Differentiated Supply Chain Strategy
- Response to a fragmented and complex market

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Differentiated Supply Chain Strategy: Response to a fragmented and complex market

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Skövde, May 2008

Per Hilletofth
Supply Chain Management (SCM) aims to synchronize the requirements of customers with the flow of materials from suppliers, in order to satisfy the needs of the customers as cost-efficiently as possible. This has become a difficult task due to several developments in the market, such as increased competition, increased demand variability, increased product variety, increased amounts of customer-specific products, and shortening product life cycles. These developments, due in part to globalization, provide additional management challenges and new practices in which supply chains are designed and managed, and can eventually make the difference between companies staying competitive or not.

The overall purpose of this thesis is to investigate how complexity and globalization affect supply chain design and operations. The main emphasis has been on producing descriptive results of the studied phenomenon. This research involves five case studies covering international transportation structures used in SCM, the selection of supply chain strategies in different business environments, and the role of information systems and technology in achieving the objective of SCM.

In this thesis it has been concluded that in order to cope with increasingly complex and fragmented markets companies need more differentiated transportation structures, modes, and supply chains. Furthermore, to effectively manage this, information systems and advanced decision support tools are required. In addition, this thesis has shown that current taxonomies for supply chain strategy selection are too simplistic due to three major problems: they mediate that it is a question of choosing one supply chain strategy for the entire company, they regard markets as rather homogeneous, and they link each supply chain strategy to a specific business context. Instead, it has been concluded that in order to better satisfy differing customer needs in various markets it is increasingly necessary to develop a differentiated supply chain strategy by utilizing different manufacturing and delivery strategies concurrently. Thus, a need exists for new taxonomies for supply chain strategy selection which recognize that the markets are becoming more fragmented and complex, that customer preferences differ across customer/market segments, and that there is a need to differentiate the supply chain strategy.

This thesis also highlights several requirements of a differentiated supply chain strategy. Firstly, extended supply chain collaboration is required, since a differentiated supply chain strategy will involve more supply chain partners than a traditional supply chain strategy. Secondly, there is a need for more transportation mode alternatives, particularly intermodal, both in supply and distribution operations, due to the fact that differentiation requires diversity. In this thesis, intermodal landbridge freight services are highlighted as one interesting avenue, which could potentially facilitate a more differentiated supply chain strategy. Thirdly, more integrated information systems are needed along with decision support tools. This study illustrates that agent based modeling appears to be an interesting method for developing realistic decision support tools in the context of complex supply chains.

An interesting aspect for further research is to investigate how different manufacturing and delivery strategies can be used concurrently in international supply chains. Moreover, there are several requirements and opportunities of a differentiated supply chain strategy, and these have to be investigated further.

Keywords: Supply chain management, strategies, differentiation, globalization, complexity
This thesis is based on the work contained in the following four papers, which are appended in full and referred to in the text by the Roman numerals I, II, III, and IV:


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1. INTRODUCTION

In this chapter, the motivation for the study, as well as the purpose and objectives of the thesis, are presented and discussed. The overall purpose of this thesis is to investigate how complexity and globalization affect supply chain design and operations. This is followed by an outline of the thesis as a whole.

1.1 Motivation for the Research

Ever since the pioneering work of Forrester in the 1950’s, academics, consultants and practitioners have been searching for the theory, method or solution that will cure all of their supply chains ills (Forrester, 1958). A view has emerged which recognizes that the route to competitive advantage, nowadays, lies in the management of supply chains (e.g. Copper and Christopher and Towill, 2002; Cooper et al., 1997; Lambert and Cooper, 1998; Lambert et al., 1998). Indeed, it has been suggested that “supply chains compete, not companies” (Christopher, 1992). A supply chain can be defined as a network of autonomous organizations (suppliers, manufacturers, distributors and retailers) through which raw-materials and components are acquired, transformed and delivered to the consumers (e.g. Christopher, 1992; Swaminathan, 1998). It can become very complex with several parallel processes occurring that ensure the right products of the right quality are delivered in the right quantities, at the right place, at the right time, in a cost-effective way (Mentzer et al., 2001).

The objective of Supply Chain Management (SCM) is to synchronize the needs of the consumers with the flow of materials from suppliers in order to satisfy the needs of the end-users as cost-efficiently as possible (Fisher and Raman, 1996; Houlihan, 1985; Houlihan, 1987). It involves all the activities necessary to bring a product to the market, including procuring raw-materials, producing products, transporting and distributing the products as well as managing the selling process (Cooper et al., 1997; Lambert and Cooper, 2000; Lambert et al., 1998; Lummus and Vokurka, 1999).

SCM has received considerable attention in the popular business press and academic literature since it was introduced by consultants in the early 1980s (Olivier & Webber 1982), even though the associated problems have sometimes been underestimated. It has become a major subject in numerous industries, as it has proven to be successful in improving supply chain efficiency through enhanced collaboration and information exchange (Gunasekaran and Ngai 2004; de Treville 2004; Heikkilä, 2002). There are many reasons for the increased interest in SCM. Specific drivers may be traced to trends in specialization, globalization and increased national and international competition (e.g. Christopher, 1992; Lummus and Vokurka, 1999; Mentzer et al., 2001).

In recent years, with the reduction of trade barriers and the development of a global transportation infrastructure, supply chains have become more international in scope, due to a considerable expansion of supply chain operations into different international locations, especially in the automobile, computer, and apparel industries (Taylor, 1997; Dornier et al., 1998). This globalization trend can be seen in the growth of world trade compared to growth in world Gross Domestic Product (GDP). Figure 1-1 shows that the growth in world trade (illustrated through value of export and import) exceeds growth in world GDP. This signifies that supply chains have become international in scope, since world GDP should have outperformed world trade, if supply chains where national in scope.
The growth in globalization, as well as the additional management challenges it brings, have motivated both practitioner and academic interest in international SCM (Meixell and Gargeya, 2005). Because of the complexity of today’s supply chains, due in part to globalization and outsourcing, the way in which supply chain are designed and managed can make the difference between success and ruin (Christopher and Towill, 2002). Several researchers argue that international supply chains are more difficult to design and manage than domestic supply chains (Dornier et al., 1998; Wood et al., 2002; MacCarthy and Atthirawong, 2003). For example, the geographical distances in global supply chains increase transportation costs and complicate decisions regarding inventory levels due to increased lead-times (Meixell and Gargeya, 2005). Moreover, infrastructural deficiencies in developing countries in transportation and telecommunications, as well as inadequate worker skills, supplier availability, supplier quality, equipment and technology present additional management challenges (Meixell and Gargeya, 2005).

The implementation of an international supply chain strategy concerns the centralization, consolidation and standardization of sourcing, manufacturing and distribution operations along with the management of these to achieve economies of scale and simultaneously meet the needs of local and differing markets (e.g. Chopra and Meindl, 2004). Economies of scale are similar to economies of scope, but imply efficiency gains resulting from expansion of scale, that is, increase in the volume of total output of a single product type within a single manufacturing plant, rather than from an expansion of scope, that is, increase in the number of different output types produced within a single manufacturing plant (Goldhar and Jelinek, 1983; Levitt, 1983).

The selection of an appropriate sourcing strategy in international supply chains comprises two dominant strategic parameters: the choice among various supply markets, and the choice among various supply channels (Åkesson et al., 2007). The first parameter of sourcing strategies, the choice among various supply markets, primarily reflects the availability of the resource required by companies, unskilled cheap labor, as well as the trade-offs arising from cultural and geographical distances and obtained quality-price levels (Bolisani and Scarso, 1996). Depending on numerous factors – such as supply of required resources, quality, labor costs and labor skills – companies can basically choose to supply manufacturing plants nationally (i.e. domestic) or internationally. This is a well-covered topic in which researchers...
have developed several models and concepts to help companies handle these issues, particularly in relation to low-cost sourcing that is specifically considered to generate often-neglected hidden costs (e.g. Meijbom and Vos, 1997; Christopher and Towill, 2002; Jin, 2004). The second parameter, the choice among various supply channels, primarily reflects the companies’ strategic choices in terms of manufacturing. Initially, there is a make-or-buy decision (Ca’nez et al., 2000; Fill and Visser, 2000), which implies sourcing from a company’s internal manufacturing facilities or sourcing from external suppliers (outsourcing). Bolisani and Scarso (1996) distinguish between direct investments and joint ventures as two types of internally controlled manufacturing operations, and subcontracting as sourcing from external suppliers.

Nowadays, manufacturers of logistically convenient end-items, whether company controlled or external suppliers, (i.e. it is economical and, within time dimension, sensible to move item around) usually follow the principles of focused factory. This was Skinner’s main proposal for productivity improvement during 1970’s (Skinner, 1974). Manufacturing operations can quite easily be outsourced through subcontracting, when Original Equipment Manufacturers (OEMs) utilize focused factory principles (e.g. Hilmola et al., 2005; Hilmola et al., 2007).

The idea behind focused factories is simple; by limiting the number of manufacturing plants (quite often below 10), as well as the range and mix of products manufactured in a single manufacturing plant, the company can achieve economies of scale (Skinner, 1974). In other words, a low number of manufacturing plants, each focusing on a small number of different product families, take care of the entire world production. In some situations, it could be necessary to establish regional focused factories due to geographical issues. Companies can gain productivity by utilizing smaller regional focused factories, and distribution points that are closer to the customer enable companies to cut total transport and distribution logistics costs (Ross, 1995).

These focused factories are located where production is most profitable, which depends on numerous aspects, such as manufacturing costs, availability of raw-materials, proximity to final markets, and transportation costs (Christopher and Towill, 2002). They can be supplied by national or international supplier networks. These supplier networks need to be developed to serve high volume challenges, and tight delivery schedules.

In the literature, it is often suggested that nowadays companies, to a larger extent, are moving manufacturing from Europe and North America to newly emerging economies in the Far East – such as China. Figure 1-2 displays the development of manufacturing employment in China, Europe and North America during 1997-2006. Employment in secondary industry was used for China, since employment statistics concerning the manufacturing sector were not available. The secondary industrial sector, also called manufacturing industry, either takes the output of the primary sector (i.e. raw-materials) and manufactures finished products, further processes goods manufactured by other secondary industries, or builds capital articles used to manufacture consumer and non-consumer goods (Encyclopædia Britannica, 2008). However, secondary industry also includes energy-producing industries (e.g. hydroelectric industries) as well as the construction industry. This sector may be divided into light and heavy industry (Encyclopædia Britannica, 2008).
As shown in Figure 1-2, the development of manufacturing employment during 1997-2003 has been rather similar in China and Europe. Furthermore, the figure shows that the number of employees has significantly decreased in North America during 2000-2003. However, during this period the number of employees has been rather constant in China and only decreased modestly in Europe. After 2003 manufacturing employment has increased significantly in China, while it has decreased modestly in Europe and North America. It seems that companies are investing heavily in building new factories with global capabilities in newly emerging economies, such as China. However, these factories do not appear to be taking manufacturing work opportunities from Europe and North America, since the modest decrease in manufacturing employment during 2003-2006 in Europe and North America, that is, in developed economies, is probably due to production improvements enabling companies to produce in greater quantity at less cost with a smaller workforce. As shown in Figure 1-3, GDP per hour work has increased in Europe and North America during 1997-2006.
This implies that across the globe several competing manufacturing zones have evolved and that the most cost-efficient location of focused factories can be in either of these developed zones, that is, in low-cost countries like China or close to major final markets in Europe and North America. This development becomes quite clear when studying Foreign Direct Investments (FDI). As shown in Figure 1-4, FDI has continuously increased in Europe, North America and Asia, which signifies that companies have continuously invested in all of these manufacturing zones.

![Figure 1-4. Foreign Direct Investments. Source: United Nations Conference on Trade and Development (UNCTAD).](image)

This implies that the most interesting research question is not how we in the developed economies can increase our competiveness against newly emerging economies. Instead, the most interesting research question is how companies can exploit each of the evolved manufacturing zone’s advantages (i.e. economies of scale, low cost production, close to final market) through developing efficient and effective international supply chains.

In developing and managing international supply chains, a number of crucial trade-offs arise which require careful examination. The most obvious trade-off is the effect on transport cost and delivery lead-times. Some researchers argue that the cost of shipping products, often relatively low value, across greater distances may erode some or all of the production cost saving (e.g. Christopher, 2005). However, this is not entirely true, since the transportation of materials or low cost products that are easy to transport (i.e. containerized freight) is very cheap. Instead, increased inventory holding due to the longer lead-times and lost sales are factors that could erode some or all of the production cost saving. Furthermore, quality problems and price fall during the transportation period (seasonal products and electronics) could erode some or all of the production cost saving. More international supply chain problems may be encountered, such as where the need for local packages exists, for example, with labeling in different languages or even different brand names and packages for the same product. This problem could be overcome by postponing the final packaging until closer to the point of sale (e.g. Pagn and Cooper, 1998; van Hoek et al., 1998; van Hoek et al., 1999). Another issue is created by customers ordering a variety of products from the same company on a single order, but which are produced in a number of focused factories in different locations. The solution here may be some type of transshipment or cross-dock operation, where flows of goods from diverse localities and origins are merged for onward delivery to
the customer (e.g. Kinnear, 1997). Other problems of international supply chains are their impact on delivery flexibility. While focused production and flexibility are not necessarily mutually incompatible, it may be so that companies, who focus on low-cost production, could be at risk in markets where responsiveness and the ability to provide variety are key success factors (Christopher and Towill, 2002). Finally, in the same way that the advent of globalization has encouraged companies to rationalize sourcing and production into fewer locations, many companies are now recognizing the advantage of managing worldwide distribution (including inventories) on a centralized basis (see e.g. Abrahamsson and Brege, 1997). However, to do so successfully requires an information system that can provide complete visibility of demand from one end of the pipeline to the other in as close to real time as possible. Equally, such centralized systems will typically lead to higher transport costs since products inevitably have to move greater distances and often high-cost air express will be necessary to ensure short lead-times for delivery to customers.

