this method allows the conduction of sensitivity investigations without the need for time and resource consuming simulation experiment conduction.
7.8 Reflection

As can be derived from the analysis above, Taguchi’s ideas on loss function and experimental design have been applied in logistics. Logistics’ academic literature and practice have found Taguchi’s methods for robust design relevant and value added especially in the logistics network design, but also in logistics customer service fields. Taguchi’s loss function, which encompasses the belief that the costs rise by the square of the deviation from the target value of a quality characteristic, has attracted the attention of logisticians with respect to the time and money associated with the movement of defective products through the logistics channel.

There are some limitations with respect to the adoption of Taguchi’s methods for robust design in the logistics context. Concerning the loss function, although there has been an attempt to extend the scope of this function to incorporate logistics costs, the quality indicators that are examined are still merely manufacturing related. In this approach, poor quality is only considered to be created during the production phases, e.g. by producing defective products. It is assumed that there are no errors directly related to logistics services, e.g. in-transit damage of goods and transportation deficiencies with respect to time and place.

In addition, the whole reverse logistics functions have been completely omitted from any analysis, although the cost of returning defective products from point of destination to point of origin is more than significant.

In relation to Taguchi’s experimental design, timing is the most eminent limitation. To achieve the benefits of this technique, an accurate plan of action should be at hand well in advance, of the logistics system operation. This can be difficult for two main reasons, data unavailability and data value degradation due to the rapid dynamic nature in which business logistics functions operate in. Lastly, Taguchi’s technique for experimental design deals purely with experimental factors of discrete nature. However, continuous and qualitative factors are often the case in logistics, and thus, are excluded from Taguchi’s parameter design methodology.

Suggestions for the enhancement of the use of Taguchi’s methods in a logistics context could be that these methods are modified to incorporate the partially qualitative nature of the business logistics environment. This for example, can be achieved through the use of a fuzzy logic approach to derive quantitative discrete factors that incorporate quality nature. Furthermore, the quality indicators and the roots of poor quality should not focus merely on production and manufacturing processes. In this way, a more logistics oriented loss function mind-set can be resulted with a broader inter-functional and inter-organizational perspective.
Figure 7.7: Robust design and logistics classification, investigation and suggestion for further applications.
8 Statistical Process Control in Logistics

Following the Do step of the PDSA cycle, which it has been employed in this thesis as the step were the quality is designed in logistics, this and the subsequent chapters deal with quality management methodologies that can be used to study the quality level of logistics while on operation. Hence, after the previous approaches that facilitate the establishment of quality before operation, quality management tools and techniques that have been thoroughly used to measure, monitor and control operating processes, will be placed in the Study step of the PDSA improvement cycle of logistics.

Throughout this chapter, the well established and thoroughly utilized methodology of statistical process control, (SPC), will be briefly presented. In addition some interesting applications of this “hard” statistical technique on logistics operations will be given and analyzed. Finally some insights for the promotion for further use of SPC in logistics will be provided.

SPC, which was the primary method in early Quality Control, is explicitly utilized to manufacturing operations; however, the interest to this aged technique has lately shifted to non manufacturing operations in general and to logistics in particular.

8.1 Variation, the Reason behind SPC

In every situation in life there exists variation, which doesn’t certainly mean that is bad. Imagine a world without variation where there is no randomness and anything can be prejudged and predicted in advance. Kaoru Ishikawa, one of the most prominent quality experts, said that we live in “a world of dispersion” (Bergman and Klefsjö, 2003).

While in everyday life variation is considered as welcome (if not bad), in the business environment, variation leads to difficulties in planning, which in turn lead to costs and pure performance and thus, is considered as unwelcome. Causes of variation can be classified to common causes, which are natural and have a relatively contribution to the overall variation, and assignable causes, whose impact is large and lead to significant inconvenience and can be identified and eliminated.

According to Bergman and Klefsjö (2003), the purpose of Statistical Process Control, is to identify assignable causes in order to eliminate them and create, a predictable process. In addition, to supervise the process, so that no further assignable causes are introduced and continuously give information from the process, so that new causes of variation can be identified as assignable and eliminated.

The goal of SPC, thus, is to improve the capability of a process, by reducing its variation, leading to a more stable process, which in turn becomes more predictable over time, Shewhart (1931) defined this condition as being “in control”:
A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. (Shewhart, 1931, as cited in Bergman and Klefsjö, 2003: p 209)

8.2 Presenting Variation with descriptive Data Set Measures

There are various ways to measure and present the variation of a process. A common way to aggregate information, after gathered through data collection of a process output, is by calculating various measures. These measures can be classified in categories, depending on the type of information they carry, namely measures of central tendency, measures of dispersion, measures of skewness and kurtosis and measures of association.

Although these measures achieve to combine information in a precise and straightforward way they fail to by descriptive, static in nature and unsuccessful in exhibiting the dynamics of a process output, e.g. tendencies and drifts. More on data set descriptive measures, which are omitted here since are outside this thesis’ scope, can be found in every introductory textbook in engineering statistics or quality control, as for example Mitra (1993) and Montgomery and Rungen (2003).

8.3 Control Charts

A way to present the dynamic nature of a process’ variation is through control charts. The control chart was the prime tool introduced by Shewhart to find if assignable causes of variation exist, in order to make manufacturing process predictable.

The basic idea behind a control chart is to take information from the process at regular time intervals, create one or more suitable process quality indicators and based on this, check whether the process characteristics perform in a suitable and predictable way (Mitra, 1993; Bergman and Klefsjö, 2003; Montgomery, 2005). By incorporating time while measuring the variation of an output measure, the dynamic nature of a quality variable is taken into consideration. Thus, the drawbacks of static descriptive data measures are altered.

More specifically, an output measure should throughout the time that is examined lie within a set boundaries and if drifts is said to be out of control. These boundaries are the main concepts of every control chart and are mostly known as control limits, i.e. the restriction levels, which if surpassed an abnormal behavior of the output measure under examination is indicated (Montgomery, 2005).
All control charts, in one or another way, are based on this rather straightforward notion of control limits. What distinguishes control charts among each other is the way that these control limits are calculated and subsequently, the way an abnormal drift is signaled.

The most common method to calculate control limits is by adding or subtracting three times the standard deviation of the output measure under examination from its mean value resulting, in the upper or lower control limits, respectively. The measure of three times the standard deviation both sides of a measure’s mean is known as the natural variation\(^{13}\) of a variable and is attributed to Shewhart (1931). Thus, a control charts that its limits are calculated in this way are called Shewhart charts (Bergman and Klefsjö, 2003).

Control charts designed in this principle may give a false alarm, i.e. an indication of an out of control situation while in control\(^{14}\), with a relative small probability of 0.3%. In the chapter 10, which discusses the six sigma methodology in logistics it will be presented that this probability although small is not enough.

The most common among the control charts for process output are the $\bar{x}$ and $R$ chart which are employed to monitor the mean value and the mean of a process output respectively. Other widespread control charts are the $s$-chart for monitoring standard deviation, the $p$-chart for monitoring fraction of non-conforming and the $c$-chart for nonconformities (defects).

\[\text{Figure 8.1: The basic principle behind any control chart. A process output is monitored in regular time intervals, while its value lies within the control limits the process is said to be in control.}\]

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\(^{13}\) More on natural variation of process variable can be found in chapter 9 – capability measures in logistics and chapter 10 – the six sigma improvement methodology in logistics.

\(^{14}\) This is called Type I error, the error of giving a signal while there is no shift and in this kind of chart is 0.3%. There is also a Type II error in case that there is no signal while there is a shift. More on Type I and II errors and statistical hypothesis testing can be found in every introductory textbook on statistical analysis and quality control, e.g. Montgomery and Runge (2003) and Mitra (1993).
8.3.1 Sensitivity of Control Charts

The sensitivity of a control chart is best described by the average time until alarm after a certain change has occurred in the process (Montgomery, 2005). A way of representing this sensitivity graphically is the Average Run Length or ARL-curve. The ARL-curve presents the mean of the random variable of the number of points plotted until the first one ends up outside one of the control limits (Mitra, 1993; Bergman and Klefsjö, 2003).

![Figure 8.2: A generic Average Run Length curve (ARL-curve).](image)

8.3.2 Cumulative Sum Control Charts

Another type of control chart often used in practice is the cumulative sum control chart or CuSum chart. In contrast with the common, or Shewhart control charts, where each plotted point represents information corresponding to the observation of that sample only; in the case of CuSum charts, each plotted point uses the information from all of the prior observations or samples by displaying the cumulative sum of the deviation of the quality indicator from the specified target value (Mitra, 1993).

Compared with the Shewhart control charts CuSum charts, due to their property of containing information in each point from previous samples are more effective in detecting relative small shifts of the process output from the target value. Furthermore, CuSum charts are particularly effective with samples of size one, which makes them preferable in process or manufacturing industries where the measurement of the quality indicator takes place automatically right after a single product or batch production (Montgomery, 2005).
On the other hand CuSum charts are usually designed to detect small changes of the process output and thus, may be slow to detect large deviations. In addition, the cost of training personnel to use and maintain CuSum charts is usually higher than of the Shewhart charts, since CuSum are considered more sophisticated.

The basic mechanism behind the CuSum control charts is that if the process output shifts upward to a higher value than the target, an upward drift will be observed in the value of CuSum chart. Similarly for a downward drift of the process output a downward drift in the value of the CuSum chart will be observed. The task is to determine whether the trend of the CuSum chart either upward or downward, is significant enough to allow us to conclude that the process is out of statistical control.

In a similar fashion as with the Shewhart charts statistical control limits are utilized for this reason. There are two ways of designing and representing control limits in CuSum charts, the tabular and V-mask techniques (Montgomery, 2005).

### 8.3.3 Tabular CuSum Charts

Tabular CuSum, or algorithm CuSum, first proposed by Page (1954), work by accumulating deviations of the process output from the target value with two statistics\(^{15}\), one for upper deviation and one for lower deviations respectively. If these deviations exceed a decision interval then it is said that the process is out of statistical control.

\(^{15}\) The underlying principle of determining the cumulative statistics and the decisions intervals are omitted since this discussion is out of the scope of this thesis. The reader can find thorough information regarding these issues in e.g. Montgomery (2005).
8.3.4 The V-Mask Procedure for CuSum Charts

An alternative procedure to the use of tabular CuSum charts is the V-mask control scheme proposed by Barnard (1959), which is applied to successive values of the CuSum statistics. The decision procedure consists of placing the V-mask on the last point of the cumulative sum control and parallel to the horizontal axis; see figure 8.4. If all previous cumulative sums lie within the two arms of the V-mask then the process is said to be in statistical control. On the contrary even if one point lies outside the arms of the V-mask the process is to be out of statistical control (Mitra, 1993; Montgomery, 2005).

There are two parameters which need to be determined while designing a V-mask, the lead distance and the angle of each decision line, which are determined based on the level of statistical risks, which the decision maker is willing to tolerate (Johnson, 1961).

![Figure 8.4: An example of a V-mask for use of making decisions about cumulative control charts. Adapted from Mitra, (1993).](image)

Both the tabular and the V-mask techniques produce better results in terms of ARL sensitivity than Shewhart chart control limits, when it comes to small shifts of a process output (Mitra, 1993). In general tabular CuSum control limits are preferable of V-mask control since they are considered to be less sophisticated and thus, easier to communicate. In addition, the ambiguity associated with the statistical risk within the V-mask design procedure further advocates for the use of tabular CuSum control limits (Montgomery, 2005).