All in all, it appears that the total logistics impact of global supply chain is complex and worth studying. Thus, this research aims to add to the understanding of SCM by investigating how complexity and globalization affect supply chain design and operations. The main emphasis has been on producing descriptive results of the studied phenomenon. However, some steps of the research process can be described as being explorative, and the analysis relating both to the individual manuscripts and this final synthesis include explanatory elements, building on, for example, cross-case comparison (Yin, 1981). The primary research approach consists of case studies, which was considered an appropriate approach in order to tap in-depth data.

1.2 Research Purpose and Objectives

The overall purpose of this thesis is to investigate how complexity and globalization affect supply chain design and operations. Complexity and globalization certainly affect supply chain design and operations in numerous ways. However, in the thesis this topic is pursued through three more specific objectives (Figure 1-5).

**How does complexity and globalization affect supply chain design and operations?**

- To analyze transportation structures used in international supply chains
- To analyze the employment of different strategies in international supply chains
- To analyze complexity of decision making in international supply chains

**Figure 1-5. Research Aim and Objectives.**

Firstly, this research aims to analyze transportation structures used in international supply chains. This is an interesting topic since globalization has resulted in companies consolidating and centralizing their operations in the most profitable locations – often far from major final markets – which implies that efficient and effective transportation structures and modes are needed to be successful in the market (Christopher, 1998). Moreover, specialization among companies (i.e. focused manufacturing), the availability of low cost transportation and new
emerging economies have resulted in a situation where we are currently transporting more than ever, as transportation growth is compared to global GDP growth (United Nations, 2005; United Nations, 2007).

Secondly, this research aims to analyze the employment of different supply chain strategies (i.e. lean, agile, and leagile strategies) in international supply chains. This is an interesting topic since globalization has caused several developments in the market, such as increased competition, increased demand variability, increased product variety, increased numbers of customer-specific products, and shortening product life cycles (e.g. Christopher et al., 2004; Lummus and Vokurka, 1999; van Hoek et al., 1998; van Hoek et al., 1999). These developments provide additional management challenges and new practices in which supply chains are designed and managed (Christopher and Towill, 2002). However, globalization also offers advantages since companies can exploit economies of scale to deliver volumes worldwide and contribute to overall cost-efficiency (van Hoek et al., 1999). This implies that globalization affects both demand and supply characteristics, and these in turn determine the most appropriate supply chain strategy (Christopher et al., 2006).

Finally, this research aims to discuss the complexity of decision making in supply chains. This is an interesting topic since globalization has made SCM a more complex task. As highlighted above, this is the case particularly in international supply chains and global transportation structures, where operations are dispersed across the globe. Nowadays numerous researchers regard SCM to be an incredibly complex task (e.g. Bowersox and Closs, 1996; Lumsden et al. 1998; Nilsson and Darley, 2006; Nilsson and Waidringer, 2004; Waidringer, 2001; Wilding, 1999), because it has become more complicated to match demand with supply and to handle different supply chain problems, such as the bullwhip effect (Lee et al., 1997a; Lee et al., 1997b; Lee et al., 2000; Miragliotta, 2006), due to the above mentioned market developments. Moreover, the difficulties in controlling and coordinating supply chain operations within and among companies are expected to increase, since the interdependence among cooperating companies is intensifying (Prater et al., 2001).

Table 1-1 illustrates how each of the included manuscripts (Papers I-IV) contributes to the research objectives.

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As can be noted, the first research objective – to analyze transportation structures used in international supply chains – is covered in Paper I through literature review, case studies and discussion. The second research objective – to analyze the employment of different strategies in international supply chains – is covered in Paper II through literature review, case studies, simulation and discussion. The third research objective – to analyze the complexity of
decision making in international supply chains – is covered in Papers III and IV through literature review, case studies and discussion.

1.3 Structure of the Thesis

Chapter 2 continues with an overview of SCM, providing a description of the fundamentals of SCM, supply chain strategies, the bullwhip effect, as well as information systems and technology. In addition, the chapter includes an overview of international transportation corridors used in international supply chains.

Chapter 3 provides an overall description of the research methodology used in this thesis. A description of the research process is followed by an explanation of the applied research methods. The chapter concludes with a discussion concerning research quality.

Chapter 4 summarizes the four original manuscripts incorporated in the thesis and presents their main findings and contributions to the research process. The objective of the first paper is to establish why such a small proportion of total container traffic between Asia and Europe is transported by intermodal landbridge services, and how this can be increased. The objective of the second paper is to establish which supply chain strategy is the most adequate to meet the challenges of volatile and turbulent demand representative of the fashion and textile markets. The objective of the third and fourth papers is to provide insights concerning the complexity of decision making and operations in manufacturing and service supply chains and to discuss how agent based modeling can help managers handle this complexity.

Chapter 5 presents a discussion and conclusion of the research findings. This chapter also outlines the wider implications of the research results as a whole. Finally, directions for future research are presented and discussed in Chapter 6.
2. PRIOR RESEARCH ON SUPPLY CHAIN MANAGEMENT

To create a basis of understanding of the studied phenomenon, this chapter starts with a presentation of the main ideas of SCM followed by a more detailed description of three relevant areas of SCM. Firstly, the highly relevant bullwhip phenomenon is presented to highlight existing problems in SCM today. Secondly, different supply chain strategies are described in order to show different approaches for matching supply with demand and for handling different supply chain problems, such as the bullwhip effect. Thirdly, the role of information systems and technology in SCM is presented to emphasize their importance in achieving the objective of SCM. Finally, to highlight the importance of efficient and effective transportation modes in global SCM, challenges for the new landbridge transportation alternative are explored.

Several researchers include management aspects in their definitions of the supply chain (e.g. Christopher, 1998; Lambert et al, 1998). For example, Christopher (1998) defines the supply chain as:

“A network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from supplier to end-user”.

However, it is important to recognize that supply chains exist whether they are managed in a comprehensive and mutual way or not (Mentzer et al., 2001). The supply chain as a phenomenon of business still exists even if supply chain members do not actively implement any of the concepts, methods or theories discussed in the SCM literature to manage the supply chain (Mentzer et al., 2001). Thus, there is a definite distinction between supply chains as phenomena that exist in business and the management of those supply chains. The former is simply something that exists (often also referred to as distribution channels) while the latter requires management efforts by the organizations within the supply chain (Mentzer et al., 2001). Consequently, a more appropriate definition of a supply chain is:

“A network of autonomous organizations (suppliers, manufacturers, distributors and retailers) through which raw-materials and components are acquired, transformed into products, and delivered to the end-user”.

As stated by Stevens (1989), the scope of the supply chain begins with source of supply and ends at the point of consumption. However, this “ultimate” supply chain from initial source of supply to consumption can be separated into three supply chain levels (Mentzer et al., 2001):

1. Direct supply chains;
2. Extended supply chains; and
3. Ultimate supply chains.

As illustrated in Figure 2-1, a direct supply chain consists of the focal company and its direct suppliers and customers involved in the upstream and/or downstream flows of products, services, finance and/or information. An extended supply chain, in addition to the above, also includes suppliers of the immediate suppliers and customers of the immediate customers. The
ultimate supply chain, however, includes all the organizations involved in all the upstream and downstream flows of products, services, finances, and information from the ultimate supplier to the ultimate customer (i.e. end-user or consumer).

As illustrated in Figure 2-1, supply chains can become quite complex with several parallel processes occurring in order to ensure that the right products are delivered in the right quantities, with the right quality, at the right place, at the right time, in a cost-effective way (Mentzer et al., 2001).

The objective of managing supply chains (i.e. SCM) is to integrate and synchronize the materials, information and financial flows (i.e. requirement of the customer with the flow of materials from suppliers) across the supply chain in order to satisfy the needs of the customers as cost-efficiently as possible, that is, match supply with demand (Fisher and Raman, 1996; Jones and Riley, 1985; Houlihan, 1985; Houlihan, 1987). The design and operation of efficient and effective supply chains is of fundamental importance to every organization (Stevens, 1989).

This understanding of SCM has created confusion concerning the differences between logistics management and SCM (Cooper et al., 1997; Lambert and Cooper, 2000; Mentzer et al., 2001; Lambert et al., 1998; Lummus et al., 2001), due to the fact that logistics management has always represented a supply chain orientation from the point of origin to the point of consumption (Cooper et al., 1997; Ericsson, 2003). Indeed, a key characteristic of logistics is the management of the materials, information, and financial flows across the supply chain and thus logistics management can be defined as:

"Planning, development, coordination, organization, integration, control and review of the materials, information and financial flows point of origin to the point of consumption".

Logistics management is an important part of SCM (Cooper et al., 1997). However, it should be noted that logistics management is primarily concerned with the synchronizing of materials and information flows at an operational and tactical level, while SCM is a
management strategy used to enhance overall customer satisfaction that is intended to improve a company’s competitiveness and profitability (Giunipero and Brand, 1996). It includes elements that are not typically included in a definition of logistics, such as information system integration and coordination of planning and control activities (Cooper et al., 1997). Furthermore, logistics management is often limited to one organization and its inbound and outbound operations (i.e. the direct supply chain), while SCM concerns the entire supply chain (Christopher, 1998). SCM can thus be defined as:

“The systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long term performance of the individual companies and the supply chain as a whole” (Mentzer et al., 2001).

SCM aims to coordinate and manage all activities necessary to bring a product to the market including procuring raw-materials, producing products, transporting and distributing the products and managing the selling process. It is an integrative philosophy for managing and integrating the entire materials, information and financial flows across the supply chain in order to enable a market facing orientation to be achieved (Gimenez and Ventura, 2005). It involves integration across organizations (internal or intra-organizational) and throughout the entire supply chain (external or inter-organizational). Internal integration refers to the coordination and collaboration between departments within an organization, while external integration refers to the coordination and collaboration between autonomous organizations in the supply chain (Gimenez and Ventura, 2005).

The overall purpose of SCM is to create an environment in which all organizations in the supply chain think and act as one entity in order to optimize the performance of the whole supply chain (Towill et al., 2000). A key to success is that the entire supply chain has to be viewed as one system (Lummus and Vokurka, 1999), which implies that managers across the supply chain must take an interest in each other’s success and work together to make the entire supply chain competitive.

SCM has received considerable attention in the popular business press and academic literature since it was introduced by consultants in the early 1980s (Olivier & Webber 1982). It has become a major subject in numerous industries, as it has proven to be successful in improving supply chain efficiency through enhanced collaboration and information exchange (Gunasekaran and Ngai 2004; de Treville 2004; Heikkilä, 2002). There are many reasons for the increased interest in SCM. To begin with, companies have realized that maximizing the performance of individual departments or functions leads to less than optimal performance for the entire supply chain (Lummus and Vokurka, 1999). In addition, companies have become more specialized, that is, moved away from vertical integration, which implies that it has become more critical for companies to manage the supply chain to optimize overall performance (Lummus and Vokurka, 1999). Moreover, companies have experienced increased national and international competition (Lummus and Vokurka, 1999). The increasing competition has created a customer service explosion, which means that in order to stay competitive a company must enhance customer value by making the product worth more in the eyes of the consumer, because service has added value to the core product (Christopher, 1992). Furthermore, time compression is taking place in supply chains when product life cycles are becoming shorter, retailers require just in time deliveries and consumers have a growing choice of products and retail outlets to choose from (Christopher, 1992). Customers are demanding products that are consistently being delivered faster, exactly on time and with no damage. Each of these necessities requires closer coordination across the supply chain.
(Mentzer et al., 2001). Finally, there is a clear trend towards globalization. Companies, to a larger extent, employ global sourcing strategies resulting in demand for more effective ways to coordinate the flow of materials into and out of the company (Mentzer et al., 2001). Furthermore, retailers are merging in order to grow bigger, and offshore manufacturing and worldwide selling are increasing (Christopher, 1992).

### 2.1 The Bullwhip Effect

A seminal and central part of the SCM theory is the detection of the bullwhip effect (also known as the Forrester effect, the whiplash effect, and the demand amplification effect) in supply chains (e.g. Forrester 1958). Basically, the identification of the bullwhip effect has established the SCM research discipline. Moreover, the bullwhip effect has become a major research area within the SCM domain, due to its immense impact on the objective of SCM, that is, the synchronization of supply and demand, and its major contribution to excess supply chain costs (e.g. Lee et al., 1997a; Lee et al., 1997b; Lee et al., 2000; Miragliotta, 2006).

The first academic description of the bullwhip effect is usually credited to Forrester (1961) who showed that supply chains suffer from large demand swings when companies within a supply chain solve upcoming issues individually. However, its roots can be traced back to the pioneering works of Simon (1958) and Forrester (1958). Later, numerous researchers have continued the research on the bullwhip effect and its impact on the supply chain (e.g. Blanchard, 1983; Blinder, 1982; Burbidge; 1961; Burbidge, 1984; Kahn, 1987; Lee et al., 1997a; Lee et al., 1997b; Lee et al., 2000).

Burbidge (1984) was the first to provide a detailed definition of the bullwhip effect: “if demand for products is transmitted along a series of inventories using stock control ordering, then demand variations will increase at each transfer”. In more general terms, the bullwhip effect can be defined as “a supply chain phenomenon revealed by a distortion (demand variability amplification) of the demand signal as it is transmitted upstream the supply chain” (Miragliotta, 2006). In other words, demand variations in final markets are amplified upstream the supply chain resulting in higher variations for the manufacturer and significantly higher variations for the supplier (Lee et al., 1997a).

Common symptoms of the bullwhip effect which significantly contribute to excess supply chain costs are: overall higher inventory levels (i.e. excessive inventory), frequent stock-outs, poor product forecast, insufficient or excessive capacities, poor customer service due to unavailable products or long backlogs, uncertain production planning (i.e. excessive revisions), high cost for corrections, such as for expedited shipments, and over time as well as higher transportation costs due to inefficient scheduling (Lee et al., 1997a).

A significant amount of research has been conducted on the bullwhip effect (e.g. van Ackere et al, 1993; Baganha and Cohen, 1998; Chen et al., 2000; Dejonckheere et al., 2004; Disney et al., 2004; Disney et al., 2006; Lee et al., 2004; Li et al., 2005; Potter and Disney, 2006; de Treville et al., 2004; Zhang, 2004; Zhang and Zhang, 2007). Miragliotta (2006) distinguishes between three major research streams:

1. Bullwhip effect measurement and empirical assessment;
2. Causes of the bullwhip effect; and
3. Solutions for the bullwhip effect.

The two research streams of interest in this thesis, causes and solutions to the bullwhip effect, are described in more detail below. For more information concerning the third research stream, measurement and empirical assessment of the bullwhip effect, please see Miragliotta (2006).
2.1.1 Causes of the Bullwhip Effect

One important research stream is that concerning the causes of the bullwhip effect. This research stream can basically be separated into two major disciplines: the system thinking discipline and the operations management discipline (Miragliotta, 2006).

The first discipline has a strong background in system theory and is focused on the ‘systemic’ nature of the supply chain, reflecting a holistic perception of the causes of the bullwhip effect (e.g. Forrester, 1980; Senge, 1992; Senge and Sterman, 1992 Sterman, 1989; Sterman, 2000; Towill, 1982). For example, Sterman (1989) shows that human behavior, such as misconceptions about inventory and demand information, may cause the bullwhip effect. One of the most accredited researchers in this discipline is Forrester (e.g. Forrester 1958; Forrester 1961; Forrester, 1980) who argued that complexity, feedbacks and the non-linear nature of the supply chain are the main causes of the bullwhip effect.

The second discipline, in contrast, is more focused on single and isolated factors, whose presence could generate the bullwhip effect (e.g. Blackburn, 1991; Lee et al., 1997a; Lee et al., 1997b; Lee et al., 2004; Naisih, 1994). For example, Blackburn (1991) argues that time delays are the main cause of the bullwhip effect, while Naisih (1994) argues that demand uncertainty and incorrect forecasts are reasonable explanations for the bullwhip effect. Lee et al. (1997a), in contrast to Sterman (1989), show that the bullwhip effect is a consequence of the supply chain members’ rational behavior within the supply chain’s infrastructure. They argue that in order to control the bullwhip effect companies should focus on modifying the supply chain infrastructure and related processes rather than the decision makers’ behavior.

Lee et al. (1997a) have identified four major causes which have become the explanatory standard for the bullwhip effect. These four identified causes are:

1. Demand processing;
2. Order batching;
3. Price fluctuation; and
4. Rationing and shortage gaming.

The demand processing cause refers to distorted demand information which may arise upstream the supply chain if only local information is used by each supply chain member to make decisions under uncertainty (Lee et al., 1997a). Consequently, the demand signal can be significantly altered upstream the supply chain, and the bullwhip effect may arise. Long lead-times may amplify this fact since the longer the lead-time, the higher the target inventory level set in the replenishment model (Miragliotta, 2006).

The order batching cause refers to delayed and accumulated order quantities that arise when companies employ order batching principles to achieve scale economies (e.g. large quantity discounts, full truck load shipments, etc.). This implies that instead of ordering frequently, companies order weekly, biweekly or even monthly which causes high demand variability for suppliers (Lee et al., 1997a). This variability is, of course, significantly higher than the demand the company itself faces, that is, the bullwhip effect (Lee et al., 1997a).

The price fluctuations cause refers to delayed and accumulated order quantities that arise when companies tend to order according to current price levels (Lee et al., 1997a). In other words, companies build up inventory when the price levels are low and place no order in the following periods since they have large amounts of stock. Consequently, a stable demand pattern can be significantly altered, and the bullwhip effect may arise.

The rationing and shortage gaming cause refers to inflating order quantities that may arise when manufacturers, due to higher demand than production capacity, must ration products to their customers according to the size of the orders (Lee et al., 1997a). If the customers recognize the rationing criterion, they will react by increasing order quantities to obtain the
desired number of products, and later cancel the excessive amount ordered. Consequently, the manufacturer has a poor perception of the actual demand, and the bullwhip effect may arise.

2.1.2 Solutions for the Bullwhip Effect

Another important research stream is that concerning the solutions for the bullwhip effect. As a consequence of the two separate research disciplines presented above, the proposed solutions can also be divided into two categories. The first discipline – the system thinking discipline – essentially suggests investments in training programs to increase managers’ ability to perceive, understand and react to the bullwhip effect (e.g. Senge and Sterman, 1992) while the second discipline – the operations management discipline – conversely suggests more operative solutions. For example, Lee et al. (1997a) have developed a qualitative framework to suggest solutions for each of the four causes in their explanatory model presented above. They group all the solutions into three main categories:

1. Information sharing;
2. Channel alignment; and
3. Operational efficiency.

The information sharing category includes all those actions which speed up the information flow from final markets upstream the supply chain. Within this category, sharing information on sales, capacity and inventory are recommended. The channel alignment category includes all those actions which aim at increasing the coordination of processes across the supply chain. Within this category, vendor managed inventories, continuous replenishment and everyday low price programs are recommended. The operational efficiency category includes all those activities which aim at improving efficiency and shortening lead-times across the supply chain. Within this category, lead-time reduction programs, computer aided ordering, and improved control systems are recommended.

In recent years, information systems and technology have become more and more important for handling different supply chain issues, such as demand variability amplification. Basically, the implementation and integration of information systems supports all of the above presented groups of solutions, particularly information sharing and supply chain alignment, but also operational efficiency. Moreover, the concept of agent based systems and simulation (i.e. Agent Based Modeling, ABM) has gained interest for addressing the bullwhip effect in supply chains in recent years. For example, Liang and Huang (2006) have developed an agent system that controls inventory and minimizes total costs for a supply chain by sharing forecast and information knowledge. Moreover, Zhang et al. (2006) have developed an agent based approach that enables manufacturing organizations to dynamically and cost-effectively integrate, optimize, configure, simulate, restructure and control not only their own manufacturing systems but also their supply networks, in a coordinated manner to cope with the dynamic changes occurring in a global market. Agent based systems, as well as information systems and technology from a more general perspective, are further elaborated in section 2.3.

2.2 Supply Chain Strategies

SCM incorporates all the theories, methods, techniques and tools to coordinate and manage all activities necessary to bring a product to the market. This also involves the handling of different supply chain issues, such as the bullwhip effect. Depending on the business context, the most appropriate theories, methods, techniques and tools (i.e. supply chain strategy) will
certainly differ (Shewchuck, 1998). This implies that SCM requires several supply chain strategies to handle differing business contexts and supply chain issues. In this section, alternative supply chain strategies regarding lean, agile and leagile supply chain paradigms are presented. Moreover, the relevance of these theories to the business context of today is elaborated.

As stated above, the objective of SCM is to synchronize the requirement of the customers with the flow of materials from suppliers – that is, match demand with supply – to satisfy the needs of the customers as cost-efficiently as possible (Fisher and Raman, 1996; Jones and Riley, 1985; Houlihan, 1985; Houlihan, 1987). This has become an incredibly difficult task due to several developments in the market, such as (Christopher et al., 2004; van Hoek et al., 1998; van Hoek et al., 1999; Lummus and Vokurka, 1999):

1. Increased national and international competition;
2. Increased demand variability in both time and place;
3. Increased product variety;
4. Increased amounts of customer-specific product; and
5. Shortening product life cycles.

These developments, due in part to globalization and outsourcing, provide additional management challenges, and the way in which supply chains are design and managed can make the difference between success and ruin (Christopher and Towill, 2002). However, the trend towards globalization also offers advantages, since companies can exploit economies of scale to deliver volumes worldwide and contribute to overall cost-efficiency (van Hoek et al., 1999). Consequently, one important issue in developing and managing the supply chain is to increase responsiveness to consumers’ needs while simultaneously achieving cost-efficiency through centralization, standardization and economies of scale.

It is now increasingly accepted that “one size fits all” supply chain strategies do not support a wide range of products with different demand characteristics sold in a diversity of markets (Shewchuck, 1998). Thus, there are no supply chain strategies that are applicable to all types of products and markets. Instead, the supply chain strategy needs to be tailored to match the specific demand characteristics of a product, product family or market (Christopher et al., 2006). In other words, different types of products or markets require different types of supply chain strategies. This implies that the sourcing, operation, and distribution strategies that constitute the supply chain strategy need to be appropriate to a specific product or market condition.

In recent years, the SCM literature has focused on the ability of the supply chain to satisfy different types of markets or business environments through the employment of different types of supply chain strategies (e.g. Childerhouse and Towill, 2000; Christopher and Towill, 2000; Fisher, 1997; Hilletofth and Hilmola, 2007; Mason-Jones et al., 2000a; Mason-Jones et al., 2000b; Naylor et al., 1999; Stratton and Warburton, 2003; Warburton and Stratton, 2002). This implies that the constraints of the market must be known in order to identify the best starting point for the development of an effective and efficient supply chain strategy. Only when the possibilities of the market are known and understood can an organization attempt to develop strategies that will meet the requirements of both efficiency and effectiveness (Christopher and Towill, 2001; Fisher, 1997). Different supply chain paradigms and strategies are presented and discussed below. Moreover, several taxonomies for supply chain strategy selection are described.
2.2.1 Lean and Agile Supply Chain Paradigms

One of the more interesting debates in recent years concerning supply chain strategy has centered on the ability of the supply chain to be either “lean” (Womack and Jones, 1996) or “agile” (Goldman et al., 1995). The idea of lean manufacturing has been described by Womack et al. (1990), and later expanded into the wider concept of “lean thinking” by Womack and Jones (1996). The focus of lean thinking has essentially been on the reduction or elimination of waste, also known as muda (Christopher and Towill, 2001). The origins of the lean approach can be traced to the Toyota Production System (TPS) with its focus on the efficient use of resources through level scheduling (Ohno, 1988). Lean thinking, or leanness, from a supply chain perspective means “developing a value stream to eliminate all waste, including time, and to enable a level schedule” (Naylor et al., 1999). This could, for instance, involve reduction of inventories, reduction of lot-size, reduction of the supplier base, evaluating suppliers based on quality and delivery performance, establishing long-term contracts with suppliers, and elimination of paperwork (de Treville, 2004). It has been suggested that lean principles are applicable in markets where demand is relatively stable and therefore predictable, and where variety is low (Christopher, 2000).

In contrast, in those markets where demand is volatile and the customer requirement for variety is high, a much higher level of agility is required (Christopher, 2000). Agility is primarily concerned with responsiveness, and the ability to match supply and demand in volatile and unpredictable markets. Essentially, it is about being demand-driven rather than forecast-driven. Gunasekaran (1998) has defined agility as the ability to respond to market changes in a cost-efficient and profitable manner, while Christopher (2000) has defined agility as “a business-wide capability that embraces organizational structures, information systems, logistics processes and in particular, mindsets”. Thus, it could be argued that agility concerns the utilization of market knowledge and a responsive organization to exploit profitable opportunities in a volatile marketplace (Naylor et al., 1999). A key characteristic of an agile organization is flexibility (Christopher, 2000). Certainly, the origins of agility as a business concept lie partly in Flexible Manufacturing Systems (FMS), which through automation (i.e. reduced set-up times) try to enable rapid changeovers and, as a result, create responsiveness to changes in product mix and volume (Christopher and Towill, 2001). Later, this idea of manufacturing flexibility was extended into the wider business context by Nagel and Dove (1991), and the concept of agility as a supply chain paradigm was born. The focus of improvement efforts in the agile approach is on integrating the information flow across the supply chain with the objective of creating a market-responsive supply chain that responds quickly to unpredictable demands to minimize lost sales, forced markdowns and obsolescent inventory (Mason-Jones and Towill, 1999; van Hoek, 2000). A market-responsive supply chain emphasizes market mediation to a greater degree than the role of ensuring the efficient physical supply of the product (de Treville, 2004). This requires reduction of process and information lead-times throughout the supply chain (Mason-Jones and Towill, 1999). This could, for instance, involve coordinated planning, improved communication, and increasing access to demand information throughout the entire supply chain (de Treville, 2004). Table 2-1 shows a comparison of attributes between lean and agile supply chains.
Although lean and agile approaches are often discussed as opposing paradigms, they share a common objective: meeting customer demands at the least total cost (Goldsby et al., 2006). It is in terms of the characteristics of this demand and the basis of meeting customer demand that the two approaches differ (Goldsby and Garcia-Dastuage, 2003). In recent years, numerous researchers have suggested that the lean and agile approach can be integrated in a variety of ways to create so-called “leagile” approaches (e.g. Naylor et al., 1999; Childerhouse and Towill, 2000; Mason-Jones et al., 2000a; Mason-Jones et al., 2000b; van Hoek, 2000; Christopher and Towill, 2001; Stratton and Warburton, 2003; Mistry, 2005). Thus, it is not really a question of lean or agile, but rather the thoughtful selection and integration of suitable aspects of these paradigms appropriate to the specific supply chain strategy (Christopher et al., 2006).

Naylor et al. (1999) created the term “leagile” to refer to hybrids of the lean and agile approaches. Based on this merged strategy, Christopher and Towill (2001) visualized three distinct lean-agile hybrids. The first is founded on the Pareto Rule, recognizing that 80% of a company’s revenue is generated from 20% of its products. It is suggested that the dominant 20% of the product assortment can be managed in a lean Make-To-Stock (MTS) manner—given that demand is relatively stable for these items and that efficient replenishment is the appropriate objective—while the remaining 80% can be managed in an agile manner (Goldsby et al., 2006).

The second lean-agile hybrid is founded on the principle of base and surplus demand, recognizing that most companies experience a base level of demand over the course of the year. It is suggested that the base demand can be managed in a lean manner while demand peaks over the course of peak seasons or heavy promotion periods can be managed in an agile manner (Goldsby et al., 2006).