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16 Again the procedure of designing a V-mask is considered to lie outside the scope of this thesis and is omitted; the reader can find relevant information in Mitra, (1993) and Montgomery, (2005).
8.4 Improving Transportation Productivity with SPC

Improving productivity in the logistics function of transportation has been of great concern from the early eras of logistics history\(^{17}\). From the initial attention on SPC by the American Industrial firms at the late 1970s, logistics managers have noticed its potential in the logistics function of transportation. In an article from Foggin (1984) traditional management control approaches are contrasted with the new, for transportation at that time, control methodology of SPC, to investigate its effect on transportation productivity.

By examining a fictive pilot program in a hypothetical logistics carrier firm Foggin (1984), identified various causes of variation and prospective improvements in the transportation logistics function. Among others, Foggin (1984) mostly concentrated on the minimization of transportation fuel cost (i.e. miles per gallon). Numerous causes of variation relevant to fuel utilization were then presented, such as different terrains covered, different weather conditions, different load characteristics, different drivers and their experience, different maintenance settings in the equipment and different qualities in the fuel used. The first three of these sources of variation, were considered as common causes, since the firm cannot control them, while the latter three were controllable by the firm and thus, considered as assignable.

After plotting simulated data of 10 hypothetical trucks for 40 weeks into \( \bar{X} \) and \( R \) charts, significant shifts in fuel usage process were identified. This shift took place due to a simulated change in the fuel type. The alarm signal for this shift was compared with the alarm signal the management of this fictive organization would get through a traditional report based control process (Eilon, 1979). The superiority of the SPC process over traditional management control, with respect to signal availability, is then highlighted and further applications for SPC in logistics transportation is consecutively provided (e.g. transit time between origin and destination).

8.5 Inventory Management with SPC

Phohl et al. (1999) in an attempt to address the problems associated with excess and shortage of inventory introduced a model that applies methodologies of SPC control charts to inventory management. The key objective of SPC inventory management is to use historical inventory and demand data to optimize replenishment ordering and inventory levels in the future.

Control charts are utilized for this purpose to recognize non conforming inventory and demand, and to identify and then eliminate the sources for non conformance. In this way the occurrences of excess inventory and backorder situations are significantly reduced. The general outline of the SPC inventory management model is illustrated in figure 8.5.

The applicability of the model into real situation was then tested through a comparison of the model’s results in a computer simulation against actual data from a 12 warehouses of a European pharmaceutical company. The model performed significantly better than manual inventory control in terms of inventory

\(^{17}\) see chapter 2 - background
levels. The total European inventory reduction was in the level of 20 to 65 per cent for all the four types of products tested.

The backorder situation however did not exhibit a similar performance, and a significant increase in backorders was eminent in all product types. By using the SPC model there is a tendency for more backorder than with the manual control. The reason for this could be that SPC cannot forecast peaks in demand that are much higher than any peak in the past, additional information gathering activities is needed to predict these excess peaks in demand.

Figure 8.5: The main concept of the SPC inventory management model proposed by Pfohl et al., (1999).
Despite the inferior performance of the SPC inventory control model with respect to backorders, the cost reduction associated with its implementation should not be underestimated. The necessary data needed to configure the model are readily available in every firm’s information system, which leads to a low cost for the set up of the model.

In addition, the independent nature of the model provides the controller with an abundance of available time to concentrate on other non-routine tasks. The SPC system only warns the controller in case of significant problems cause be assignable causes. By this, the hands of the controller are “free” to work on improvements, and the productivity of the controller, and the inventory control system is thus, enhanced.

![Figure 8.6: The alarm signal rules and the mechanism for automatically generated inventory replenishment orders. Adapted from Pfohl et al. (1999).](image-url)
8.6 Measuring Suppliers’ Performance with SPC

Statistical Process Control has been utilized in various ways in the logistics context; one of these is the evaluation of supplier logistic performance through Shewhart control charts. Morgan and Dewhurst (2007) explored the application of SPC to measure the logistics performance of a supermarket’s numerous suppliers, through Shewhart control charts. The authors contrasted the use of descriptive statistical analysis, such as mean and standard deviation values, with basic SPC control chart techniques to construct a framework to improve supplier logistics performance.

Initially, supplier logistics performance metrics were established through a literature review. The key replenishment operational performance measures used were stock availability at the point of sale (OSA), Supplier service (SS), and central stock availability (CSA). Further, they focused on two closely linked SPC methods, the improvement of process capability and Shewhart control charts. The reason behind this focus was that attention on the achievement of a good supplier process capability will help to the direction of eliminating costs related to supplier delinquency and subsequent supplier monitoring. Moreover, control charts provide a reliable method for gathering and monitoring trustworthy information regarding the supplying process. Presenting supplier performance metrics in a time related manner facilitates the identification and communication of causes of variation in the supplying process.

After agreeing on what to monitor, an abundance of historical data from the retailer’s enterprise resource system was examined. Performance targets were then established for each performance measure. Twelve non conforming suppliers were identified and their performance, with respect to the supply measures, was plotted in control charts.

Following the examination of all 36 graphs -12 suppliers multiplied by 3 performance metrics- the authors concluded that major defaults, which mostly took place on the public holidays of Christmas and Easter but extended long after, were previously signaled by a continuous suppliers’ erratic performance. There was no indication of a sudden and unexpected deterioration in any supplier’s logistics performance metric.

The previous observation suggests that consistent measurement of relevant logistics performance in the supplier-buyer dyad can be very effective in enhancing the processes that link the two parties. Inconvenience, such as stock outs, caused by inferior supplier logistics performance can be signaled well in advance through the use of control charts. In addition, control charts strive for the establishment of common logistics performance measures and target values for suppliers and buyers, leading to enhanced communication and shared goals, within a supply chain framework.

While drawing a conclusion, Morgan and Dewhurst (2007), state that the best solution to improving supplier logistics performance would be to adopt a composite approach in which descriptive statistics is used to establish target values, especially in situations of a ERP data availability, and control charts are used as a common basis for measuring and monitoring actual supplier performance and subsequently form the foundation for a mutual buyer and supplier problem solving.
8.7 Load Dispatch Planning with CuSum Quality Control Charts

Quality control techniques have also been applicable in the logistics field of shipment consolidation. Higginson (2007), proposed a model based on concepts of cumulative quality control charts, for determining when a consolidated shipment load should be dispatched.

The conflicting nature of load dispatch decisions, i.e. when a vehicle should be dispatched from the factory, or distribution center is been thoroughly studied in literature (Higginson and Bookbinder, 1994; Cachon, 2001; Ballou, 2004). Longer waits between dispatches provide more time for orders to accumulate, resulting in larger loads and lower per-unit transportation cost. Customer service, on the other hand, deteriorates, and inventory holding cost increases.

In Higginson (2007), it is argued that the traditional, target based, strategies for determining consolidated load releases such as time, quantity and time-quantity strategies (Higginson and Bookbinder, 1994; Cachon, 2001) may perform satisfactorily in a long run timeframe but may as well result in widely fluctuating performance on a order cycle-by-cycle basis, which in turn is detrimental to customer service.

The principle methodology behind the load dispatch CuSum model is as follows. The model calculates the accumulated weight and elapsed time of the orders whenever a customer order arrives; this gives the model a more recurrent nature. Consecutively, the model applies decision logic similar to that of CuSum charts, and signals the decision maker if the order accumulation process has deviated from the long run averages that were used in its design.

Whether a deviation from the long run average is large enough to warrant a load dispatch is determined via a method similar to that used by CuSum charts for monitoring the quality of a process, in this way a mechanism is provided to detect variation in the shipment consolidation of the logistics transportation process. After building the model and conducting a simulation run to examine the applicability of the model in real situations, Higginson (2007) concluded that CuSum dispatch models perform significantly better than traditional target based approaches when it comes to situations where the use of long run average target is not appropriate or possible.
When it comes to cumulative quality control charts, there are several characteristics that make them useful in the process of load dispatch planning. These characteristics according to Higginson, (2007) are:

- The CuSum focus on cumulative measures (all observations are considered), just as load dispatch focuses on cumulative characteristics of orders waiting to be shipped (e.g. total load weight)

- The CuSum usefulness in detecting small variations

- The applicability of CuSum charts in individual observations, i.e. sample sizes of one (Mitra, 1993), just as the arrival of each ordered is viewed as a different observation

- The CuSum illustrative nature makes them easy to understand and to apply.

Conclusively, cumulative sum models for load dispatch are emphasizing the importance of monitoring the order accumulation, rather than just waiting for targets to be reached, as traditional dispatching strategies do. These models use information that is readily available to the load planner, e.g. order weight and arrival time, thus, are not difficult to implement. However these models require greater effort in determining initial parameters (e.g. V-mask vertex angle and lead distance) than target based approaches do and require advanced computer skills to be built.
At a more fundamental level, it can be asked whether the dispatch timing problem requires the time and complexity of these models. In practice load dispatching decisions can be taken based on many factors that are not included in these models, such as destination distance, time of the day and day of the week of an order (Higginson, 2007).

### 8.8 Reflection

As presented in the previous paragraphs the Statistical Process Control has been thoroughly studied and implemented in a logistics context. SPC's capability to monitor in a timely manner indicators that encompass valuable information about a process has been transferred to logistics through monitoring inventory and demand information, order's accumulation, supplier's performance, transportation cost drivers and other. In addition, the illustration and communication provided by Shewhart and CuSum control charts assist in the accurate and immediate detection of assignable causes of variation in many logistics operations.

The applications of SPC in the purchasing logistics function are particularly important. Especially through the monitoring of supplier's performance, suppliers that do not conform to the firm requirements can be detected and actions can be taken to overcome the problems associated.

Transportation costs indicators can also be monitored via control charts and source of variation and non-conformity can be detected and eliminated. Moreover inventory management in logistics function is of great importance due to the inventory holding and backorder costs associated to this specific logistics element.

A suggestion for the further promotion of the SPC monitoring techniques in logistics could be that quality control charts can be additionally used in logistics functions such as order processing and warehousing. Order cycle components such as order-pick up, load shipments etc. can be monitored and assignable causes of variation, e.g. computer hardware delinquencies, can be identified and then eliminated.

Moreover, warehousing elements, such as product time spent in the warehouse and the meters a product walked inside a warehouse can be monitored and plotted in control charts, thus, the benefits deriving from the use of SPC techniques can be enhanced and further promoted in logistics.
Figure 8.8: SPC, and logistics classification, investigation and suggestion for further applications.
9 Capability Measures in Logistics

A field of statistical process control that has lately attracted a lot of attention is process capability, or the ability of a process to produce units with dimensions within the tolerance limits (Bergman and Klefsjö, 2003). The concept of process capability compares how the inherent or natural variability of a process in contrast with the specifications or requirements of the output of the process.

Again, as it was the case with the previous chapter, capability measures are employed to study the quality level of logistics while on operation. Hence, this quality management tool has been thoroughly used to measure, monitor and control ongoing processes and thus, will be place in the Study step of the PDSA improvement cycle of logistics.

A way of investigating and measuring the ability of a process to produce units, or provide services, within the set of tolerance limits takes place by utilizing the information obtained from statistical process control, and with the condition that the process is in statistical control, we can define various measures of this capability.