The third lean-agile hybrid is founded on the principle of postponement (Goldsby et al., 2006). Postponement means that certain supply chain activities (e.g. logistics and manufacturing activities) in the supply chain are postponed until customer orders are received (Pagh and Cooper, 1998). Postponement is described in more detail in the following section.

### 2.2.2 Postponement Strategies

The concept of postponement was first introduced by Alderson in 1950 (Alderson, 1950), who noted that postponement can change the differentiation of products (form, identity and
inventory location) to as late a time as possible, and thus improve the efficiency of a
distribution system. Later, these ideas were expanded by Bucklin (see. e.g. Bucklin, 1965;
Bucklin, 1966). The foundation of postponement is that risk and uncertainty costs are linked
to the differentiation of products that occurs during the activities in the supply chain (Bucklin,
1965). Furthermore, these costs can be reduced, or fully eliminated, by postponing certain
activities (e.g. logistics and manufacturing activities) in the supply chain until customer orders
are received (Pagh and Cooper, 1998). In other words, one decides which activities should be
performed after orders are received and managed according to agile principles (i.e.
responsive, order-driven and customized), and which activities should be performed before
orders are received and managed according to lean principles (i.e. efficient, planned and
standardized). This implies that companies can finalize/customize the product in accordance
with specific customer preferences (van Hoek, 2001; Yang et al., 2004) and at the same time
achieve cost-efficiency. Thus, postponement can help companies achieve mass customization
(Feitzinger and Lee, 1997; van Hoek et al., 1998; van Hoek et al., 1999).

Postponement increases the company’s ability to fine tune products to specific customer
wishes (Hoek et al., 1998). Furthermore, it significantly reduces inventory carrying,
warehousing and obsolescence costs (van Hoek et al., 1998). However, it should be noted that
postponement may lead to smaller sized shipments over longer distances (van Hoek, 2001).
Consequently, postponement is often more relevant when products are more sensitive to
inventory than transportation costs (e.g. higher value added products with large product
variety). Moreover, lead-time constraints in the supply chain could limit the possibility of
performing postponed activities while still assuring delivery according to customer required
lead-time (Bucklin, 1965; van Hoek, 1998; van Hoek, 2001).

Postponement strategies can be applied to form, time and place (Hoek et al., 1998). Form
postponement (or manufacturing postponement) means that companies delay production,
assembly, or even design until after customer orders have been received (Bowersox and Closs
1996). Time and place (or logistics postponement) means that the forward movement of
products is delayed as long as possible in the chain of operations, and that products are kept in
storage at central locations in the distribution chain (Bowersox and Closs 1996).

Industry has increased the use of postponement principles in recent years. Numerous
European industrial companies are currently implementing postponed supply chain systems
(Hoek et al., 1998). These systems combine the three types of postponement: the
customization of products is delayed until products are ordered (form postponement), the
distribution of products is delayed as long as possible (time postponement), and products are
stored at central locations (place postponement). The concepts of logistics and manufacturing
postponement are described in more detail below.

Logistics Postponement
Traditionally, products are stored close to customers and distributed through a decentralized
distribution system, including international, national, and local inventories. The purpose of
logistics postponement is to maintain a full-line of anticipatory inventory at one or a few
strategic locations (Bowersox and Closs 1996), that is, postpone inventory location
downstream in the supply chain to the latest possible point (Bucklin, 1965). This means that
the forward movement of products is delayed as long as possible in the chain of operations
and products are kept in storage at central locations in the distribution chain (Figure 2-2). In
other words, the Customer Order Point (COP) is moved upstream the supply chain. The COP
is the point in the supply chain where the customer order penetrates and that distinguishes
forecast and order-driven activities, that is, where real demand penetrates upstream the supply
chain, or where the strategic inventory is stored (Ericsson, 2003).
The major reason to postpone logistics operation upstream the supply chain is cost-reduction (Yang et al., 2004). Logistics postponement allows a company to delay deciding where inventory should be finally located, thus significantly reducing the risk of wrong time and place utility of products (Bowersox et al., 1993). Further benefits of logistics postponement are reduced inventory levels in the supply chain as well as improved customer responsiveness (Yang et al., 2004).

**Manufacturing Postponement**

Based on forecasts and speculations, companies traditionally perform all manufacturing activities – including design, sourcing, manufacturing, assembly, packaging and labeling – before they have received any customer order (Zinn and Bowersox, 1988). Depending on whether the company employs logistics postponement, these products are either stored at local or central warehouses.

The purpose of manufacturing postponement is to retain the product in a neutral and non-committed status as long as possible in the manufacturing process (Bowersox and Closs 1996), that is, postpone differentiation of form to latest possible point (Bucklin, 1965). This means that companies delay sourcing, production, assembly, or even design until after customer orders have been received (Figure 2-3). This allows companies to separate the customization of products from the primary manufacturing of standard products or generic modules (van Hoek et al., 1998). This separation frees primary manufacturing to focus more on large economical runs (i.e. leanness), while secondary or final manufacturing can be focused on responding to customer needs (i.e. responsiveness). Consequently, this postponed manufacturing system simultaneously enhances customer service and efficiency (van Hoek et al., 1998).
FIGURE 2-3. DIFFERENT MANUFACTURING STRATEGIES BASED ON POSTPONEMENT OF THE CUSTOMER ORDER POINT UPSTREAM THE SUPPLY CHAIN.

Postponed manufacturing has several advantages (van Hoek, 1998). Firstly, inventory can be held at a generic level resulting in fewer stock-keeping variants and hence less inventory in total. Secondly, because the inventory is generic, its flexibility is greater, given that the same components, modules or platforms can be embodied in a variety of end products. Thirdly, forecasting is easier at the generic level than at the level of the finished item. Finally, the ability to customize products locally means that a higher level of variety may be offered at a lower total cost, enabling strategies of “mass-customization” to be pursued.

In order for manufacturing postponement to succeed, a reliable supplier network that can supply parts and services is necessary (Feitzinger and Lee, 1997). Furthermore, it is important to consider product families and explore the commonality/modularity of products and processes to find generic modules or platforms that can be embodied in a variety of end products (Zinn, 1990). However, it is important to note that too much standardization can reduce product differentiation, leading to a cannibalization effect (Swaminathan, 2001).

As can be noted, the application of postponement in manufacturing is a logical extension of implementing logistics postponement while postponement in sourcing and design are logical extension of implementing manufacturing postponement (Battezzati and Magnani, 2000). This means that the scope of postponement has expanded from logistics through manufacturing to the entire supply chain (Yang et al., 2004). Postponement can occur along the entire supply chain, from design to final distribution. It can be applied to a minor or a major share of the activities in the supply chain. Companies should first consider every postponement opportunity along the supply chain and then balance the trade-offs not from an individualistic perspective but from a supply chain perspective (Yang et al, 2004).

2.2.3 Taxonomies for Supply Chain Strategy Selection

A number of classification schemes have been proposed in the literature to guide the choice of supply chain strategy (e.g. Fisher 1997; Christopher, 2000; Christopher et al., 2006; Mason-Jones et al., 2000a).

Fisher (1997) initiated this type of research when suggesting that companies need to understand their environment and product requirement and build supply chains accordingly.
As shown in Figure 2-4, Fisher (1997) distinguished between functional and innovative products and argued the latter should be supplied with responsive supply chains (i.e. agile supply chains) while the former should be supplied with efficient supply chains (i.e. lean supply chains).

There is an essential difference between lean supply chains that focus primarily on efficiency (i.e. costs and productivity) and agile supply chains that focus primarily on responsiveness. Supply chains emphasizing efficiency create a risk that production does not meet customer demand, while supply chains emphasizing effectiveness create risk of low production efficiency (Fisher, 1997). If the supply chain is ineffective, there is an impending risk that when the customer wants to buy an innovative product, the shelf in the shop is empty, which leads to lost sales and low customer satisfaction. On the other hand, if the supply chain is not responsive to demand changes, there is a huge risk for a high level of unsold goods that must be disposed of at reduced prices (leading to customer stocking at home, and cannibalizing future season sales; see Stratton and Warburton, 2003; Warburton and Stratton, 2002).

![Figure 2-4. How the type of product determine supply chain strategy selection. Source: Fisher (1997).](image)

An essential and popular concept for determining manufacturing strategies is the concept of “order qualifiers” and “order winners” (Hill, 1993). It is important for every organization to understand what the basis for entering into a competitive area is, since this constitutes the “order qualifiers”. Moreover, to obtain an order requires specific capabilities and these Hill termed the “order winners”. Consequently, the definitions of order qualifiers and order winners logically define the specification of the appropriate manufacturing strategy.

Mason-Jones et al. (2000a) borrowed these ideas when they developed their taxonomy for supply chain strategy selection (Figure 2-5). They proposed that the supply chain strategy should be tailored to match the required “market winning criteria” of the market. The lean paradigm is most powerful when cost is the market winner, while the agile paradigm is most powerful when service and customer value are the market winners.
Christopher (2000) has proposed a taxonomy for supply chain strategy selection consisting of the following three parameters: volume, variety, and variability (Figure 2-6). Christopher (2000) argues that lean principles are applicable in markets where demand is relatively stable and therefore predictable, and variety is low, while agile principles are applicable in those markets where demand is volatile and the customer requirement for variety is high.

Christopher et al. (2006) discuss a classification model consisting of the following three parameters: products (standard or special), demand (stable or volatile), and replenishment lead-times (short or long). Special product refers to a product with low volume and erratic demand, a short life cycle, or a high level of customization. In contrast, standard product refers to a product with a more stable demand, longer life cycle, or with no or limited customization. Christopher et al. (2006) argue that replenishment lead-time has to be included in any useful taxonomy for supply chain strategy selection, due to its critical impact on responsiveness, and since globalization tends to extend these lead-times. Moreover, they argue that since predictability and type of product tend to be related, that is, standard products are more predictable, it is possible to simplify the taxonomy into only two dimensions: predictability and replenishment lead-times. Figure 2-7 shows the resulting matrix and the four suggested supply chain strategies.
As can be noted, the matrix suggests that there are four possible generic supply chain strategies. Firstly, when demand is predictable and replenishment lead-times are short, a lean continuous replenishment strategy is appropriate. In contrast, when demand is unpredictable and replenishment lead-times are long, a leagile supply chain strategy is appropriate. As mentioned earlier, postponement is one way to realize leagile supply chain strategies. Moreover, when lead-times are long and demand is predictable, a lean supply chain strategy is appropriate, for example, make and source ahead of demand in the most efficient way. Finally, when demand is unpredictable and lead-times are short, an agile supply chain strategy, based on rapid response, is required. In addition, Christopher et al. (2006) argue that within each cell of the matrix, the tactics adopted can also be influenced by whether the product is “standard” or “special”. For example, in the postponement cell for a special product, we may postpone manufacturing, but for a standard product, it could be better to postpone distribution (Pagh and Cooper, 1998).

2.3 Information Systems and Technology

The advances in and possibly the existence of SCM are based on the rapid development in information systems and technology. Increased competition and globalization have radically changed the business environment and resulted in companies’ need to reduce total costs in the entire supply chain, shorten lead-times, reduce inventories, expand product assortment, provide more reliable deliveries, as well as improve customer service, quality, and efficiently coordinate world-wide demand, supply and production (Li et al., 2006; Umble et al., 2003). In order to accomplish these objectives, effective enterprise information systems are required (Liao et al., 2007; Sun et al., 2005). Moreover, the implementation and integration of information systems support information sharing and supply chain alignment, which can considerably reduce demand uncertainty, demand variability amplification, and inventory levels. The purpose of this section is to clarify the major role of information systems and technology in today’s supply chains. The area is presented for the very specific purpose of establishing its use in the SCM of today, and some of its expected use in the future. However, it is in no way a comprehensive coverage of the large field of information systems and technology.
The utilization of information systems and technology has numerous advantages. At a strategic level, Alkadi et al. (2003) highlight that utilization of information systems and technology can increase the efficiency of supply chains. Moreover, Williams et al., (1997) underline that the use of information systems and technology can increase the alignment between supply chain strategy and business strategy. In addition, Kotha et al. (2000) and Byrd and Davidson (2003) maintain that the exploitation of information systems and technology in supply chains can increase overall growth and profitability. On a more operational level, Kincade et al. (2001) have linked the utilization of information systems and technology to an increase in product offerings and customer service levels, while Brandbyberry et al. (1999) have linked the employment of information systems and technology to an increase in quality and timeliness of production information.

As illustrated in Figure 2-8, information systems and technology are supposed to increase the efficiency of individual supply chain processes, that is, efficient utilization of resources, such as transportation, warehousing, inventory control, order processing, and logistics administration (Mentzer and Konrad, 1991). They should also facilitate intra-organizational and inter-organizational integration across the supply chain, that is, the integration between different systems, as well as enable collaboration with supply chain members (Kumar and Diesel, 1996). In other words, the overall purpose of utilizing information systems and technology in supply chains is to achieve the objective of SCM, that is, satisfy the needs of the end-users as cost-efficiently as possible. This requires strategic collaboration between the supply chain participants, to achieve a balance between cost, quality, speed, and flexibility. That is why SCM has evolved from logistics management to become a necessity.

![Figure 2-8. Application and system integration in the supply chain.](image)

Information systems and technologies are crucial to the development of efficient and effective supply chains. Each supply chain process or function can include several different information systems. Examples of information systems that support planning activities in the supply chain are:

- Material Requirements Planning (MRP);
- Enterprise Resource Planning (ERP);
- Production/Capacity planning;
- Demand/Sales planning;
- Transportation planning;
- Distribution Requirements Planning (DRP); and
- Customer Relationship Management (CRM).
Moreover, numerous technologies can be used to support, plan, and control activities within the supply chains, such as:

- Bar codes;
- Electronic Data Interchange (EDI);
- Quick Response (QR);
- Cross-docking;
- Radio frequency identification (RFID); and
- Web-services.

The ERP-system, CRM-system and agent based system are discussed in more detail below.

### 2.3.1 Enterprise Resource Planning Systems

An ERP-system is an enterprise-wide information system that integrates all necessary business functions, such as product planning, purchasing, inventory control, sales, financial and human resources, into a single system with a shared database (Liao et al., 2007; Yang et al., 2007). The key idea of the ERP-system is using information technology to achieve the capability to plan and integrate enterprise-wide resources (Kumar et al., 2003).

The ERP-system is increasingly important in modern business, because of its ability to integrate the flow of materials, finance, and information to support organizational strategies (Yusuf et al., 2004). The ERP-system was developed and derived from the previous Materials Requirement Planning (MRP) systems and Manufacturing Resource Planning (MRPII) systems (Yang et al., 2007).

A successfully implemented ERP-system can offer companies several benefits, for example, automated business processes, timely access to management information, and improving SCM through, for example, the use of e-commerce (Yusuf et al., 2004).

The selection of an appropriate ERP-system and its implementation are not easy tasks. There are numerous examples in which companies were not successful in obtaining the potential benefits that motivated their investing in an ERP-system (e.g. Chen, 2001; Davenport, 1998; Davenport; 2000; Nah et al., 2001). Thus, the question of how to successfully select (e.g. Liao et al., 2007; Wei et al., 2005; Yang et al., 2007; Ziaee et al., 2006) and implement (e.g. Kumar et al., 2002; Kumar et al., 2003; Li et al., 2006; Nah et al., 2001; Sun et al., 2005; Umble et al, 2003) an ERP-system remains an essential research topic.

### 2.3.2 Customer Relationship Management Systems

Customer Relationship Management (CRM) systems are a fairly new genre of computer-based applications where the concern is to improve the selling and revenue generation processes of companies (Corner and Hinton, 2002). Payroll, accounting, and manufacturing and control systems, as well as ERP-system, are well established applications. These ERP-systems, as discussed above, are concerned with accounting, sales order processing, manufacturing and other application areas generally regarded as “back office” systems. CRM-systems, on the contrary, are regarded as “front-office” systems, since they are concerned with customer relationships.

There has been a great deal of recent interest in CRM-systems (Robinson, 2000), which certainly has its origin in the emphasis on a customer-oriented organization and supply chain (Li et al., 2002). As pointed out by Robinson (1998), CRM is an inclusive concept, referring
to the applications that business can use to manage all aspects of customer encounters. Three types of applications can be distinguished (Li et al., 2002; Robison, 1998):

- Applications for data gathering about customers;
- Applications to understand customers and meet their needs; and
- Applications used by customers, such as self-service web sites where customers can obtain information on, or purchase products.

Other self-service applications can allow customers access to the companies’ databases, for example, when airline companies allow customers access to current flight information on a web site, or a delivery company’s truck location can be traced (Li et al., 2002).

2.3.3 Agent Based Systems

In recent years agent based systems have gained interest in the SCM community, due to the similarity between supply chain participants (e.g., factories, inventories, customers), and agents in agent based systems. Another motivating aspect for implementing agent based systems for supply chain issues is the resemblance of characteristics between a company in a supply chain and the characteristics of an agent. A company in a supply chain carries out some tasks autonomously, without any intervention from external entities, and has some kind of control over its internal state and actions. Like an agent, a company in the supply chain, by itself, cooperates with its environment and other companies by, for example, placing orders. Furthermore, like an agent, a company has to adapt to a changing environment (i.e. the market) in a reactive (e.g. respond to changes in demand), and proactive (e.g. launch new products in the market) manner.

Agent systems are formed when several agents interact and communicate with each other to achieve common goals. The agents’ ability to collaborate, coordinate and interact is the most important feature of agent systems. By sharing information, knowledge, and tasks among the agents in the system, collective intelligence may emerge that cannot be derived from the internal mechanism of an individual agent. The ability to coordinate within an agent community makes it possible for agents to coordinate their actions among themselves, that is, taking the effect of another agent’s actions into account when making a decision. According to Wooldridge and Jennings (1995), agents can be defined as hardware or software-based computer system with four general characteristics:

- Autonomy;
- Social ability;
- Reactivity; and
- Pro-activeness.

Autonomy implies that agents are autonomous in the sense that they operate by themselves without any direct human intervention, and have some kind of control over their internal state and behavior in an environment. Social ability implies that agents have the capability of interacting with other agents and with its environment. Reactivity implies that agents have the capability to perceive their environment and, in response, react to the changes in the environment. Pro-activeness implies that agents are capable of pursuing their own goals by controlling their future in a proactive manner. From a supply chain perspective, cooperation is a better word than social ability and reactivity, and pro-activeness can be merged to adaptation. Adaptation implies that agents are capable of adapting to the environment – in a reactive and proactive manner – and can learn from the experience in...
order to improve themselves in a changing environment. Cooperation implies that agents are capable of interacting with other agents and their environment.

Agent Based Modeling (ABM) represents a new paradigm in modeling and simulation of complex and dynamic systems distributed in time and space (Jennings et al., 1998; Lim and Zhang, 2003). In ABM the focus is on agents and their relationships with other agents or entities (Cicirello and Smith, 2004; d’Inverno and Luck, 2001; Jennings et al., 1998). Since manufacturing and logistics operations are characterized by distributed activities as well as decision-making – in both time and in space – and can be regarded as complex, the ABM approach is highly appropriate for these types of systems (Choi et al. 2001; Lim and Zhang, 2003; McCarthy, 2004; Nilsson and Darley, 2006; Nilsson, 2005).

There is a growing interest in using ABM in several business-related areas, such as manufacturing (Anosike and Zhang, 2007; Brandolose et al., 2000; Caridi and Sianesi, 2000; Kotak et al., 2003; Lim and Zhang, 2003; Mohanty, 2004; Shen et al., 2006; Shen et al., 2007; Wang et al., 2007; Zee, 2006), maintenance (Hilletoft et al., 2007; Yu et al., 2003), logistics (Nilsson and Darley, 2006; Smirnov et al., 2004; Teruaki et al., 2002), and SCM (Albino et al., 2007; Chen et al., 2008; Davidsson et al., 2005; Fung and Chen, 2005; Gerber et al., 2003; Jiao et al., 2006; Julkà et al., 2002; Kaïhara, 2003; Labarthe et al., 2007; Liang and Huang, 2006; Lin and Lin, 2006; Lou et al., 2004; Mele et al., 2007; Ren and Anumba, 2004; Santos et al., 2003; Xue et al., 2005). ABM is considered important for the development of industrial systems (Davidsson and Wernstedt, 2002; Fox et al., 2000; Karageorgos et al., 2003) and it provides a pragmatic approach for the evaluation of management alternatives (Swaminathan et al., 1998).

Based on literature reviews, Davidsson et al. (2005) and Cantamessa (1997) conclude that very few field experiments and developed systems are reported in the academic literature. Davidsson et al. (2005) reviewed the maturity of agent approaches presented in the literature and used the following four main levels: Conceptual proposal, Simulation experiment, Field experiment, and Deployed system. Their sample of 56 journal articles published between 1992 and 2005 only identified one level 4 and three level 3 research works. A literature review reported in one of the included manuscripts confirms that this situation still exists (see appendix in paper III). In a sample of 33 journal articles published between 2000 and mid 2007 (one research work from 2008 was available through early view), only one paper included empirically verified results after the implementation of ABM (see Nilsson and Darly, 2006). Furthermore, the literature review revealed that very few agent based frameworks have been developed, based on empirical information, and most of the articles only include developed prototype systems.

Nilsson and Darly (2006) conclude in their empirical study that managers aided by agent based models and simulations can benefit in several ways. Firstly, they acquire an increased understanding of the impact of unscheduled factors, such as breakdowns, accidents and changes of demands. Such factors are often found in reality, but usually reduced or even ignored when transferred to most traditional models. This implies that the optimized solutions from these traditional models mislead managers into believing in future scenarios which do not reflect reality. Secondly, agent based simulations can guide managers’ instincts, since interactive agents generate an emergent pattern which can be explained and understood and can therefore benefit the improvement of decision-making in companies. Thirdly, ABM can help managers find where the highest leverage can be gained among improvement alternatives. This is based on the fact that ABM allows models to encompass several business functions that can affect each other. Finally, there are at times even opportunities to improve predictability based on the scenarios generated.
2.4 Challenges for New Transportation Route

Efficient and effective transportation modes have become more and more crucial in SCM, partly due to specialization, globalization and outsourcing. Companies nowadays frequently follow the principles of focused factories by consolidating and centralizing their production to a few manufacturing plants in those zones where production is most profitable. This entails that manufacturing operations are often located far from major final markets in Europe or North America, which implies that companies need efficient and effective transportation modes to be successful in these markets. This section presents and discusses challenges for the new potentially important landbridge transportation alternative.

There has been a significant increase in the volume of container traffic between Asia and Europe (Shu 1997; Vellega and Spens 2006). The majority of these containers are transported by sea vessels (Shu 1997; United Nations 1999; Gorshkov and Bagaturia 2001; Vellega and Spens 2006). Sea vessel transportation increases the supply chain lead-time and can take up to forty days (Vellega and Spens 2006; Kasunga 1997). Additionally, in-transit costs are relatively high (Vellega and Spens 2006), as well as safety stock holdings in port of loading and port of discharge. These factors limit companies with global sourcing in designing and managing the supply according to lean principles (e.g. high volume and periodical ordering), which in volatile markets truly contribute to supply uncertainty, variability amplification and overall higher inventory levels.

An alternative method of transport between Asia and Europe would be to use intermodal transportation via landbridges (also known as transcontinental bridges) between these two continents (Shu 1997; Kasunga 1997; United Nations 1999; Gorshkov and Bagaturia 2001; Otsuka 2001; Lee 2004; Rodrigue 2006; Vellega and Spens 2006). The landbridge services could be considerably faster than sea vessel transportation (TSTR 1999).

Intermodal transportation refers to freight transportation utilizing more than one mode of transport (road, rail, sea or air) to move goods, in a container or vehicle, between an origin and destination, without any handling of the freight itself when changing modes (Abbasi 1996; Jones et al. 2000; Cranic and Kim 2005). The advantage of employing this method is that it reduces cargo handling, and so improves security, reduces damages and loss, and allows freight to be transported faster. This crucial transport system mainly relies on the maritime/railway interface, which has been considerably improved by double-stacking trains (enabling two stack containers and doubling the capacity) and also by more efficient port and rail terminals (Rodrigue 2006).

There are two major characteristics of a landbridge freight service. First, there is a single bill of lading issued by the freight forwarder that covers the entire intermodal journey. Second, the goods remain in the same container for the entire journey. Three types of landbridges exist (Miller 1977; Rodrigue 2006): Micro-bridges, Mini-bridges, and Landbridges. Micro-bridges involve a link between a foreign origin and an inland destination via a port of entry. Mini-bridges involve a foreign origin, but the destination is a port reached from another port of the same continent. The Trans-Siberian Railway (TSR) was the first mini-bridge to operate in 1967, linking the harbors of the Pacific Ocean coast to the harbors of the Baltic and Atlantic coasts of Europe. However, it should be noted that the TSR consists of several sub-railways which were vital during the years before the Japanese Russian war of 1904-1905 (C.R.B. 1905) and in the Second World War (Grajdanzev 1941). Another mini-bridge example on the US continent linking the west and east coasts (from New York to Seattle) can save nearly 30% in distance compared to the Panama Canal alternative (Knowles 2006). Landbridges use the rail system as a link between a foreign origin and destination. The continental mass is simply used as a link between two maritime services. The transport mode is almost exclusively rail, because it is faster, although more expensive than maritime
transportation. An example would be shipping a container from Asia to Europe by using the North American landbridge.

Theoretical intermodal landbridge freight services have a lead-time advantage compared to traditional sea vessel transportation, although costs would not be significantly higher. Consequently, the utilization of landbridge freight services could reduce supply uncertainty, variability amplification and overall inventory levels. There are two major groups of international transportation corridors, both including several corridors, supporting intermodal transportation between Asia and Europe: the North American landbridge, and the Eurasian landbridge.

The North American landbridge utilizes the North and Central American continent as a “bridge” between Asia and Europe. It includes an American (US), Canadian, and Mexican corridor (Rodrigue 2006). For example, a shipment could proceed from Hong Kong to Seattle (or Vancouver) by sea. The containers would then move by double stack trains to an east coast port such as Boston (or Halifax). They would subsequently be reloaded aboard another vessel for the final leg between Boston (or Halifax) and Rotterdam.

The Eurasian landbridge employs the Eurasian continent as a “bridge” between Asia and Europe. For example, a shipment could travel from Tokyo (or Busan) to Vladivostok (or Lianyungang) by sea. The containers would then move by trains to Rotterdam through Russia (or central Asia). It includes five main corridors (Zepp-LaRouche 1997; Tennenbaum 2001):

- The northern corridor;
- The central corridor;
- The southern corridors;
- The transport corridor of Europe-Caucasus-Asia; and
- The north-south corridor.

These corridors connect a significant share of the total world population – approximately 4 billion people can be reached by them (Tennenbaum 2001). In the following section, the northern corridor (NC) and central corridor (CC) of the Eurasian landbridge are described and analyzed in more detail, since they already have the infrastructure needed to provide an efficient landbridge service between Asia and Europe.

2.4.1 The Northern Corridor

The NC (also known as the TSR) stretches from Western Europe to Eastern Asia, connecting the Netherlands, Germany, Poland, Belarus, Finland, Sweden and Russia (Otsuka 2001; Tennenbaum 2001; Fadayev 2004; Lee 2004; Howkins 2005; Vellega and Spens 2006). The 9,200 km long TSR covers much of this route and currently carries significant amounts of freight from East-Asia to Moscow and further to the rest of Europe. Potentially, the NC could be extended to include both North and South Korea since the rail system of South Korea could be linked to that of North Korea to connect with the TSR (Nesirky 2002; Financial Times 2006a; Vellega and Spens 2006). This would provide the advantages of a very fast all-surface route for goods manufactured in South and North Korea and an extremely short sea leg for Japanese products. However, due to political problems with North Korea, this project has stalled and freight from South Korea and Japan must currently be shipped by sea to the port of Vladivostok to access the NC (Financial Times 2006b; Vellega and Spens 2006).