Most of the specific capability measures employed to assess the potential of a process to produce units, or to provide services, within the set of tolerance limits are based on the principle idea of projecting the space of the natural variation of the process that the tolerance interval occupies.

\[
\text{Capability} = \frac{\text{Tolerance}}{\text{Natural Variation}}
\]

Ratios like the one above are widely used to describe the capability of a process to produce units or provide services within specifications. However, in order these ratios to be applicable; there are three assumptions that must be made first. These assumptions if not true, then the interpretation of the above ratios will surely lead to misjudgments and wrong conclusions (Montgomery, 2005). Firstly, the process output should have a normal distribution, i.e. the mean of the output is centered on a value and its variation is dispersed symmetrically on a bell-shaped style; see figure 9.1. Secondly, the process is in statistical control; see chapter 8.1. Thirdly, in the case of a two-sided specification, the process output mean is centered between the specification limits.
It is worth mentioning here a word of warning. Many researchers and practitioners, blurred by the simplicity and easiness of these measures have widely and unquestionably employed capability indexes. However, due to the simplicity of these indexes, their routine use and interpretation may lead to wrong conclusions about the process under examination. As Montgomery (2005) says:

...they are an oversimplification of a complex phenomenon. Certainly, any statistical measure that combines information about both location (the mean and process centering) dispersion and that requires the assumption of normality for its meaningful interpretation, is likely to be misused (or abused). (Montgomery, 2005: p. 339.)
9.1 Supplier Selection based on Capability Index Models

Singhal (1990) introduced a graphic chart to analyze the performance of a group of processes, the CpkMPZone chart. Linn et al. (2006) based on the CpkMPZone chart proposed a model for supplier selection based on the capability index Cpk, which also includes price comparisons, the CPC chart.

The CpkMPZone graphical chart divides the sample of processes to different zones or categories based on their performance on the Cpk index. As it is shown in figure 21, a CpkMPZone chart contains six capability zones (F, D, C, B, M and A).

The x axis represents the Cpu and the y axis represents the Cpl, i.e. upper and lower adjusted capability index respectively (Bergman and Klefsjö, 2003). For each individual process the Cpu and Cpl are calculated, and the pair (Cpu, Cpl) for each supplier is plotted on the chart.

Consecutively, depending on the capability index value processes are classified into the following six categories, F: Inadequate, D: Capable, C: Satisfactory, B: Excellent, M: Motorola’s requirements (Bergman and Klefsjö, 2003) and A: Super.

Figure 9.2: The CpkMPZone chart for analysis of various process performances introduced by Singhal (1990).
Linn et al. (2006) extended the CpkMPZone logic to incorporate price sensitivity and developed a model that integrates the process capability indexes and price as metrics and uses those in the process of supplier selection.

In their model, Linn et al. (2006), instead of collecting information for various processes as was the case in CpkMPZone chart, the data collected are information about suppliers’ processes. Data from functions, dimensions, appearance and materials used by each supplier are collected and properly studied to determine critical characteristics, and consecutively, calculate Cpk indexes for each supplier.

In addition, a target price to quoted price ratio is the calculated for each supplier. These price ratios together with the Cpk index for each supplier are then plotted and integrated on a common Cpk-price comparison (CPC) chart; see figure 9.3.

The logic behind the CPC-chart is similar to the one of CpkMPZone and is as follows. Again the supplier space is divided in six zones (U, H, C, S, G and E). Those failing in the U zone are simply not acceptable because their Cpk index is too low. Those failing in the E zone offer high quality performance and low cost quotation.

Thus, the supplier selection should start from E zone and follow the sequence E to G to S to C to H and finally to U. Within the same zone, these suppliers that fall into the lower half zone (below the 45° line) have a better cost performance and should be preferred in case of a more price sensitive product or part. Similarly those falling into the upper half zone (above the 45° line) have a better quality performance and should be preferred in case quality performance is of higher concern (Linn et al., 2006).

![Figure 9.3: The Cpk-price comparison (CPC) chart used for supplier selection introduced by Linn et al. (2006).](image-url)
Supplier selection and purchasing is an important part of supply chain management and a key function of logistics. Numerous techniques have been proposed for this process, such as price comparison, factory visit, certification (e.g. ISO 9001) and process capability.

By CPC chart, Linn et al. (2006), proposed a graphical model to integrate the most used, i.e. price comparison (Ourkovic and Handfield, 1996), and the most effective, i.e. (Singhal, 1990) methods for selecting quality products and parts.

Unsurprisingly, other factors may be included in consideration when it comes to supplier selection, such as quality performance history of the supplier, proximity, delivery time etc. The decision policies may vary from one company to another, but through the CPC model an easy to understand and communicate methodology can be utilized to give some further insights in this critical to quality and to survival of a firm logistics function.

9.2 Reflection

The aforementioned example confirms that capability measurement and analysis with the employment of index measures is used in logistics operations, through their applications in the supplier selection process of purchasing. In addition the improvement programs associated with the studies of capability indexes, such as Six Sigma\textsuperscript{18}, have also be adopted in logistics operations and further promoted the use of capability indexes to measure logistics performance.

Capability indexes are a precise exact and straight-forward tool to understand a process and identify improvements and their directions. In addition, as illustrated in the paper written by Linn et al. (2006), customers’ demand on suppliers, mostly in an industrial purchasing context, to perform on a certain quality level, indicated by an analogous capability index value, is leverage for the further promotion of such indexes in logistics. International standard systems, such as ISO 9000 and QS 9000, are also advocating to the further encouragement of the use of such indexes in logistics operations and functions.

In the case of Linn et al. (2006) presented before, only a sample of product units were available from suppliers. In that case, there is no direct observation of the process or its history. While employing such capability measures to quantify the performance of a process that we did not directly observe, Montgomery (2005) advocates to more properly call these studies “product characterization”, to distinguish them from the “process capability” studies. In the former case, we can say nothing about the dynamic behavior of the process or its state of statistical control, while in the latter case, by knowing the time sequence of the data collection, inferences can be made about the stability of the process over time.

\textsuperscript{18} The six sigma improvement program and its applicability in logistics is discussed in chapter 10 – six sigma in logistics
A suggestion for the further promotion of the capability measurement and analysis methodologies for identifying improvement areas could be to utilize these methodologies, beyond the mere manufacturing related areas of an organization.

These techniques are thoroughly utilized when it comes to the measurement of product characteristics and their conformity to the set tolerance limits. On the other hand, logistics service elements are not, as broadly as product characteristics, measured and tested in terms of capability indexes.

Although easily quantifiable, logistics service elements that are time-based, such as invoicing, pick-up, transportation and total order cycle time are found to be only monitor through control charts\(^{19}\) and not measured and analyzed in a capability context. Such an analysis would further facilitate the identification of improvement potentials and the proper direction towards the improvement efforts.

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\(^{19}\) see chapter 8 – statistical process control in logistics

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**Figure 9.4**: Capability measures and logistics classification, investigation and suggestion for further applications.
10 Six Sigma in Logistics

Throughout this chapter the Six Sigma methodology will be examined with respect to its applicability in logistics operations. The Six Sigma improvement methodology has, over the last decade, attracted industry’s attention in a large extent. This attention is mainly attributed to the significant financial results that large corporations experienced in association with their Six Sigma methodology implementation.

The topic of this and the subsequent chapter, Six Sigma and benchmarking respectively, deal with quality management tools and methodologies that aim at the improvement of a present situation. Thus, these quality management practices are positioned on the last step of the logistics improvement cycle, namely Act.

Following the understanding, the design and the operation of logistics with respect to the values of quality management, the Six Sigma improvement methodology is utilized to refine the position of quality with logistics and improve its present situation.

The Six Sigma methodology had such a sound impact on business practitioners and researchers that led to the misunderstanding of being superior to total quality management (Klefsjö et al., 2001). In the following lines a brief presentation of the Six Sigma methodology will be provided together with an investigation of the differences between manufacturing and service applications of the core DMAIC operations of Six Sigma. Finally, a conceptual model for the application of such methodologies to supply chain management followed by two cases of successful Six Sigma adoptions in logistics operations.

10.1 What is Six Sigma?

Six Sigma was introduced by Motorola in the 1980s, as the name for their improvement program, focusing on reduction of unwanted variation. It can be seen as a systematized methodology consisting of various tools that strives for improved profitability results through variation reduction based on a strong top management commitment (Magnusson, et al., 2002).

To result into significant variation reduction, Six Sigma methodology strongly adopts a process orientation. By understanding the various business activities as processes (influenced by the words of Deming, 1994), Six Sigma applies statistical quantitative techniques to understand and eliminate variation of the process outcome on a significantly low level.
This level, which actually gives the name to the methodology, is defined as the distance from the process mean to the nearest tolerance limit of at least six times the standard deviation (σ) of the process; see figure 10.1. By assuming a normal distribution for the process output, this benchmark results in a probability of maximum 3.4 defects per million opportunities (dpmo), even in the case of a shift in the process mean of a magnitude of 1.5σ.

![Figure 10.1: The six sigma benchmark for a process output. From Magnusson et al. (2002).](image)

### 10.2 The Six Sigma Framework

By adopting the previous metric as a goal for the improvement project, the work is usually carried out in a form of a well structured methodology comprising of the following distinct operations: Define, Measure, Analyze, Improve and Control, or DMAIC.

The Define phase includes the identification, evaluation and selection of improvement projects and project team members. In the Measure phase, data are collected and critical to quality (CTQ) characteristics are determined. Consecutively, during the Analyze phase, the data are thoroughly examined and the "vital-few" determinants of performance are established. Successively, through the Improve phase, experiments are carried out to identify the cause and effect relationships and optimize the process. Finally, in the last phase of Control

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There are other set of operations used within Six Sigma improvement projects, depending on the nature of each project. Some of them are DMADV, which is used in process redesign, where Design and Verify are used in place of Improve and Control and DABTL, which is used for systems development, where Architect, Build, Test and Launch are used (Yang et al., 2007). Nevertheless, DMAIC is the most known set of operations and is considered as a synonym to Six Sigma.
a design of the control and a plan for stability is carried out together with a scheme for monitoring (Thawani, 2004).

This set of operations results in a cyclic process of the same type as the improvement cycle Plan, Do, Study and Act, or PDSA, and various tools and techniques of total quality management are utilized in its context (Klefsjö et al., 2001).

Although the DMAIC systematized way of carrying out projects, provides a structured method to be followed, if the people that are involved and participate in these projects are not familiar with the requisite tools, the projects are likely to be failures. Towards this direction, a thoroughly systematized education and training program for improvement leaders at various levels (white, green and black belts) is launched and is therefore an important element within Six Sigma.

A measurement scale that is simple and straightforward is communicated throughout the performing organization, and is used in Six Sigma to achieve consistency among all participants, such as project team, project leader, top management and customers. The measurement scale used in defects per million opportunities (dpmo) and can be converted in Sigma terms, and then compared with the target benchmark; see figure 10.1.

Finally, everybody that somehow affects or is affected by the improvement project should actively participate and share the goals and visions with the rest of the team members. Especially, the top management should be committed and guide and mentor the improvement project throughout its life, from the initial idea to the finally evaluation of the results.

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**Figure 10.2:** The overall framework for Six Sigma with the DMAIC set of operations surrounded by the four most important principles. From Magnusson et al. (2002).

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21 This conversion is not always correct, and is a common mistake among practitioners and academics of Six Sigma. More on this issue can be found in 10.8, the reflection paragraph of this chapter.
10.3 Differences in Manufacturing and non-Manufacturing Applications of Six Sigma

The Six Sigma improvement methodology has over the past two decades predominately used to improve manufacturing processes. However, Six Sigma is being increasingly applied to a wider range of non-manufacturing operations (Magnusson et al., 2002). Of major concern in this chapter is the examination of the applications of the six sigma improvement methodology on a non-manufacturing operation, such as logistics.

Thus, an investigation of the differences that exist in the core DMAIC set of operations between manufacturing and non-manufacturing applications of Six Sigma will be of help to scrutinize the nature of the projects in logistics. By adopting a process view on business processes that do not produce a physical product but directly or indirectly support the overall business mission, Does et al. (2002) provide a mapping of the differences in each step of the DMAIC set of operations between manufacturing and non-manufacturing applications of Six Sigma.

In the Define phase, the scope of the improvement project is defined. This is usually straightforward in manufacturing operations where quantitative approaches are common in practice and the different production stages are clearly distinctive. However, this is not always the case in non-manufacturing applications where services are produced and clear borders do not exist between different service creation stages. In addition, in non-manufacturing operations performance measurement schemes for the various process is not a common practice and measurements of quality are not well established making the evaluation of the bottom line effect of the Six Sigma improvement program a vague estimation.

<table>
<thead>
<tr>
<th>Define</th>
<th>Measure</th>
<th>Analyze</th>
<th>Improve</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficult to define project scope due to unclear service stage boarders</td>
<td>Flowcharts usually do not exist</td>
<td>Uncontrollable, unquantifiable factors more frequent</td>
<td>Formal experimental design may not be applicable</td>
<td>Transfer steps for configuration and warm up periods do not take place</td>
</tr>
<tr>
<td>Difficult to evaluate the bottom line effect of the project due to non-established measurement of quality</td>
<td>There is no repeatability in data gathering</td>
<td></td>
<td>Difficult to formulate due to the elimination negative influences through creativity</td>
<td></td>
</tr>
<tr>
<td>Difficult to formulate teams since responsibilities and accountabilities are not clear</td>
<td>Difficult to give operational definitions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capability indexes and performance measures do not attain the same meaning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 10.3:* Major impediments in the application of Six Sigma improvement projects in non-manufacturing operations. From Does et al. (2002).

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22 In this context, logistics is a supporting operation for the business strategy, since it provides value creation through time and place utility, see chapter 2 – background.
Finally, the assignment of responsibility and accountability is non clear in service providing operations making the team selection and the planning of the project a time consuming task.

With respect to the Measure phase, the confusion of goals and responsibilities within each process, results in difficulties in the development of process maps. Unlike manufacturing operations, in non manufacturing operations flow charts that describe the sequence of steps within a process are usually complete absent and must be generated from scratch.

However, the absence of process maps results in quick gains, since new insights are engendered that resolve many problems. It is fortunate that in six sigma projects related to non manufacturing operations, that relationships between business metrics and associated quantitative quality characteristics is relatively straightforward. In non manufacturing operations metrics are usually a count that can relatively easy converted in monetary terms, an example from a logistics related operation could be the number of missed on time deliveries. On the other hand, in manufacturing, measurements are typically repeatable, which is usually not the case in non manufacturing operations, e.g. inventory stock out situation. Thus, in service related operations, validity is much more an issue than repeatability.

In non manufacturing operations careful development of operational definitions is of out most importance, and more difficult than in manufacturing. An example of this difference is that in a manufacturing operation, a product can be defined as defective if it exceeds a set of specification requirements, on the other hand, the definition of a defective or missed delivery is more vague and specification requirements more fuzzy.

In particular, logistics related improvement programs have target values of zero, e.g. missed deliveries, thus, making specification limits not available or possible. Since, specification limits are usually unavailable, capability and performance measures do not attain the same meaning in non manufacturing as in manufacturing related Six Sigma projects. Hence, in non manufacturing Six Sigma projects measures of central tendency and dispersion are often used instead of capability indexes. In addition, data derived from non manufacturing operations exhibit non normality, e.g. binomial distribution of missed deliveries or stock out occurrences, making the calculation of capability indexes even more difficult.

When it comes to the Analyze phase, despite the fact that methods used to discover and select factors that potentially influence the response quality characteristics are the same between manufacturing and non manufacturing Six Sigma projects, factors are of a different nature. In non manufacturing Six Sigma projects, where services are examined in stead of products, uncontrollable and unquantifiable factors are more frequent. This can be attributed to the fact that human beings substitute machinery in the service creation. In a logistics context, psychological factors affecting the drivers can be a factor to be considered while transportation mistakes are examined.

Moving to the Improve phase, formal experimental design methods may not be applicable, or may require combination with other qualitative approaches, to establish functional and cause and effect relationships between quality characteristics and input factors of non manufacturing projects. Improvements in non manufacturing are typically realized by eliminating negative influences of

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23 see chapter 8 – SPC in logistics
uncontrollable and unquantifiable noise factors through intervention in the process, while creativity and imagination may be used instead of rigid statistical experimentation.

Finally, due to the fact that improvements take place through intervention in the process, during the Control phase of non manufacturing projects, transfer steps for configuration and warm up periods do not take place. Control charts are also applicable in non manufacturing processes\textsuperscript{24}, and together with mistake proofing and failure mode and effect analysis (FMEA) constitute a useful toolset for the prevention and control of service processes.

10.4 A Conceptual Framework for the Application of Six Sigma in a Logistics Network

Taken into account the significance of variation within the logistics network of collaborative firms, Knowles \textit{et al.} (2005) developed a conceptual model that addresses the potential of Six Sigma in generating improvements across a supply chain, rather than within a single organization.

The performance of collaborative logistics networks is impaired due to different variation causes, such as fluctuations in demand, delivery quantities and qualities caused by suppliers inconsistencies. All these fluctuations result in poor performance indicated by large lead times, excessive inventories and less on time deliveries, which may disrupt and damage the supply chain process; see figure 9.4.

According to Poirer (1999) approximately 65 per cent of the cost of a product is related directly to the logistics activities of its associated supply chain, thus, the six sigma methodology, which is designed to generate immediate improvements in profit margins (Knowles \textit{et al.} 2005), seems to be the proper technique to be followed.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure10.4}
\caption{Reducing variation in lead time results in reduced costs and better performance. From Billinge (2002).}
\end{figure}

\textsuperscript{24} see chapter 8 – SPC in logistics
By taken into account the various needs that emerge from the nature of an application of a Six Sigma projects to a logistics network context, Knowles et al. (2005) composed a conceptual model based on the DMAIC set of operations; see figure 10.5. The Supply Chain Conceptual Improvement model consists of seven distinct steps, which in turn are part of two complementary cycles, the strategic cycle and the operational cycle.

These cycles tie the project with the organizational objectives. The strategic cycle ensures that the organizational strategies are developed into useful objectives and deployed into a set of measures for supply chain performance that are consistent with an aligned to organizational drivers. Consecutively, the organization’s performance against these measures is the driver that defines the projects with the maximum strategic impact on the areas of poor performance, and triggers the operational cycle deployment.

The nature of the operational cycle is similar to the generic DMAIC set of operations and makes use of standard six sigma tools together with some additional ones. Finally, by the project’s completion, the operational cycle feeds back into the strategic cycle to refine and assess the outcome of the project.

Figure 10.5: The Supply Chain Conceptual Improvement model, (SCCIM), together the additional tools, techniques and activities. From Knowles et al. (2005).
By the use of the balanced scorecard (Kaplan and Norton, 1992), supply chain performance is linked to strategy, and a strong and clear linkage between operational measures and strategic decisions is thus taking place. In addition, the focus on supply chain operations can be increased by the use of the supply chain operators reference (SCOR) model, which facilitates significantly the identification and understanding critical supply chain processes and metrics (Swartwood, 2001). Hence, the strategic cycle of the SCCIM model provides an ongoing guidance to the achievement of critical strategic goals by the Six Sigma improvement project.

Since logistics networks involve numerous firms and owners, improvement projects related to logistics networks have further to cope with the complexity and confusion of these organizational relationships. Thus, a collaboration set up is of critical importance to assure agreement among all the interesting parties prior to the improvement projects start. In this way the necessary resources and the potential gains will be shared towards a common goal. Successively, together with the standard Six Sigma approaches of process mapping for the Measure phase, time compression techniques provide a lean focus on logistics activities and operational scorecards link the performance of key measures back to higher level measurements.

During the Analyze phase lean analysis tools, such as value stream maps and time base process mapping (Gregory and Rawling, 1997), are utilized together with the standard Six Sigma tools of the Analyze phase. Since removing a non value adding activity will address the variation associated with the process and reducing variation in a process will reduce the resulting waste, lean and Six Sigma approaches overlap, and are thus complementary in a Six Sigma logistics network improvement methodology. In addition, the deployment of organizational goals to the key measurable elements of the process is facilitated by the operational scorecard, which serves as a way to assure continuous focus on the improvement of critical factors.

After the improvement directions have been identified, verification of the feasibility and applicability of those on a real situation can be done through simulation techniques. Finally, sharing of the benefits gained among the participating organizations should be ensured as per the initial agreement and the project results and actions should be communicated.

Benefits from this structured and systematized approach of Six Sigma application in a logistics network which various organizations and owners can be derived. The fact that there is a strong linkage to strategic objectives of the entire network will ensure that the improvement projects focus on the most important, from a strategic perspective, areas. In addition, the feedback after the operational cycle completion to the strategic cycle allows for refinement of the focus for future improvement projects.

An important parameter when dealing with improvement projects that affect or are affected by various organizations is that resources and gains sharing should be commonly agreed and decided. This is done in this framework in the early stages prior to the improvement project start as well as at its end. Lastly, the complementary activities of waste and variation reduction are employed throughout the various operational phases of the improvement methodologies, allowing for realization of significant benefits.
10.5 The Six Sigma Metric for Supply Chain Performance Measurement

Many researchers have highlighted the importance of right metrics for the performance measurement and evaluation of supply chains and individual supply chain members (Lambert et al., 1998; Murphy and Wood, 2004). Although the nature of the processes performing in the same network is different, their performance should still be compared, in addition their performance should be combined to form the performance of the entire supply chain.

In this context, the Six Sigma methodology can be very successful, since it reduces things to a common denominator –defect per million opportunities and sigma levels\(^{25}\). In turn, this provides a common language and the ability to benchmark against processes of similar or dissimilar nature (Dasgupta, 2003).

Dasgupta (2003) argues that since all logistics functions should be recognized as processes (Lambert et al., 1998) and that the Six Sigma metric is used to measure the performance of processes (Magnusson et al., 2002), the integration of the Six Sigma metric, and the objectivity it yields, with the performance measurement of supply chains seem rather straightforward. Thus, by utilizing the common Six Sigma metrics of defects per unit (dpu) and rolled throughput yield (RTY), (Pyzdek, 2000), Dasgupta (2003) introduced a framework for evaluating the performance of an entire supply chain.

After the initial identification of the supply chain structure and the managed links among its processes, the critical to quality (CTQ), characteristics relevant to the particular set of business processes are identified. Consecutively, norms for the CTQs with respect to each specific process within the chain are established. To obtain sample data from each specific process, a suitable time frame and population if sample units, should first be defined.

By analyzing the data, dpu and yield\(^{26}\) for each particular process are calculated, and by multiplication the RTY\(^{27}\) for the entire chain is obtained. Finally, with the help of standardized normal tables the RTY is translated to sigma levels. Care must be taken here, since the false and mistranslation of defects per million opportunities and defects per unit lead to wrong conclusions. In case of wrong conclusions, management can be deceived and the actual improvement may never happen. On the other hand, in case of a correct and proper use of the dpmo and Sigmas, these metrics enable benchmarking and comparison with world class performances of any type of processes.