Historically, the NC was an alternative to the North American landbridge and sea vessel transportation for traffic between Asia and Europe. At one time it carried over eleven percent of the container traffic in this market (Bergstand and Doganis 1987). This was at the height of the Soviet Union when railroads were the prime mode of transport. Today the NC carries only
below one percent of this volume, due to inconsistent levels of service and the cost on this route (Lee 2004; Vellega and Spens 2006). In 2005, the NC carried about 138,000 TEUs (Twenty feet Equivalent Units; i.e. 1 TEU = one 20-feet container) of international transit cargo (Gavriluk 2006). Different forecasts predict the annual transit movement of 300,000-1,000,000 TEUs within five to ten years (Bergstand and Doganis 1987; Wagstyl 2006; Pronina 2004). Nevertheless, in 2007 volumes of international container transports in the NC (TSR) have collapsed to 30,000 TEU (Hilmola et al., 2007).

The NC, in its present state, is already technically capable of transporting up to 100 million tons of cargo a year, including up to 300,000 TEU of transit container traffic from points in the Asia-Pacific region and Central Asia (Kachura 2001; RZD 2006). One related issue is whether there is an adequate supply of containers and rail container wagons (24 meter platforms) to support the anticipated volumes (up towards 1,000,000 TEU) of traffic.

Forwarders operating on the NC suffer from a shortage of rolling stock for container transportation. Altogether they own about 27,000 rail platforms, of which about 23,000 belong to TransContainer OJSC, the subsidiary of the Russian government-owned rail monopoly and the only TSR’s carrier, RZD OJSC (Transcontainer 2006). Private forwarders and operators are often unwilling to increase their own rail vehicles on the NC, because of long platform return times and inconvenient groundwork, making transportation on the company’s own platforms unprofitable. Another reason is that the owner must pay for repairs and empty runs (Sergeyev 2005). Some shippers and forwarders in Japan and other Asian countries have had to provide their own containers for the intermodal services in direct contrast to deep-sea services, where shipping companies supply adequate numbers of containers to their clients.

If the NC were restored to consistently high quality service (competitive and transparent price levels, safety and cargo security taken into account, traceability of cargo during transport reality, short lead-times and accurate schedules), then it would be a much preferred landbridge service to the North American landbridge, since it involves much shorter sea legs and would be considerably faster. It would also be competitive with sea vessel transportation.

Despite the fact that modern deep-sea vessels have continued to improve their average speed, they are still a few tens of a percentage below the average speed of container block trains (1000-1200 km/day). Moreover, the NC has a competitive advantage due to a significant decrease in transportation distance. Using the NC provides a 30 percent decrease in transportation distance from Japan to Rotterdam, compared to sea vessel transportation. Likewise, the distance from Japan to Berlin will decrease by 33 percent and to Helsinki by an impressive 58 percent (Arsenov 2006).

Theoretically, the NC could transport a container from Asia to Europe within 9 days. This has been proven in a demonstration journey from Nakhodka-Moscow-Brest which took place between the 16-25 April, 1998 (Pekhterev 2000). The journey of over 10,500 km took slightly less than nine days. An average speed of over 50 km/h was achieved, which is very good for rail freight services in Europe (Lewis et al. 2001). If such high quality service could be provided on a regular basis, it would divert considerable volumes of containers from traditional sea vessel transportation. In 2004 and 2005, demonstration journeys of block container trains were organized at the initiative of UNESCAP. These demonstration journeys reveal that the use of block container trains on the NC can reduce the average transit time of container delivery by providing transit times of 15-20 days from Japan (or South Korea, China, and Taiwan) to Finland, 17-22 days from Japan to Sweden and Poland, and 22-28 days from Japan to Southern European countries (RZD 2006). Simultaneously, the leading deep-sea carriers on the route between Europe and Asia provide transit times of 25-30 days from Europe to Japan and 24-31 days from Europe to South Korea. The variation in delivery
times is explained by the location of European ports serving Eurasian transit (on the Mediterranean Sea or North Sea) and the number of stops during the trip (Arsenov 2006).

Until recently there has been resistance by some shippers and forwarders to using the NC. A recent master’s thesis at Maastricht University in the Netherlands provides a summary of the major reasons why there is still some reluctance to use the NC (Yarema 2002). The thesis was based on questionnaires sent to business managers, politicians and railway officials from five countries (Belgium, Germany, Netherlands, Russia and the Ukraine). In some cases follow-up interviews were also held with respondents of the survey. Yarema’s (2002) research found the following impediments to greater usage: Political (e.g. Khabirova 2006), Financial and Technical.

The first impediment (political) results from the uncertainty within the transportation service, arising from different stakeholders with conflicting objectives and desired outcomes from the system not being the same among actors. Implications could include, for example, suddenly changing tariffs, delays in the transportation process and antiquated legislation with respect to real-life demands (e.g. in Russia it still concerns transportation modes, and intermodal transports are problematic issues). Financial problems are sector specific. For Russian railways, balancing passenger transports and freight operations is a challenge, since freight transport profits support the deficits of passenger transports (e.g. Guriev et al. 2003). As a result, freight operations cannot develop themselves based on the cash flow coming in from their operations, and external parties are not willing to invest in wagons and containers. A number of technical issues are related to financial ones (Yarema 2002: 19-24; see also Orlov 2001 and Transcontainer 2006), and lead to such situations as port infrastructure that is inadequate in terms of quality and quantity, thus causing further delays. Furthermore, the training of personnel (Duthy 1998; Yarema 2002) and knowledge of market economy supply chains are still identified as constraints.

2.4.2 The Central Corridor

The volume of freight carried between Asia and Europe is massive. However, a surprisingly small part of it is transported through the CC. The CC stretches from Western Europe to Southeast Asia, connecting the Netherlands, Germany, Poland, Hungary, the Ukraine, Belarus, Russia, Kazakhstan and China (Shu 1977; Otsuka 2001; Tennenbaum 2001).

In 2000 the CC carried about 20,000 TEU (Azovskiy 2006). Most of these container shipments were destined for Uzbekistan and Kazakhstan, but there was virtually no east-bound freight. Currently the relation between west and east-bound freight is 90/10.

Shu (1997) provides a summary of the major reasons why the volume carried by the CC is low compared with other routes, particularly sea vessel transportation. The first major category of impediments is different land and sea freight tariffs. The Chinese section of the railway from Lianyungang to Alashankou covers 4131 km. Rail freight costs calculated at Chinese rates plus additions for miscellaneous fees, port charges, handling costs, and so on, total about USD 1,950 per TEU. Tallying the freight and the additional costs in the other countries involved brings the final total transport cost of one TEU from a port on the east coast of China to a European port to USD 3,500. Shipping a similar-size container by sea from a Chinese port to a European port would total about USD 1,200, and prices by sea are falling due to severe competition. Consequently, the railway route costs about three times as much as the sea route (Shu 1997).

A second category of impediments is the total transportation time. Previously, it was thought that the railway would be faster and cheaper than the sea route between the Asian-Pacific region and Europe. From a geographical point of view, the journey by sea from Lianyungang to Rotterdam is about 19,900 km, whereas the land route is 10,900 km (Shu
In other words, the railway is about half the distance of the sea route. Furthermore, trains are faster than ships (Kasunga 1997; Shu 1997; Gorshkov and Bagaturia 2001; Lee 2004; Vellega and Spens 2006). Consequently, the land route should represent a huge saving in time, but it does not work out that way. Currently, the speed of rail freight in China is very slow and the journey from Lianyungang to Alashankou is about 18 days (Shu 1997). Still today major Chinese trade flows are being handled through its large-scale sea ports, and most important industrial parks are located very close to them. However, currently there are several transportation problems in China, especially concerning inland transports (e.g. Ta et al. 2000; Goh and Ling 2003; Wang et al. 2004). Intermodal transportation faces severe problems, due to the level of automation of material handling, as well as in the level of provided transportation services (as containers will proceed from port by rail or road transports). Infrastructure investments are lacking behind transportation volume growth (e.g. road), and logistics development programs are needed to rationalize current practices. Additionally, the breakdown of the Soviet Union has created a situation where railway routes must cross several new countries, each increasing the time and cost primarily through customs procedures and tariffs. Currently, non-containerized freight from Lianyungang to Rotterdam takes a little more then 40 days, while containerized freight still takes more than 30 days (Shu 1997). Although the distance by sea is twice as long, the size of ships coupled with speed increase and navigation improvements have cut the journey time to 25 days (Kasunga 1997; Shu 1997; Lee 2004). However, CC has the potential to improve performance as demonstration trains have reached a lead-time of 12-15 days (UNESCAP 2003).

A third category of impediments is poor infrastructure and complex paperwork. Railway freight requires two total transfers and repacking: once at the China-Kazakhstan border, and again at the Poland-Belarus border. According to China’s Ministry of Foreign Trade, three problems are restricting development of the CC. Firstly, Alashankou has inadequate facilities; transfer capacity and storage is limited. In early 1996, over 400 rail carriages were backed up in Kazakhstan alone. Secondly, Alashankou inspections and formalities are unduly bureaucratic, creating a situation where goods are held too long, sometimes up to 6 days. Finally, various fees charged at Alashankou are extremely taxing, running up to US$600 (Shu 1997).

A fourth category of impediments is poor freight tracking. In 1991, the Chinese government allocated funds to install freight movement tracking equipment at all main stations along the Lianyungang-Alashankou route, but the system is still not in use and the freight owners cannot track movement of goods in a timely fashion. Furthermore, there is no guarantee that goods will be dispatched on time. Owners and shippers have reacted strongly to these problems (Shu 1997).

A final issue deals with the fierce competition from the NC. The NC is the main land competitor to the CC – and the former has the advantage of running almost entirely within Russia (Shu 1997; Otsuka 2001; Tennenbaum 2001; Fadayev 2004; Lee 2004; Howkins 2005; Vellega and Spens 2006), whereas the CC has only a small section running through Russia (Shu 1997). Since more freight travelling on the CC could cause great losses for the NC, it is no surprise that Russian tariff policy during 90’s favored the NC over the CC (Shu 1997): To compete with the CC, Russia lowered the NC fees to US$0.15 per km, while transports on the CC were obligated to pay double this amount (Otsuka 2001; Tennenbaum 2001; Fadayev 2004; Lee 2004; Howkins 2005; Vellega and Spens 2006).
3. METHODOLOGY

In this chapter, the research methodology used in this thesis is presented and discussed. First, a description of the research process that has been conducted during a two-year period and reported in the form of four independent scientific articles is provided. This is followed by a description of the applied research methods; the main emphasis has been on producing descriptive results of the studied phenomenon. The primary research approach consists of five case studies in order to reach an in-depth access to data and facilitate a thorough understanding of the research topic. Finally a discussion concerning the quality of the research is given.

3.1 Research Process

This study reflects research carried out by the author in the form of several sub-projects during a two-year period (Figure 3-1). As the thesis itself consists of a set of independent articles built on individual approaches towards the studied phenomenon, it is difficult to provide a general methodological description of the study as a whole. However, the respective approaches for each research phase build on common philosophical assumptions of the studied phenomenon, and respective methods have been considered in terms of their ‘fit’ to this setting and the research problem itself (Arbnor and Bjerke, 1997).

Overall, the main emphasis in this study has been on producing descriptive results of the studied phenomenon. However, some steps of the research process can be described as being explorative, and the analyses relating both to the individual papers and this final synthesis include explanatory elements, building on, for example, cross-case comparison (Yin, 1981). The study does not hold specific normative ambitions.

![Figure 3-1. The Research Process And Phases.](image)

When conducting research, one normally distinguishes between inductive and deductive research. According to Eriksson and Wiedersheim (1999), inductive research can be explained as “from separate phenomena in reality we derive general statements”. In addition, deductive research can be explained as “from theory we form hypotheses, which are testable statements about reality, through logical conclusion we derive the result” (Eriksson and Wiedersheim, 1999). Figure 3-2 illustrates the differences between the inductive and deductive research approaches.
The emphasis of different methodological aspects has varied during the research process, that is, this study incorporates both inductive and deductive research approaches. However, the inductive approach dominates. In the first paper, an inductive approach was chosen to enhance current knowledge on international transportation corridors by investigating described logistics systems used by companies in a qualitative manner. In the second paper, a deductive approach was chosen to enhance knowledge of the supply chain strategies by testing a hypothesis – the hybrid supply chain strategy is a universal solution to remain competitive in turbulent and volatile markets – derived from the theory in a qualitative and quantitative manner. In the third paper, an inductive research approach was chosen to enhance current knowledge on the complexity of decision making and operations in manufacturing supply chains by investigating described logistics systems used by companies in a qualitative manner. In the fourth paper, an inductive research approach was chosen to enhance current knowledge of SCM by investigating how agent based issues can be formulated, and what information systems could look like in a qualitative manner. In the final research phase (i.e. final synthesis), the results attained in the individual papers, as well as the overall results, have been compared with extent theory.

Qualitative research was applied in order to achieve a deeper understanding of the studied phenomenon through examining qualitative information from only a few chosen elements (Merriam, 1994), while quantitative research was applied in order to describe some elements of the studied phenomenon in more detail (Patel and Davidsson, 1994). The research strategies applied in the individual articles are obviously described in each publication. However, the respective methods of data gathering and analysis are also summarized in the following.

### 3.2 Applied Research Strategies

Research can be conducted in various ways including carrying out case studies, experiments and surveys. Each strategy has particular advantages and disadvantages, depending on three conditions (Yin, 1994):

1. Type of research question posed;
2. The extent of control an investigator has over the actual behavioral events; and
3. The degree of focus on contemporary as opposed to historical events.