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\(^{25}\) This conversion is not always correct, and is a common mistake among practitioners and academics of Six Sigma. More on this issue can be found in 10.8, the reflection paragraph of this chapter

\(^{26}\) Yield is defined as a percentage of met commitments (total of defect free events) over the total number of opportunities. Rolled Throughput Yield is similarly defined as the Yield of a sequence of processes (Pyzdek, 2000)

\(^{27}\) This requires that the processes, which comprise the supply chain, are independent
10.6 Transportation Process Improvement through Six Sigma

An example of an application of the DMAIC set of operations on a logistics improvement context is presented by Thawani (2004). A transportation company located in central Europe, which manages outbound cargo from a distribution center to different stores, faced problems in meeting the delivery schedules. Deliveries of heavyweight and lightweight cargo are made on owned trucks and by hired ones.

The goal was defined as to reduce the number of delayed deliveries by 50% by the end of the same year that the project was undertaken, in order to better meet customer requirements of timely delivery. More specifically, the goal was to deliver orders within a time window of ±1 hour of the scheduled time. The scope of the project was defined to focus on the delivery process for customers that generate relatively high revenue for the company. And the boundaries of the process were set from the time an order is received from the store to the time the freight is received and signed for by a customer at their store.

To effectively measure the delivery process, a SIPOC\(^{28}\) process map was made that helped to identify all relevant elements of the process improvement project before the actual project began. The employment of the SIPOC tools helped to define the nature of the delivery improvement project that may have been not well scoped; see figure 10.6. Consecutively, the CTQ characteristics were identified, and by the help of a simplified House of Quality\(^{29}\) matrix the relationships between the improvement variable of and the response measures were underlined; see figure 10.7.

\[\text{Figure 10.6: SIPOC map of the delivery process. From Thawani (2004).}\]

\(^{28}\) SIPOC stands for Suppliers, Input, Process, Output, Customers and is a six sigma tools employed usually in the Measure phase

\(^{29}\) see chapter – 6 Quality Function Deployment in Logistics
Timely deliveries would result in increased productivity and thus, savings for the customers and at the same time would reduce the need for extra hired trucks and drivers, which were much costlier than the company owned resources. A capability analysis was conducted and reveals that the current performance of the transportation company at that time was at a 2.43 sigma level or 175,889 dpmo.

A Cause and effect diagram was generated for analysis and for identification of the major causes of variation. The driver and the distance of each shipment were found to be as the key factors for fluctuation in the delivery time. Since, the distance factor was outside the company’s influence the analysis phase focused on the driver factor.

A more detailed, second level, cause and effect diagram revealed that the size of the vehicle, the type of engine, the type of tires and the fuel capacity were the potential root caused as to why the driver influenced the delivery time. Numerous experiments were then designed and conducted using truck type and tire size as independent variables. It emerged that larger tires took a longer time on certain routes where the area was cramped and time was lost in maneuvering.

To improve the process the dispatch process was modified to by routing smaller trucks to more restrictive areas. A pilot period was established and data collection and study revealed that out of 600 units, only five were found to be out of time yielding a sigma level of 3.94 or 7,353 dpmo. Finally, controls were established to sustain the results.

![Table](image)

<table>
<thead>
<tr>
<th>Delivery within ± 1 hour of the scheduled time</th>
<th>Deviation from scheduled time</th>
<th>On-time delivery (Yes or No)</th>
<th>Actual delivery time</th>
<th>Happy Store Manager (Yes or No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong Rel/ship</td>
<td>Strong Rel/ship</td>
<td>Medium Rel/ship</td>
<td>Weak Rel/ship</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 10.7: A simplified House of Quality for the delivery process.**
*From Thawani (2004).*
10.7 Surplus Inventory Reduction through a DMAEV Set of Operations

The applicability of the Six Sigma improvement methodology in a logistics context is further highlighted by a surplus inventory reduction program within a large-scale logistics network. Yang et al. (2007) presented a Six Sigma methodology which is a modification of the DMAIC set of operations to fit within the system redesign needs of a large electronics supply chain. Their approach to six sigma improvement consisted of five sequential phases, Define, Measure, Analyze, Enable and Verify.

In the Define phase the overall project and the specific problem to be tackled are identified together with the project’s goals, scope, outcomes and schedule. By carefully examining the business outer and inner environment, through tools such as the voice of the business (VOB) and the voice of the customer (VOC), the increased cost associated with the surplus inventory was found to be the problem to be addressed.

After the thorough examination of the related processes, i.e. material purchasing, manufacturing, order fulfillment, production planning, sales forecasts etc, two potential CTQ characteristics were then elicited, demand stabilization and inventory visibility. Further investigation concluded that the surplus inventory was the critical to quality response variable, CTQ-Y, and is given by the formula:

\[
\text{Percentage of Surplus Inventory} = \left( \frac{\text{Total Excess Inventory}}{\text{Total Inventory}} \right) \times 100,
\]

The Measure phase in turn, identifies the current level of the CTQ-Y, sets up a new target and elicits the key explanatory variables X. With respect to this inventory improvement project, the level of surplus inventory rate was measured to be 10 per cent and a new target was set at 6 per cent.

Further, potential root causes were identified and further refined to a set of seven causes, namely, recording past surplus inventory, planning surplus inventory, early detection of surplus inventory, standard for managing excess inventory, standard for managing surplus inventory, standard for managing safety stock and web user interface design.

For all the previously mentioned Xs, data was collected in the Analyze phase and a thorough study using quantitative and qualitative techniques was conducted to evaluate the hypotheses of relationships between Xs and CTQ-Y. Recording past surplus inventory, standard for managing excess inventory and web user interface design were found to be the vital few Xs that significantly affect the level of surplus inventory.
Subsequently, in the Enable phase, the three significant Xs, led to three possible actions for improvement of the current surplus inventory. A House of Quality tool was utilized to determine the impact of each required improvement with respect to each improvement subject, and to assist in the deciding which improvement action to undertake. The web-based user interface design for inventory management was found to be highly relevant to the overall improvement subjects.

In the last phase of Verify, two stages of pilot test were conducted in a business unit within the network to confirm the outcome of the project. The pilot tests indicated a reduction in surplus inventory of 3.9% resulting in significant gains for the whole logistics network of approximately $1 million. Finally, in order to proceed and accelerate the adoption of the optimal solution, a control plan and a change management plan were developed to sustain the results.

### 10.8 Reflection

From the paragraphs above the applicability of the Six Sigma improvement methodology to logistics operations is evident. Six Sigma has been adopted in various logistics functions such as orders’ shipment dispatching, transportation routing and inventory management. The fact that the Six Sigma methodology as well as logistics functions are mostly considered by practitioners and researchers as process oriented approaches further motivates their integration.

In addition, the project nature of six sigma and its structured techniques enforce a more discipline approach in the various logistics processes and ensure that are executed methodically. Moreover, the potentials for cost savings in logistics operations are great since logistics operations are labor intensive and comprised of a high volume of transactions.

The application of the various Six Sigma methodologies into logistics can be further enhanced by transferring and implementing the structure of Six Sigma projects into more logistics functions. Salvage and Scrap Disposal processes can also be monitored and improved through set of operation like DMAIC. In addition, warehousing processes which account for the largest part of logistics costs due to the capital tied up associated, offer the a great potential for improvement through costs reduction. Design for six sigma techniques, techniques that address variation from the initial stages prior to the operation logistics, can be employed towards the design logistics networks that are robust and stay within the six sigma target.

Finally, maybe the most significant contribution of Six Sigma to logistics can be found in the very nature of logistics. The fact that the main target of every Six Sigma project is the reduction of variation can be combined perfectly with the nature of logistics which are highly dynamic. Variation in the early stages of the logistics activities from the supplier to the manufacturer is amplified along the chain to the end customers. Thus, the nature of the industrial dynamics found in logistics (Forrester, 1961) can be a glorious battlefield for Six Sigma improvement projects.
On the other hand, it is important to mention that the Six Sigma methodology focuses on the quality improvements mostly associated with the fulfillment of basic, Must-be needs. Thus, the significance of the other types of needs which are of outmost importance to logistics service receivers should be addressed in a bigger extent by Six Sigma improvement projects.

Finally, a word on a frequent and at the same time severe pitfall of the Six Sigma improvement methodology and its associated measurement system much be put down. It is common practice among Six Sigma practitioners and researchers to treat dpmo and sigma levels as synonyms. The translation of dpmo to sigma levels and vice versa may not be applicable and conclusions can be drawn that will fail to be incorrect.

The number of observation needs to be large enough to realistically comprehend the variation of a process output over time. It is not rare that only a small sample of a process output is measures to derive the dpmo values. In addition, on should be able to judge whether the process under examination is predictable, i.e. in statistical control, or not. Utilizing information from few observations does not assist in judging about a process’ predictability.

Moreover, to convert dpmo to sigma levels requires that the process output under investigation follows a normal distribution. Despite the fact that aggregative histogram representations of data often suggest that skewed, i.e. non symmetric, distributions are more suitable for fit than the normal distribution; it is seldom the case that a non normal distribution is employed for representation of a process output performance.

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30 see chapter 5 – The Kano model in Logistics
11 Benchmarking in Logistics

Throughout this chapter the benchmarking improvement methodology and its applicability to logistics will be examined. Benchmarking is a way of finding improvement opportunities for process improvements, by comparing processes and benefit from the comparison.

Benchmarking, in contrast with most of the quality management tools and techniques that have their roots in manufacturing, has initially been introduced and applied in a logistics context (Tucker et al., 1987). As is the case with the Six Sigma improvement methodology, benchmarking is a continuous scheme for performance enhancement, and the attention it has attracted is mostly attributed to the breakthrough improvements it leads to, especially with respect cost reduction.

As is the case with the Six Sigma improvement methodology, benchmarking is placed on the Act step of the logistics improvement cycle. Since it deals with the refinement and improvement of a present situation in logistics towards a better performance, is subsequent to the understanding, designing and operating logistics processes with respect to the values of total quality management (Bergman and Klefsjö, 2003).

11.1 What is benchmarking?

Benchmarking, while being a systematic management process, involves continuous monitoring and measurement of a company’s performance against the “best-in-class” companies, i.e. firms that have attained peak or world class performance. Its goal is to ultimately learn and incorporate process and product innovations that have proven successful in other organizations (Bagchi, 1996). Benchmarking should thus, emphasize not merely on the outcome, but on the process employed to achieve the outcome.

Through the employment of benchmarking improvement projects, a link is provided between functional performance and the corporate strategic position (Bagchi, 1996). Benchmarking studies can identify sources of competitive advantage steaming from functional areas that can be exploited more vigorously to provide distinctive competence throughout the company. By aligning operational activities on the functional level with the overall needs of the corporation, benchmarking is capable to provide the strategic focus at the functional level (Bagchi, 1996).

As with any improvement process, benchmarking must be seen as a continuous process (Spendolini, 1992). Although benchmarking processes are time consuming, costly and require discipline, such process can be a viable tool providing useful information for improving virtually any business activity.
For some companies, benchmarking is an integral part of their overall organizational improvement process, whereas others consider benchmarking more a proactive mechanism for keeping themselves updated in the business arena. Hence, benchmarking is used by organizations for a variety of purposes (Spendolini, 1992).

Although benchmarking provides a systematic process to learn and adapt an organization to the best practices, it must be emphasized that the goal is not to merely copy. Ambition of benchmarking studies is to encourage learning and to provide a platform to use innovation and continuous improvement to achieve even better performance than the one that is been benchmarked (Bergman and Klefsjö, 2003).