In all of the appended manuscripts, it was considered that case studies were the most appropriate research strategy, since the aim was to analyze contemporary events, capture
wider and in some extent new problem areas, and because the researcher had no control over the events (Bonoma, 1985). Case study research is particularly suitable for addressing problems where research and theory are still formative (Eisenhardt, 1989, Benbasat et al., 1987). Moreover, case study research is suitable where ‘how’ and ‘why’ questions are addressed concerning a contemporary set of events over which the investigator has little or no control (Yin, 1991), and where the context of action is critical (Benbasat et al., 1987, Yin, 1991).

There is a widespread misunderstanding that various research strategies should be arranged in a hierarchical order, that is, the case study approach is used in explorative studies, the survey approach in descriptive studies, and the experimental approach in explanatory studies (Yin, 1994). However, all research approaches can be used for the three types of studies: explorative, descriptive, and explanatory. Yin (1994) holds that it is possible to combine research strategies, for example, by using a survey within a case study. An explorative study is useful for designing a more precise problem definition (Hellevik, 1984). Moreover, in a descriptive study, the researcher conducts more systematic studies of precise problems, while in an explanatory study the researcher tries to identify the factors underlying the characteristics found in the study (Hellevik, 1984).

According to Yin’s (1981) classification model, there are four types of case study strategies, and in this study two of them were used in the course of the research process (Figure 3-3).

In the first paper, a descriptive embedded multi-case study approach was employed to enhance current knowledge of transportation structures used in SCM. This was carried out by investigating why such a small proportion of total container traffic between Asia and Europe is transported by landbridge freight services, despite its considerable potential to be faster than traditional sea vessel transportation. In the second paper, a descriptive embedded multi-case study approach was employed to enhance current knowledge of SCM by analyzing key issues related to the employment of lean, agile and legile strategies in international supply chains. In the third paper, a descriptive embedded single-case study approach was employed to enhance current knowledge of SCM by discussing the complexity of decision making and operations in manufacturing supply chains. In the fourth paper, a descriptive embedded single-case study approach was employed to enhance current knowledge of SCM by discussing how agent based issues can be formulated, and what information systems could look like.
The case studies have been complemented with literature reviews and also with system dynamics simulation in one of the papers. Table 3-1 shows the applied research strategies in the appended manuscripts.

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<tbody>
<tr>
<td>Literature review</td>
<td>International Transportation Corridors</td>
<td>Supply Chain Strategies</td>
<td>Agent Based Modeling</td>
<td>Agent Based Modeling</td>
</tr>
<tr>
<td>Case study</td>
<td>Finnish Manufacturer and Finnish Retailer</td>
<td>Swedish Apparel Retailer (H&amp;M) and Spanish Apparel Retailer (Zara)</td>
<td>Swedish Appliance Manufacturer (Electrolux)</td>
<td>Swedish Maintenance Service Provider (Euromaint Industry)</td>
</tr>
<tr>
<td>Simulation</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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</tbody>
</table>

The case studies incorporated in papers II and IV have been conducted directly by the author while the case studies in papers I and III have been conducted by research teams to which the author is associated. However, the case studies in paper II build on secondary data, which implies that primary data collection in paper IV has been accomplished mainly by the author, while primary data collection in papers I and III has been completed by research colleagues.

### 3.3 Data Collection Techniques

Primary data consists of the information that the investigator (or research teams) has collected while secondary data is an interpretation of primary data previously collected by other researchers (Bell, 1995). It could be argued that it is the degree of closeness that determines whether data is primary or secondary. Examples of primary data sources include eyewitness descriptions and first hand accounts, while books, scientific reports and scientific journals are examples of secondary data sources (e.g. Bell, 1995; Ejvegård, 1996). In this thesis both primary and secondary data sources have been utilized.

Data collection can be conducted in various ways, including carrying out interviews, observations, interpretation of documents, video recordings, surveys and questionnaires. An advantage of the case study method is the possibility to combine several data collection techniques and data sources (Yin, 1994). In all of the papers, empirical data has been collected from various sources using several data collection techniques, to enhance understanding by examining the research from several perspectives. The use of multiple methods and data sources was found to correspond well with the purpose of this study. It was also considered necessary, as prior investigations concerning some of the research areas were limited, and because the phenomenon under examination was highly complex.

In the included manuscripts, interviews, documents and simulations have been applied. Interviews were applied as the main data collection technique in Papers I, III and IV, while documents and simulation were the main data collection technique in Paper II. Digital recording in combination with note taking was the main interview method. In order to find relevant information the interviews were prepared carefully (Bell, 1995). Furthermore, interviewees were able to read the transcribed interview text afterwards to avoid misunderstandings (Ejvegård, 1996). Other research works have also been used to achieve validity in analysis, and provide further insights from other companies. Documents produced by the case companies or external organizations were also important for the studies.
The collected qualitative data has been analyzed primarily by applying the principles of pattern-matching and explanation-building (Yin 1981), while the quantitative data has been analyzed through distilling large database format data.

### 3.4 Research Quality

The quality of a research work is an important issue and an endless subject of debate, especially for a qualitative case study approach, and validity and reliability are the most important measures (Yin, 1994; Eisenhardt, 1989). However, it should be noted that validity and reliability are mainly related to quantitative research. Nevertheless, validity and reliability have been discussed in relation to the case study method (e.g. Eisenhardt, 1989; Yin, 1994; Voss et al., 2002) and an overview is offered in Table 3-2.

**Table 3-2. Reliability and Validity in Case Study Research. Source: Yin (1994).**

<table>
<thead>
<tr>
<th>Tests</th>
<th>Case study tactic</th>
<th>Phase of research in which tactic occurs</th>
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<tbody>
<tr>
<td>Construct validity</td>
<td>Use multiple sources of evidence</td>
<td>Data collection</td>
</tr>
<tr>
<td></td>
<td>Establish chain of evidence</td>
<td>Data collection</td>
</tr>
<tr>
<td></td>
<td>Have key informants review draft case study report</td>
<td>Data collection</td>
</tr>
<tr>
<td>Internal validity</td>
<td>Do pattern-matching</td>
<td>Data analysis</td>
</tr>
<tr>
<td></td>
<td>Do explanation building</td>
<td>Data analysis</td>
</tr>
<tr>
<td></td>
<td>Do time-series analysis</td>
<td>Data analysis</td>
</tr>
<tr>
<td>External validity</td>
<td>Use replication logic in multiple-case studies</td>
<td>Research design</td>
</tr>
<tr>
<td>Reliability</td>
<td>Use case study protocol</td>
<td>Data collection</td>
</tr>
<tr>
<td></td>
<td>Develop case study data base</td>
<td>Data collection</td>
</tr>
</tbody>
</table>

The concept of validity in case study research can be divided into three different types of validity: construct validity, internal validity, and external validity (Yin, 1994). A more detailed discussion of the reliability, construct validity and external validity of this study follows. The internal validity is not considered applicable in this study since no explanatory case studies have been conducted (Yin, 1994). The discussion is mainly inspired by Yin (1994).

Reliability means the accuracy and certainty of the measuring instrument (Carlsson, 1990) and concerns the question of whether the study is carried out in such a way that the data collection can be replicated (Yin, 1994). The basis of high reliability is that the research should provide the same results at different times if the conditions are identical (Bell, 1995). A way of minimizing the occurrence of random errors is to increase the number of observations or question of a certain area (Hellevik, 1984). The possibility of replicating the case studies and obtaining the same results is an important question. The data collection in the included manuscripts has been well documented and digitally recorded, which increase the reliability of the case studies. However, it should be noted that all case studies are unique and the companies are continuously changing, meaning that the conditions can never be identical.

Construct validity is concerned with the extent to which correct operational measures have been established for the phenomena being studied (Voss et al., 2002). As shown in Table 3-2, there are several tactics for increasing the construct validity, such as the utilization of multiple sources of evidence, chain of evidence, and having key informants review the draft case study report (Yin, 1994). An advantage of the case study method is that it enables the use of several different sources of evidence (Yin, 1994). By using triangulation, the potential problems of
construct validity can also be addressed, because multiple sources of evidence essentially provide multiple measures of the same phenomenon (Yin, 1994). However, it should be noted that triangulation does not show that the researcher is correct, but rather indicates data agreement between different methods (Denscombe, 2000). In the appended manuscripts, two of the stated tactics have been applied to increase construct validity. Firstly, multiple sources of evidence have been used, and secondly, the draft case study report has been reviewed by the respondents. Furthermore, the interviews were digitally recorded and the interviewer asked follow-up questions if there was uncertainty regarding the answers. Different sources have been used to answer the same questions. Therefore, triangulation can be said to have been used in order to increase construct validity.

External validity is concerned with the question of whether the study’s findings can be generalized. Yin (1994) distinguishes between two types of generalization: analytic generalization, and statistical generalization. Statistical generalization is the classic approach employed in surveys and, as the name indicates, uses statistical methods. In case studies, there is another type of generalization, namely analytical (Yin, 1994). In analytical generalization “previously developed theory is used as a template to compare the empirical results of the case study” (Yin, 1994). According to Yin (1994), it is possible to use analytical generalization for both single and multiple cases. In this study, the analytical generalization has been applied, and the results have been validated by comparing case study findings with other case studies from similar or different type of businesses.

In this study, the use of triangulation has contributed to improving the rigor, depth, and breadth of the results (Denzin and Lincoln, 1994), which can be viewed as comparable to validation (Yin, 1991). However, it also enhanced the investigator’s ability to achieve a more complete understanding of the studied phenomenon (Jick, 1979; Scandura and Williams, 2000). Nevertheless, in retrospect, the overall reliability and validity of the study could have been further improved by, for example, applying more rigor to statistical analysis, increasing the number of informants, and extending the period of data gathering to encompass multipoints in time rather than providing a retrospective snapshot.
4. SUMMARY OF ORIGINAL MANUSCRIPTS

In this chapter, the four included original manuscripts are summarized and their main findings and contributions are presented. The overall purpose of this thesis is to investigate how complexity and globalization affect supply chain design and operations, and this topic is pursued through three more specific objectives (Figure 4-1).

**Figure 4-1. Research Objectives in Relation to the Focus of Each Paper**

The first research objective – to analyze transportation structures used in international supply chains – is addressed in Paper I. The second research objective – to analyze the employment of different strategies in international supply chains – is addressed in Paper II, while the third research objective – to analyze complexity of decision making in international supply chains – is addressed in Papers III and IV.

4.1 Paper I: Using Eurasian Landbridge in Logistics Operations

The objective of this paper is to establish why such a small proportion of total container traffic between Asia and Europe is transported by intermodal landbridge services, and how the container volume transported by intermodal landbridge services between Asia and Europe can be increased. The main literature and empirical findings from this paper are presented below. This is followed by a discussion of the conclusion and contribution of this paper.

4.1.1 Literature Review

According to the literature review presented in this paper, the major reasons for the low volumes transported through landbridge freight services are lack of competitiveness, unpredictable variations in transportation time, and poor service quality related to malfunctions of harbors and railway transport. There are also inadequate and inefficient connections (e.g. harbors or railway) from the Russian side to the final destinations of Asia. Other issues include, insufficient amount of appropriate wagons and containers available for railway transportation in the corridors and changing tariff practices, which create unneeded instability for logistical decision making. However, based on the literature review, the Northern Corridor (NC) has been identified as a main line of increasing volumes of the Eurasian landbridge.
In order to make landbridge freight services more competitive the reliability of transportation time and quality of the landbridge services have to be improved. Countries involved in the different landbridges have to overcome political, economic and ideological differences and start to collaborate in order to achieve efficiency and cost reduction. The infrastructure at the Russian side also has to be improved, particularly concerning harbors, both in numbers and efficiency, in order to create possibilities for an effective intermodal landbridge service. However, improvement does not entirely lie in the hands of governments; more influential companies in the logistics market are also needed to combine different transportation modes for a total transportation service.

4.1.2 Empirical Study

The empirical part of this paper presents an embedded multiple case study. The first case company (i.e. a Finnish manufacturer) represents a global manufacturer where the logistical challenges between manufacturing units (technically leading European, and cost efficient Asian and Latin American) as well as the characteristics of the end-products make this an interesting case (products are more than 10 meters long; in other words do not fit in standard TEU). This case is strengthened by another case study, which concerns a Finnish retailer operating in Russia through its own sales units as well as by the means of franchising. Transportation and logistics in this case were formerly arranged through railway transports using the beginning of the Trans-Siberian Railway (TSR, early part of NC), but the current configuration is organized to support road transport.

The empirical study accomplished in this paper shows a slightly different picture compared to the literature findings. However, it should be highlighted that previous and largely already known theoretical understanding is simply further supported by two cases, and they validate earlier findings from the field. The empirical research results confirm the need and potential, which landbridge services could give to manufacturers; lead-time compared to sea transport would decrease considerably, but costs would not be significantly higher. However, malfunctioning sections of harbors and railway transport hinder the larger potential of this transportation alternative.

The optimal solution for the Finnish manufacturer’s case would be the NC (TSR), but the current lead-time of this alternative varies too much, and harbor connections from the Russian side to final destinations in Asia are too few and infrequent. This forces the manufacturer to rely on sea and air transportation rather than the landbridge. Similar outcomes are found in the Finnish retailer’s case, where operations in the Russian market have been increased and the use of railways has been changed to favor road transports. The reasons for the retailer using another alternative are almost the same as in the manufacturer’s case. However, the retailer’s distribution structure is more advanced, and an export strategy (from the Finnish harbor) is used to enter Russia. This entry strategy is in most of the cases implemented with flexible and responsive road transports. It is still an open question whether the retailer will ever return to railway transportation again – WTO membership of Russia will most probably simplify and smooth border control procedures between Finland and Russia, and eventually this will increasingly favor road transports. If this is the case, then the future of TSR is on the landbridge operations, rather than in short distance transports. This is similar to what has occurred with US railway freight. The average freight lead in the US, which was approximately 1000 km in 1980 (when deregulation took off), has increased to nearly 1400 km in twenty years (World Bank 2006). This development is mainly due to the long haul intermodal port-railway and landbridge services as well.
4.1.3 Conclusion and Contribution

The conclusion and contribution of this paper is that a potential demand for landbridge freight services between Asia and Europe exists; this is illustrated by the Finnish manufacturer’s case as well as the literature review. A recent survey (Hilmola & Szekely 2006) has also revealed that the largest Swedish and Finnish companies recognize a substantial increase in transportation volume between Europe and Russia as well as Europe and China in the period 2006 to 2011. However, a number of problems must first be solved in order to fully utilize the potential that has been identified. For example, the reliability of transportation time and quality, capacity and equipment, as well as the infrastructure on the Russian side need to be improved. Landbridge freight service has a lead-time advantage compared to sea vessel transport, but malfunctions in harbors and railway transports limit the greater potential of this transportation alternative.