Even though the usual aim of benchmarking is to achieve better performance in terms of customer satisfaction, it is the lure of cost reduction that persuades top management to dedicate resources to such studies. Thus, as Stalk and Hout (1990) note, benchmarking and the resultant process reengineering have simply become efforts to catch up than to get out in front.

While benchmarking can certainly help keep track of what is happening in the business environment and can provide a platform to act, the only way to achieve improvements is by developing competences in core business areas (Bagchi, 1996). The lack of competence deployment within benchmarking is attributed by many researchers (Watson, 1992; Bagchi, 1996) as the most serious shortcoming of the benchmarking method as a strategic competitive tool.

### 11.2 The Benchmarking Process

Ever since Xerox used benchmarking in the early 1980s (Tucker et al., 1987) to cope with its Japanese competitors, researchers and practitioners have dedicated their efforts to provide a structured framework for conducting benchmarking studies. Watson (1992) based on the pioneering work of Camp (1989), provided a sound description of the steps involved in a benchmarking study in conjunction with the Plan-Do-Study-Act cycle of the continuous improvement process; see figure 11.1. Due to the broad definition of each step, this process framework can be applied in any kind of benchmarking study, regardless the nature of the benchmarked function.

According to the framework proposed by Watson, (1992) a sequence of 6 steps should be pursued, followed by a feedback loop for further refinement and continuous assessment. The sequence of these steps is to be employed, in a continuous manner, as long as further improvement opportunities are identified.
Initially, during the plan step the benchmarking company should identify its core competencies, its key business processes and the critical factors with respect to each key process. The processes to be benchmarked are then documented and their current capability is assessed.

Subsequently, in the search step the requirements for the benchmarking partners are established with respect to the nature and the scope of the benchmarking study. In addition, any particular company that may be a potential benchmarking partner should be characterized as to the degree of relevance with the company’s own processes.

Throughout the following observe step, internal, external as well as indirect data are collected. These data are gathered from the in-house company, the benchmarking partners, trade journal and annual reports respectively. By organizing and graphically representing the information acquired, a common measurement base is established and performance gaps are identified.

Figure 11.1: The benchmarking process in conjunction with the PDSA continuous improvement cycle. From Watson, (1992).
During the analyze step a thorough examination and investigation of the relationships between the various process characteristics takes place to obtain the root causes of the various performance gaps between the benchmarking company and the benchmarking partners.

Moving to the adapt step, the process enablers are found, which correlate to the process improvements are isolated and their adaptability to the culture of the benchmarking company is determined.

Finally, through the improve step the improvement projects that are more likely to impact the root causes are selected and the goals, requirements and actions for improvement are established.

### 11.3 Types of Benchmarking

Many researchers have divided the approaches to benchmarking in various categories (Watson, 1992; Spendolini, 1992; Hollings, 1992; Bendell et al., 1993), but most of the studies seem to agree upon four main benchmarking types, namely internal, competitor, functional or cooperative and generic benchmarking.

First, internal benchmarking refers to making comparisons with other parts of the same organization such as other departments or sites. In this case, the willingness for participation is straightforward and the benchmarking data are collected rather easily, however such studies are unlikely to lead to significant improvements since most of the time, the benchmarking is not directed to world class practices.

When it comes to competitor benchmarking, it is almost impossible to get full knowledge of how a direct competitor operates, thus making competitor benchmarking more difficult than internal benchmarking.

Functional benchmarking goes beyond the competition and involves organizations which carry out the processes of interest. This approach bares numerous advantages, such the ease to detect functional leaders and the willingness for cooperation. However, direct applicability of process innovation may not be readily apparent, since adoption of practices in different environments requires creative thinking and adaptive behavior.

Finally, the generic benchmarking, involves comparing business processes that cut across various industries and locations. This approach is likely to produce the most innovative ideas and more significant improvement potentials, nevertheless these potentials are the most challenging to implement in ones own company.
11 Benchmarking in Logistics

The Case of Quality and Logistics

11.4 Warehousing Function of Xerox. The Pioneer of Benchmarking

Xerox, a multinational manufacturer of plain paper copiers, was the first company to implement well structured benchmarking practices in order to identify improvement opportunities for its processes (Camp, 1989). The initial approach to benchmarking within Xerox was rather product oriented. The aim of these studies was to analyze unit production costs in manufacturing operations, triggered by the high competitive low prices of its Japanese counterparts. The results of the above investigations revealed that production costs within Xerox were much higher, forcing Xerox’s top management to adopt competitor’s costs as a target for each manufacturing operation. This in turn proved successful, thus, making top management to apply benchmarking techniques to all units and cost centers in the corporation (Tucker et al., 1987).

Logistics operations of Xerox, however, found it difficult to arrive at a convenient analogue to manufacturing operations. Functions within logistics began to make internal comparisons between regions. Next, specific logistics operations, i.e. the transportation, warehousing and inventory management functions of Xerox, where compared with those of the competition (Tucker et al., 1987).

While faced with the problems of competitive benchmarking (Watson, 1992) the logistics managers of Xerox abandoned the practice of paying attention on comparative costs and discovered that understanding practices, processes and methods is more important, since such a focus defines the necessary changes to reach the benchmark costs (Camp, 1989).

**Figure 11.2:** The different types of benchmarking as a "out-of-the-box-thinking". From Spendolini, (1992).
While moving their focus from cost reduction to profit generating factors, such as service levels and customer satisfaction, logistics managers identified the proper non competing companies to compare with. The selections was mostly based on trade journals, annual reports and other publication were statement of pride appeared. After such an investigation, an outdoor sporting goods retailer, L.L. Bean was found to be the most suitable benchmarking partner for Xerox's logistics operations.

Xerox logistics benchmarking initiative derived from the poor performance of the warehouse function, with the sequence receiving-through-shipping being the bottle-neck for the whole process (Tucker et al., 1987). Despite the fact that L.L. Bean's products may bear no resemblance to Xerox parts and suppliers, both companies had to develop warehousing and distribution systems to handle products diverse in size, shape and weight. Thus, L.L. Bean as a benchmarking partner was of paramount value for Xerox.

A team consisting of the person in charge of the logistics benchmarking and two representatives of the operations and field distribution employees who would ultimately asked to make any changes visited L.L. Bean’s warehouse a number of times. After further analysis, the findings of these visits revealed a range of activities that would enhance Xerox warehousing performance.

By adopting these practices the warehousing process of Xerox significantly increased its productivity by an annual level of 5% (Tucker et al., 1987). In addition, the people involved in the benchmarking process found their job enriched and felt more useful to the organization (Camp, 1989). At the same time the benchmarking partner benefited too by adopting benchmarking in its continuous improvement policy after seen Xerox’s success (Tucker et al., 1987).

11.5 Benchmarking at TNT Express

The UK subsidiary of the TNT Express logistics service provider is another firm that utilizes effectively benchmarking in its direction towards excellence. TNT Express takes benchmarking very seriously and has, among others, adopted an alternative approach to it.

By dedicating a set of finished goods storage and distribution operations on a dietary products manufacturer, as well as, by receiving and sequencing raw material and subassemblies to a car manufacturer, TNT has learned a lot about how to operate logistics processes. Thus, due to the wide range of its customers and the tailor made service it provides, TNT has the opportunity to learn from its own customers (Zairi, 1998).

But learning from its customers was not considered enough for TNT. Therefore, customer surveys were launched periodically, with an aim to identify how customers perceive the delivery of service through an evaluation of key service indicators. Successively, customers asked to score TNT Express for its performance with respect to each logistics service indicator.
This evaluation of TNT service against its customers needs is supplemented by industry wide surveys which benchmark TNT against competition. The above assessments are taken into consideration on a strategic level in TNT and are used as input for the direction of improvements.

Perhaps the most preeminent use of benchmarking in TNT, takes place through internal comparison and best practice rewards. Performance measurement is widely encouraged within all the various depots. Information taken from the measurements by each site is submitted to and analyzed by top management with continuous feedback on areas for improvement (Zairi, 1998).

On the way towards continuous improvement TNT Express has cultivated an internal competition culture were all depots are measured and compared on various key measures such as, total on time deliveries completed, percentage of late deliveries and misroutes. Good performance is rewarded and processes producing bad performance are improved through inspiration from the best. Promotional items, financial rewards and a national annual administration conference, which a trophy is given to the winning team further promote and encourage employees to strive for the best in the internal benchmark arena (Zairi, 1998).

**11.6 Analytical Hierarchy Process Approach for Benchmarking in Forestry Logistics**

From the previous paragraphs it is clear that benchmarking studies involve people from various positions and specializations, thus making benchmarking a team effort. A method with facilitates the benchmarking process team, by forming a systematic framework for group interaction and group decision making, is the Analytical Hierarch Process, (AHP), proposed by Saaty, (1980).

The AHP is a process that structures a decision making problem into hierarchy of relevant factors and elicit judgments (through pairwise comparisons), that reflects ideas, feelings and emotions of the group. The method then converts those judgments to meaningful numbers, and synthesizes the results to provide prioritization of the alternative choices (Bagchi, 1995).

Korpela and Tuominen, (1996) utilized the AHP approach to propose a framework for a generic benchmarking process of forestry logistics operations. By taking the first two steps of a benchmarking study (Watson, 1992) for granted, i.e. the definition of the critical success factors and the identification of the benchmarking partners, Korpela and Tuominen, (1996) illustrated the applicability of their framework on the analysis phase of the generic benchmarking process.

More specifically, the AHP approach was utilized to analyze the performance of the benchmarking partners and to define the enablers, i.e. the means and methods that facilitate the implementation of the best practices.
Moreover the AHP approach was employed to estimate the enablers’ importance and to identify developmental actions for reinforcing strengths and eliminate weaknesses of the company conducting the benchmarking. The actual implementation of the improvement plan and the monitoring and control of the situation after the improvement, were left outside their framework scope.

Initially, the importance of the logistics success factors, which were defined by means of customer interviews and surveys were determined through pairwise comparisons. Again these comparisons should be performed by customers to form a strong customer orientation. With respect to the forestry logistics operations examined, five logistics success factors where identified and are given in a descent order of importance, namely, reliability, lead time, flexibility, cost-effectiveness, value-addition.

Consecutively, the performance of three direct competitors and three companies operating in the metal industry, which project the same logistics characteristics, was analyzed with respect to the logistics success factors. The findings of the pairwise comparison were firstly, the detection of the best performance levels and which companies operate at that levels and secondly, the identification of the overall logistics performance level of the company conducting the benchmarking compared especially with its direct competitors.

\[\text{Figure 11.3: The AHP approach to a generic benchmarking process of forestry logistics operations. From Korpela and Tuominen (1996).}\]
Successively, the processes, methods or characteristics that have helped companies to achieve an outstanding performance were identified. By using the hierarchy structure of the previous phase as a basis and examining the companies with an outstanding performance, enablers were determined separately for each success factor.

Six enablers that apply for each of the logistics critical success factor were defined, namely, logistics management system, various key process integration, effective information system, effectiveness and flexibility of the organizational structure, utilization of modern technology in different parts of the logistics system and long term contractual relationships with customers and suppliers. The importance of the above enablers, with respect to the critical success factors, was again evaluated through pairwise comparisons according to the principles of AHP.

As a final point, actions through which the performance of the company conducting the benchmarking can be improved were identified. The AHP hierarchy and the priorities of the critical success factors and the enablers from previous levels were utilized for this purpose. Potential improvements were identified through the analysis of present and potential strengths and weaknesses with respect to the enablers and the success factors of the higher levels.

Once more pairwise comparisons of the various strengths and weaknesses were conducted and priorities were derived, moreover synthesis of these priorities resulted in the overall importance of the strengths and weaknesses. Furthermore, the potential improvement actions through which the identified strengths and weaknesses can be reinforced or eliminated respectively were linked correspondingly. The normal AHP procedure was then employed to evaluate its respective actions importance.

11.7 Reflection

Benchmarking, in contrast to other quality management tools and methodologies initiated in manufacturing operations, emerged and developed from initiatives deriving from logistics functions, such as warehousing and distribution (Tucker et al., 1987). Hence, it is futile to ask the question weather benchmarking is employed within logistics or not.

On the other hand, the quest for continuous improvement of logistics operations benchmarking is not pointless at all. From the first systematized adoption of benchmarking practices by Xerox, till the latest ones, the pitfall of benchmarking improvement methodologies is mostly the fact that benchmarking projects do not include the actual improvement efforts. Thus, benchmarking projects although launched to bring about development and enhancement of performance, in numerous cases, fall to be process mapping studies that merely analyze the present situation.
A suggestion for the enhancement of the benchmarking methodology with respect to logistics operations could be to further augment the last phase of the benchmarking process, i.e. the improve step in the Watson’s (1992) generic benchmarking process.

This can be implemented by applying additional quality management tools and methodologies, such as cause and effect diagrams, control charts and FMEA, in the last Watson’s improve step, or Deming’s act step. In this way, benchmarking studies will be further facilitated to fulfill the purpose of their initiation, which is a rather forward, i.e. improve business processes.

**Figure 11.4:** Benchmarking and logistics classification, investigation and suggestion for further applications.
Part III
It is common after a long discussion to provide a closing and reflecting section. This will be conducted here in the final part of this thesis. It is the author's belief that the reader will benefit from a section that sums up and concludes the aforementioned.

This aim of this part is to facilitate towards the global understanding of this work. The conclusions of each chapter of the last part will be aggregated and combined. In addition reflection on the limitations and suggestions for future research will be provided, together with references to the literature used throughout this text.

After reading this part the reader will be able to understand the overall answer to the thesis’ question and critically reflect on the individual thesis’ components.

The contents of this part are:
Chapter 12 – The Logistics Improvement Cycle
Chapter 13 – Research Issues and Future Research Directions
Chapter 14 – References
12 The Logistics Improvement Cycle

Throughout the previous and main part of this thesis’ work, the quality improvement cycle Plan-Do-Study-Act was utilized. The content of each specific chapter was placed on a particular step of this cycle. The criteria that advocated the placement of each tool and methodology on a particular step of the PDSA cycle were mostly based on the nature of each quality practice to logistics.

In this chapter, the logistics improvement cycle will be aggregated and illustrated as one entity. In addition, for each quality management tool or methodology examined previously, an argument for its placement on the logistics improvement cycle will be given, together with the presentation on its role towards the overall aim of a logistics organization.

12.1 Illustrating the Cycle

![Diagram of the Logistics Improvement Cycle]

**Figure 12.1: The logistics improvement cycle**
12.2 Service Quality Placement and Role

Starting with the Service Quality models, their usefulness can be found in that these models facilitate towards the understanding on what logistics customers want and need from logistics services. Logistics mostly involves the provision of services rather than the production of physical artifacts, thus, its quality can be better measured in terms of service than product quality. By understanding the nature of logistics service quality it is easier to define its components and dimensions.

Following the definition of the nature of quality in logistics services, the decision makers and the logistics managers will be facilitated towards the planning and setting of logistics processes that put the focus on the customer and their needs and expectations. Hence, service quality principles and models are placed on the Plan step of the logistics improvement cycle. This tools and methodologies can be applied to assist in the understanding and definition of what is the nature of quality within logistics.

By adopting the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, logistics managers should firstly start by deciding which total quality management values should characterize the logistics organization. Subsequently, methodologies that are supportive to the previous values are identified. Finally, suitable tools within the methodologies are picked to facilitate towards the common goal. Figure 12.2 illustrates the role service quality, and its relevant models, can have towards the overall aim of a logistics organization.

Figure 12.2: The role of service quality methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefsjö (2000).

Nevertheless, the adoption of the service quality methodology and its perception against expectation models in logistics does not come without shortcomings. Service quality models emphasize on the functional rather than on technical dimensions of quality (Grönroos, 1984), i.e. how the service is delivered instead of what the service actually delivers. Although for the majority of services this may be proper, for services such as logistics, this emphasis fails to be improper.
By taking into account the business-to-business setting of logistics services, an emphasis on the functional dimension of service quality may be incorrect. In addition, in the case of logistics services, the logistics service provider is, most of the times, physically separated from the logistics service customer and the communication between them takes place through electronic means instead of physical transactions.

Moreover, the logistics service itself is directed at the goods and physical articles that are transported rather than to people. The logistics order, for e.g. transportation or storage, may be placed by human beings, but the actual receivers of the logistics service are the goods that are going to be transported or stored. Thus, e.g. an emphasis on the tangibles of a logistics service that deal with the appearance of the equipment might be superfluous.

Logistics managers should be cautious when employing service quality and its perception against expectation models in their quest to understand and define the nature of quality in logistics services. Service quality models may provide a systematized methodology towards the classification of the various aspects of logistics services, but if used unquestionably and without reflection may lead to misinterpretations and wrong assumptions. Operational, quantitative performance measures although biased and maybe outdated (Mentzer et al., 1999) still are based on the fundamental concept of logistics value addition of time and place utility (Murphy, 2004).

Concluding, it is of the author’s belief that neither service quality models, nor operational measures solely, are adequate to define the complex nature of such a compound and multifaceted service such as logistics. Furthermore, logistics services are comprised of various specialized services such as transportation, warehousing and order handling, thus a single treatment of logistics service quality will fail to be unintelligent.

### 12.3 The Kano Model Placement and Role

The Kano model of quality elements classification is a useful methodology that by its emergence in 1984 has, to some extent, caused radical changes in the way we perceive and understand quality. Kano model’s usefulness can be found in that it is a methodology that classifies, categorizes and then articulates the various dimension of quality. This expression of quality in various dimensions facilitates towards the understanding on what logistics customers want and need from logistics services. By understanding the nature of logistics service quality in Kano’s terms it is easier, for logistics managers, to define components and dimensions of logistics quality.

Following the definition of the nature of quality in logistics services, and complementarily with the Service quality models, the use of the Kano model will facilitate the decision makers and the logistics managers towards the planning and setting of logistics processes that put the focus on the customer and their needs and expectations. Hence, the Kano model and its terminology are placed on the Plan step of the logistics improvement cycle. This tools and methodologies can be applied to assist in the understanding and definition of what is the nature of quality within logistics.
With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.3 illustrates the role of the Kano model towards the overall aim of a logistics organization.

The Kano model’s classification of quality elements provides a precise description of the behavior of different types of logistics service elements. This description offers an effective way to recognize, actual and potential, advantages and disadvantages of logistics services.

However, it is of critical importance not to take a classification of a service element for granted. Changes in customer’s evaluation for quality take place in a dynamic nature as a life time of a logistics service advances. What is indifferent today tomorrow will turn to be attractive and as it becomes more and more popular in the marketplace it evolves to be expected (Kano, 2001).

Thus, logistics managers while recognizing different types of logistics service quality elements for their customers should bear in mind that this types of elements perform in a variable nature and should not be perceived as constant over time.

**12.4 Quality Function Deployment Placement and Role**

The Quality Function Deployment is a helpful and practical methodology that assists in translating customer needs and requirements to product dimensions and specifications. In a logistics context it is previously shown that this methodology is employed in the same pattern to translate customer desires into logistics service elements and to transfer those throughout the network of organizations that form a supply chain. By translating and transferring the voice of the final customer of a logistics network, the quality function deployment methodology facilitates in logistics managers and decision makers to design logistics network structures that address the needs of the end customer.

Following the understanding and the definition of the nature of quality in logistics services, the use of quality function deployment assists in transferring the
meaning and the magnitude of necessary changes. These changes are compulsory in order to adapt and survive in the ever-changing contemporary business environment. Hence, the quality function deployment methodology and its associated house of quality tool are placed on the Do step of the logistics improvement cycle. These tools and methodologies can be applied to assist in the designing of logistics services and logistics networks that address the nature of quality within logistics, and the needs and expectations of logistics customers.

With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.4 illustrates the role of the quality function deployment towards the overall aim of a logistics organization.

![Figure 12.4: The role of quality function deployment methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefsjö (2000).](image)

Yet, quality function deployment projects are time consuming. According to Gustafsson (1998), a mean duration of such a project in the mature field of new product development is six months. It is, thus, expected that quality function deployment will endure even more when are related to a genuine field of application, such as logistics services and networks. In addition, the size and time of the necessary multidisciplinary human resources is a factor that opposes to the running of such projects in a logistics, due to the associated costs.

Finally, it is common practice, although incorrect, to implement only the first step out of the four, therefore, the structural breakdown and articulation of the information that is gained normally, is lost. Thus, the main contribution of this methodology, i.e. the facilitation of changes will be vanished.
12.5 Robust Design Placement and Role

The Robust design methodology initiated by Genichi Taguchi is a methodology that has influenced managers and engineers at such a level that is said that Taguchi is the architect behind the Japanese Industry’s miracle of the last century (Bergman and Klefsjö, 2003). Taguchi’s ideas of off-line quality control, i.e. all the necessary actions that should be put towards quality assurance and improvement prior to the production of a product, came to question the practice of inspection and quality control while on production.

As was the case with the quality function deployment methodology, robust design techniques follow the understanding and the definition of the nature of quality in logistics services. These techniques are employed to design logistics services and network in a way that are robust and insensitive to variation, and thus, meet the need and expectation of the logistics customers at any time. The uncertainty and the disturbances of the logistics business environment are incorporated in Taguchi’s off-line quality control to provide logistics services with the minimum variation during their performance.

It is thus, proper to place robust design methodologies and its associated tools on the Do step of the logistics improvement cycle. Robust design methodologies are subsequent to the understanding and definition of quality in logistics and at the same time prior to the on-line, i.e. while production, quality control.

With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.5 illustrates the role of the robust design methodology and its associated tools towards the overall aim of a logistics organization.

**Figure 12.5:** The role of robust design methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefsjö (2000).
A common mistake logistics practitioners do when utilizing Taguchi’s ideas of robust design is that they neglect the qualitative nature of logistics services. The robust design methodology and its associated tools are quantitative approaches in nature. Thus, thesis techniques deal mostly with quantitative and measurable items. However, logistics services, such as every type of service incorporate qualitative aspect that are immeasurable and thus, can not be handled through robust design tools.

Another impediment to the implementation of the robust design methodology and its related tools to logistics exists in the vary nature of these techniques. Robust design techniques require a significant amount of time for experimentation prior to the operation of the logistics processes. This, although understood among logistics practitioners, may be difficult to implement since logistics processes operate on a business environment that changes rapidly.

In addition, logistics is a business function that adds to the overall organization goal through its ability to provide time related competitive advantage. Thus, it may be infeasible to stop the operation of such processes to perform off-line quality control.

### 12.6 Statistical Process Control Placement and Role

Statistical process control as an early quality management methodology for monitoring assessing and controlling the performance of processes while operating, could not have been omitted from this attempt to combine quality management and logistics.

On the contrary with the previous quality management methodologies, SPC comes succeeding the understanding and definition of quality in logistics and moreover follows the efforts to implement quality dimensions of logistics prior to operation, during the design phase.

Hence, it seems appropriate to place the statistical process control methodology and its associated tools on the Act step of the logistics improvement cycle. SPC methodologies facilitate in understanding the nature of the logistics process and in identifying reasons and cause of abnormal behavior. By the utilization of SPC techniques, setbacks during the operations of logistics processes can be timely recognized and necessary actions can be taken towards the elimination of them.

With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.6 illustrates the role of the statistical process control methodology and its associated tools towards the overall aim of a logistics organization.
As was the case with robust design methodology, statistical process control techniques are quantitative in nature and can only deal with tangible aspects of logistics services. However, logistics services, such as every type of service incorporate qualitative aspects that are immeasurable and thus, cannot be handled through statistical process control tools.

Furthermore, most of the tools associated with SPC are relatively complicated and benefits from the use of such techniques can be derived only if highly trained personnel exist in an organization. Moreover, the expenses to train the employees to use these methods are relatively high and time consuming, but still are only a fraction of the cost and time needed to introduce and establish highly sophisticated monitoring techniques on an intra-firm and even inter-firm logistics process.

### 12.7 Capability Measures Placement and Role

Capability measurement is a useful methodology that helps logistics managers to identify the state of a logistics process. In order to have a meaning, capability measures should be derived from processes that are predictable, or in statistical control. Thus, statistical process control techniques and capability measurements are tied together tightly.

Thus, as it is the case with statistical process control, capability measurements take place during the operation of logistics processes. Furthermore, these measurements should take place while logistics processes are stable and consecutively, while being running for some time. It is not adequate to have understood and defined the nature of quality in logistics, together with the implementation of quality techniques during the design of logistics processes, for a correct and accurate use of capability measures in logistics to take place. Logistics processes should be on operation some time before.
For the above reasons, it is rather obligatory to place the capability measures methodology and its associated tools on the Act step of the logistics improvement cycle. Capability measures facilitate in understanding the nature of the logistics process and in identifying reasons and cause of abnormal behavior and their magnitude. By the utilization of capability measurement techniques, drifts and their size, during the operations of logistics processes can be identified and necessary actions can be taken towards their elimination.

With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.7 illustrates the role of the capability measure methodology and its associated tools towards the overall aim of a logistics organization.

Figure 12.7: The role of capability measurement methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefsjö (2000).

The use of capability measures in logistics does not come without any pitfalls. The methodology of measuring the capability of a logistics process by the means of capability indexes has some requirements which, if not met, make the measurement of logistics process capability wrong and the conclusions drawn misleading. In addition, these measures although find their usefulness in the fact that are rather simple, they do not escape their fate, i.e. that are a simplification of a complex phenomenon, and should be considered in this way.

Finally, it is the author’s belief that when it comes to logistics, capability measures should only be employed to estimate the potential of processes with respect to providing services. Since logistics involves the provision of services rather than the production of goods, direct observation of logistics processes is only possible in this context. Data collection and timely observation of processes can only be conducted to logistics processes that provide services, rather than to the examination of sample units provided from suppliers.
12.8 Six Sigma Methodology Placement and Role

Six Sigma methodology is a systematized toolset that can assist logistics practitioners to bring breakthrough improvements to their processes in particular and to their organization in general. It is a structured roadmap that if followed to its extent leads to significant cost savings. These saving can also take place in logistics processes.

This methodology thus, as an improvement methodology is employed to advance logistics processes from one state to a better one. Usually, the nature of the Six Sigma improvement projects deals with the striving towards the reduction of variation in logistics and other processes.

In order an improvement project to take place, logistics processes should be on operation and mature enough to accept any progress. Capability measures are widely employed in Six Sigma improvement programs, in particular, the Six Sigma name is obtained from capability indexes; see figure 10.1. Thus, all the prerequisites for using capability measures are also relevant in the case of Six Sigma Improvement projects.

Hence, from the standpoint of the vary nature of these improvement projects, Six Sigma improvement methodology is placed on the last Act step of the logistics improvement cycle. Subsequent to the understanding of quality in logistics, the design and the operation of logistics with respect to quality, Six Sigma improvement methodology comes to conclude and enhance the existing performance of logistics processes, usually in a variation reduction framework.

With respect to the systematic view of total quality management (Hellsten and Klefjö, 2000; Bergman and Klefjö, 2003) on a logistics context, figure 12.8 illustrates the role of the Six Sigma improvement methodology and its associated tools towards the overall aim of a logistics organization.

![Figure 12.8](image)

**Figure 12.8:** The role of Six Sigma improvement methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefjö (2000).
Nonetheless, Six Sigma is not a panacea. Its structured nature may be easy to follow and communicate, but the tools and techniques within the Six Sigma methodology are sophisticated and human resources, thoroughly trained on statistical analysis and project management disciplines, are essential if benefits are to be achieved. Costs related with the training of employees and the establishment of the proper culture for breakthrough improvements, although will probably be met and repaid after the project’s end, are still of a significant size.

Moreover, the statistic nature of the Six Sigma tools gives room to misleading interpretations of figures and allows the drawing of incorrect conclusions that may harm the improvement project and the organization in general, to a large extent. Finally, the intangible nature of logistics services makes additionally difficult the setting of target specifications and other numerical goals.

### 12.9 Benchmarking Placement and Role

As it was the case with Six Sigma methodology, benchmarking is systematized technique that aims at improving a present state of logistics processes. This improvement takes place in benchmarking by searching, identifying and eventually adopting best practices. Benchmarking thus, is a step by step improvement process that incorporates all the necessary actions towards the enhancement of a present situation of a company’s logistics processes.

Hence, benchmarking, as an improvement methodology is employed to advance logistics processes from one state to a better one. Usually, in contrast with Six Sigma projects in which the improvement deals with reduction of variation, benchmarking improvement projects are striving for the implementation of already existing, best-in-class, practices of logistics processes.

Therefore, it is self-evident that as with the case of Six Sigma improvement methodology, benchmarking is placed on the Act step of the logistics improvement cycle. Subsequent to the understanding of quality in logistics, the design and the operation of logistics with respect to quality, benchmarking as Six Sigma methodology comes to refine and further augment the existing performance of logistics processes, usually by implementing already tested, best-in-class logistics practices.

With respect to the systematic view of total quality management (Hellsten and Klefsjö, 2000; Bergman and Klefsjö, 2003) on a logistics context, figure 12.9 illustrates the role of the benchmarking improvement methodology and its associated tools towards the overall aim of a logistics organization.
The major shortcoming of the benchmarking methodology is that in contrast with the well-structured improvement methodology of Six Sigma, benchmarking lacks of a clear roadmap to be followed. It is thus common, firms to employ benchmarking projects to improve their logistics functions, but these project attempt do not to incorporate the actual improvement effort and fail to become process mapping techniques of the firm’s and the partner’s logistics processes.

Figure 12.9: The role of benchmarking improvement methodology towards the overall aim of a logistics organization. Inspired from Hellsten and Klefsjö (2000).
13 Research Issues and Future Research Directions

In this final chapter of this thesis, a remark on some research issues that have been encountered throughout this thesis will be given. As with every thesis project, its outcome is a research text that attempts to provide answer to a specific question under examination. Towards the provision of that answer, the author should employ one, or combine various, research methods. Thus, a discussion on the nature of the research methodology that was employed in this thesis will be conducted, together with a reference on its endogenous limitations.

Moreover, it is self-evident that no research attempt is a standalone endeavor. On the other hand, every inquiry to gain a deeper understanding and further knowledge of a complex phenomenon should be placed along a continuum. As this text is based on previous research conducted by academics and practitioners of both quality management and logistics, it should add and facilitate prospect inquiries of further knowledge on its areas under examination. Therefore, a section with the author’s suggestions and directions for future research concludes this thesis work.

13.1 Research Issues

The subject of this thesis is interdisciplinary in nature. It is of the author’s belief that interdisciplinary subjects, and in turn interdisciplinary studies, offer a unique charm that can be found in its very nature. More and more today’s professional and academic environments leave behind the practices of excessive expertise and fragmentation among scientific areas. In fact, industrial management, i.e. the science that both quality management and logistics may be said to belong, is in its very nature interdisciplinary. Industrial management requires engineers and managers to closely communicate and collaborate, and requires from both parties a solid knowledge of both management and technology disciplines.

In such interdisciplinary fields of study, and especially in the case of the applicability of quality management practices in logistics, relatively little work has been done. Formal research hypotheses do not fully exist, or in the best case are currently emerging. Thus, the qualitative inquiry employed as research pattern for this thesis, seems to be a reasonable beginning point of research.

The objective of this study and the specific exploratory research methodology employed is to gather preliminary information regarding the applicability of quality management methodologies and tools in logistics. Subsequently, the information gathered will assist to further define the nature of this applicability and suggest hypotheses for its formal description. In this case, a aggregative representation and position of all the quality management methodologies and tools examined on a logistics improvement cycle is a first form of such a hypothesis generation.
The application of exploratory research is this thesis, come with the study of secondary data. A number of academic articles and textbooks where examined, providing a good starting point for research. Information which was already published could be obtained more quickly and at a significant lower cost than primary data generation. This existing knowledge was found particularly helpful towards the definition of problems and research objectives throughout this research effort.

Special care was taken in order to alleviate the problems that are strongly associated with the use of secondary data (Patton, 1990; Kotler, 1994). A thorough and extensive evaluation of all the articles and textbooks was conducted to make certain that the literature used is relevant and fits the research project needs, accurate and impartial, i.e. information reliably and objectively collected and reported, and current and up to date enough for use in this research.

13.2 Directions for Future Research

It is widely known and accepted among the theoreticians of research methodologies, in general and qualitative methods in particular, (Patton, 1990; Blumberg et al., 2005) that any qualitative quest to knowledge begins with exploring and gathering data. At this initial stage, patterns begin to emerge and a setup is starting to be visible. Subsequently, the exploratory process gives way to confirmatory fieldwork that adds depth and detail. The following of this paradigm is the main suggestion to researcher that will build on this work.

From the standpoint of the very nature of the research conducted throughout this work, it is suggested to researchers to make further use of confirmatory qualitative methodologies. Future investigation that aspires to add and complement on the endeavor of gaining better knowledge on quality management and logistics, are advised to gather primary data. The use of genuine data and confirmatory research methods will add depth and detail in this thesis question. The global patterns of the applicability of quality management practices to logistics found in this research could thus be generalized across various future cases.

In addition, the perspective of this research was party biased. As it was stated in the beginning and was implemented through the thesis, quality management was seen as the only business function and academic business are that was transmitting successful practices among the industry and academia. Moreover, logistics was seen as entity that is in its development and thus, as a receiver of methodologies and tools from quality management. This viewpoint, although suitable for the purpose of this thesis may not be totally correct. Further research should be conducted to discover if a reverse situation exist. It is not unreasonable to speculate that for example, the value addition idea of logistics and supply chain management may have influenced quality management.

As a final point, tools and methodologies of quality management that are not used in logistics and suggestions for the promotion of them to logistics, although included in this thesis purpose, were not examined. This is due to the fact that insufficient information was found that could bridge the gap between quality management and logistics with respect to those practices. It is thus, strongly suggested that future research will address the applicability of such quality management practices in logistics.
14 References


Camp, R.C., (1989), Benchmarking: The Search for Industry Best Practices that lead to Superior Performance, ASQ Quality Press, Milwaukee, WI.


Part III