4.2 Paper II: Supply Chain Management in Fashion and Textile Industry

The objective of this paper is to establish which supply chain strategy is the most adequate to meet the challenges of the volatile and turbulent demand representative of the fashion and textile markets. The main literature and empirical findings from this paper are presented below. This is followed by a discussion of the conclusion and contribution of this paper.

4.2.1 Literature Review

According to the literature review presented in this paper, one important issue is the separation of basic and fashion products and correspondingly develop supply strategies based on this division. Lean principles are applicable in environments where demand is high and relatively stable, and therefore predictable, and demand for variety is low. These demand characteristics are well represented by low-priced basic products. The products that could be identified as basic are not as sensitive to short and medium lead-times in the supply chain, due to the fact that the demand for these products is stable over time and there is a lower risk of sell-outs and mark-downs. In contrast, agile principles are applicable in those environments where demand is low and volatile, and demand for variety is high. These demand characteristics are well represented by expensive fashion products. For fashion products, short lead-times are very important, in order to fulfill customer demand as quickly as possible – before fashion trends change the demand and garments are left on the shelf unsold. Furthermore, hybrids of lean and agile principles are applicable in environments where demand is high and unpredictable, and demand for variety is high.

4.2.2 Empirical Study

The empirical part of this paper includes an embedded multiple case study (Yin 1994) together with a simulation based on the case study findings. The first case company is the Swedish fashion and textile retailer, H&M. The case company’s business strategy is to offer fashionable and quality products at the lowest possible price. This is realized by limiting the number of middlemen; buying in large volumes; relying on expertise within the design, fashion and textile industries; buying the right merchandise from the right production markets; being cost-efficient at all levels; and maintaining effective distribution procedures. One could argue that the case company uses a lean strategy, since they focus on creating fashion products at the lowest possible price. The H&M case study is strengthened by another
one concerning the Spanish fashion and textile retailer, Zara. Zara’s business strategy is to adapt the offer to customer needs in the shortest possible time. For the Spanish case company, time is the main factor to be considered, above and beyond production costs. One could argue that Zara uses a leagile strategy, since they focus on creating fashion products at affordable mass-market prices.

The empirical study presented in this paper shows a slightly different picture compared to the literature findings. Based on the theoretical division discussed above, the leagile approach would be the most profitable for fashion and textile companies selling relatively large quantities of fashion products. Some examples of fashion and textile companies selling relatively large quantities of fashion products, include Zara, Benetton, Griffin Manufacturing and H&M. However, H&M is successfully using a lean strategy, while the others use leagile ones. The above presented division has been confirmed in a simulation which showed that a hybrid of lean offshore and agile domestic sourcing (leagile) is more profitable than agile domestic or lean offshore sourcing. However, our multiple case study (real life second hand data) shows that lean strategies are somewhat better in financial terms than leagile strategies in the fashion and textile industry. This difference can be traced to the simplicity of the simulation model. This model builds on a ‘one product flow’ and does not consider different types of products, or the use of effective end of season work, which can improve the offshore strategy considerably. H&M probably has a very effective end of season SCM model, based on their financial numbers presented in the case study. Moreover, their purchase system probably plays a vital role for their success (e.g. Hilmola et al., 2008).

4.2.3 Conclusion and Contribution

The conclusion and contribution of this paper is that the leagile approach is not a universal solution for remaining competitive in a volatile and customer-oriented economy (i.e. fashion markets), since the lean approach can be successfully used in fashion and textile companies which sell relatively large quantities of fashion products. In other words, it is really a question of how the fashion and textile company would like to conduct their business, since both lean and agile strategies can successfully be applied in fashion markets. Nevertheless, it is important that companies understand their environment and product requirement, separate basic and fashion products, and build their supply chain accordingly, as argued by Fisher (1997). However, each supply chain strategy should not be limited to one specific environment. Based on this research, one could argue that the lean strategy can be applied in the same environment (fashion markets) as the leagile strategy with similar success. Although, as simulation illustrates, there is a risk for lost sales in the short-term, because of the long sourcing lead-times (low flexibility), and in the long-term, there is a risk of unsold goods, due to higher inventory levels, depending on when and how the demand declines. This implies that the lean strategy could be risky for products characterized by volatile customer demand and rapid fashion changes, suggesting that the leagile approach could be more practical in these environments. However, effective end of season work is one way of improving the lean approach.

4.3 Paper III: Multi-Agent Based Supply Chain Management

The objective of this paper is to provide insights concerning the complexity of decision making and operations in manufacturing supply chains, and to discuss how information systems and ABM can help managers handle this complexity. The main literature and empirical findings from this paper are presented below. This is followed by a discussion of the conclusion and contribution of this paper.
4.3.1 Literature Review

According to the literature review presented in this paper, ABM is a suitable approach for the management of complex supply chains, and many improvements can be achieved by using ABM for modeling, simulation and analysis. Agent systems have gained a great deal of interest in the SCM community, because of the similarity between supply chain participants (e.g., factories, customers), and agents in MAS. Another motivating aspect for implementing agent systems for supply chain issues is the resemblance of characteristics between a supply chain company and the characteristics of an agent. A company in a supply chain carries out some tasks autonomously without any intervention from external entities, and has some kind of control over its internal state and actions. Like an agent, a company in a supply chain cooperates with its environment and other companies itself, for example, by placing orders. Furthermore, like an agent, a company has to adapt to a changing environment (i.e. the market) in a reactive (e.g. respond to changes in demand), and proactive (e.g. launch new products in the market) manner.

4.3.2 Empirical Study

The empirical section of this paper presents an embedded single case study. The case company (a Swedish appliance manufacturer), which has existed for a long time, represents one of the basic consumer industries in the world. The company produces over 340 variations of three products to which suppliers deliver approximately 2,600 components.

The empirical study in this paper shows that the customers’ (i.e. internal wholesalers) manner of placing orders and the inaccuracy of their forecasts cause a great deal of disturbance in the case company’s production. Other aspects, such as late customer orders, prioritization of orders and delayed deliveries from suppliers, together with the complexity of the case company’s internal manufacturing, force them to make frequent changes in their fixed production plan. When an order in the fixed production plan is moved, other orders are shifted one step forward in time, which means that components for the new orders might not be available, because the suppliers manufacture components according to a weekly production plan that is sent to the majority of the suppliers each week.

This research shows that the case company experiences high changes of demand in both volume and product mix. They have to cope with a great deal of demand variability, which is one of the major reasons for the disturbances in their production. Moreover, these disturbances also have a widespread effect on their suppliers (i.e. the bullwhip effect). One major problem is that the suppliers need to order their direct materials three to four weeks ahead of production start, and, as shown in the research work, the predicted amount varies much during the forecasted period. This leads to an unavoidable situation in which suppliers order excessive amounts of materials to hedge uncertainty, and thus increase overall supply chain costs, in order to reduce missing delivery deadlines. Consequently, the case company’s supply chain requires high product mix flexibility – both in terms of their own manufacturing unit, as well as on the supplier network side.

In the case company, the number of product variants is still rather low, and the customer order point could be considered in most of the items at the warehouse/retail inventory holding level. However, it is becoming increasingly common that manufacturers nowadays shift from this MTS environment to ATO – where final assembly (including packaging and labeling) is postponed until orders are received (known as decoupling and postponement) – to better match supply with demand. In other words, one decides which activities should be performed after orders are received and managed according to agile principles (i.e. responsive, order-driven and customized), and which activities should be performed before orders are received and managed according to lean principles (i.e. efficient, planned and standardized).
4.3.3 Conclusion and Contribution

The conclusion and contribution of this paper is that the case company suffers from high demand variability (including both volume and mix) due to the bullwhip effect. In recent years the concept of Agent Based Modeling (ABM) has gained interest for addressing the bullwhip effect in supply chains. It is argued that by considering more complexity in models constructed, insights can be gained concerning the system-wide effects of logistics systems. Moreover, the sometimes major effects have their origin in minor occurrences or changes in behavior. These inevitably have links to costs as well as non-financial performance. Thus, a model, in which the case supply chain is modeled as a multi-agent based system, has been developed. In this model, the supply processes are managed by a set of intelligent agents that are responsible for one or more activities. Since much of the ABM literature lacks case company based models and industrial applications, this constructive research approach is justified. The purpose of the model is to increase the understanding of logistics complexity and to provide insight concerning how to deal with complexity and uncertainty. The study may also eventually serve as a catalyst for the actions of logistics managers, that is, facilitate a change in mind-set, by illustrating how managers’ decisions affect supply chain performance. This paper has also discussed considerations with regard to what kind of collaboration requirements artificial intelligence systems will face in the short and medium term.

4.4 Paper IV: Information Fusion in Maintenance Planning

The objective of this paper is to take the ideas discussed in Paper III a step further by illustrating how agent based issues can be formulated, and what information systems could look like. It concerns production technical support and maintenance focused companies (i.e. service supply chain) and not manufacturing supply chains as in Paper III. However, the supply chain issues are quite similar in both these cases, since the management of service supply chains mostly concerns exchanging time for information, while the management of manufacturing supply chains is about exchanging inventory holdings for information. The main literature and empirical findings from this paper are presented below. This is followed by a discussion of the conclusion and contribution of this paper.

4.4.1 Literature Review

According to the literature review presented in this paper, information fusion encompasses the theory, techniques, and tools conceived and employed for exploiting the synergy in the information acquired from multiple sources – sensors, databases, information gathered by humans, and so on – such that the resulting decision or action is in some sense better – qualitatively or quantitatively, in terms of accuracy, robustness, comprehensibility – than would be possible, if these sources were used individually without such synergy exploitation. An adjacent concept used in the information fusion community is ABM that can be used specifically for modeling, simulating and evaluating future scenarios. ABM represents a new paradigm in the modeling and simulation of complex and dynamic systems distributed in time and space. Since service operations are characterized by distributed activities as well as decision-making, in both time and in space, and can be regarded as complex, the ABM approach is highly appropriate for these types of systems.

4.4.2 Empirical Study

The empirical part of this paper includes an embedded single case study. The case company is the Swedish service provider, Euromaint Industry. This company is an independent service
provider within production streamlining and maintenance. Their main focus is to provide products and services to improve productivity and reliability. The Swedish automotive manufacturing industry is the main market, however, customers also exist outside Sweden as well as in other industries. The case company was, historically, a Volvo maintenance department. The difference today is that Euromaint Industry has a large variety of customers, both internally and externally, which requires a quite different structure.

The empirical study in this paper shows that the case company has numerous challenges in its order fulfillment process and management. For example, almost every employee can have contact with customers and order entry occurs at several places in the organization. Furthermore, it is not clear who should receive customer orders, or how the orders should be tied to the product and service assortment. In addition, the role of the formal order control is made difficult by the informal order control conducted arbitrarily from one person to another. This implies that the case company needs more and better information in their order fulfillment process (i.e. better information systems). For example, how many orders are received (on daily, weekly and yearly basis), how many orders are in the pipeline and what is their status, how much is each order worth, when should the orders be delivered, or have the orders been completely delivered?

In this situation maintenance planning is quite complicated, because of the lack of the necessary information. The case company has recognized the need to change the service organization in order to make their organization more efficient – optimize resource utilization – and more effective – enhance turnover and profits. Essentially, it concerns enhancing the planning of maintenance services. However, it is not clear how the service organization should be structured and managed. One solution discussed is to enlarge the current service central responsibilities in order to create a centralized order entrance handling the entirely product and service assortment. Another possible solution is to have today’s decentralized structure supported by a software application assisting the coordinators when they handle order entrance and customer service (virtual service organization). An advantage with the decentralized structure is that experts interview the customers and a disadvantage is that it makes resource planning and follow-up more difficult. The decentralized structure is also beneficial if tactical knowledge cannot be transformed into explicit knowledge.

Four conceivable scenarios have been identified as possible solutions for the current two-fold situation:

1. People at a central location handling all order entrance and customer services;
2. People at a central location guide customers in the organization;
3. An automated switchboard distributes customer calls in the organization; and
4. A software application that supports coordinators when they handle order entrance and customer services.

Questions that need to be answered in order to evaluate the alternatives are:

1. What are the risks and benefits of the alternatives;
2. What kind of information and knowledge is necessary for each alternative; and
3. Does the case company have access – or is access available – to the needed information and knowledge?

Irrespective of alternative, the service central should store, collect, and fuse information in order to provide appropriate information for advanced decision making.
4.4.3 Conclusion and Contribution

The conclusion and contribution of this paper is that information fusion and ABM could possibly improve the case company’s current situation. An information fusion cockpit has been proposed to enhance problem solving, demand visibility and resource need estimates, which hopefully will improve the performance of the case company. As a key input variable for managing large numbers of different customers, we identify incoming calls to trigger information collection from numerous different databases. The integration of this incoming “demand” is the first step to be taken in the use of more advanced systems. However, it should be noted that information fusion and agent based systems are currently at the implementation stage, since actual success cases are still almost non-existent and descriptions of real-life cases are limited. Our research has tried to fill this gap by describing industrial maintenance service provider operations, and potential application areas of information fusion theory as well as agent based solutions. However, it is still unclear how the highest levels of the information fusion model should be used in a real-life.
5. DISCUSSION AND CONCLUSIONS

The aim of this thesis has been to investigate how complexity and globalization affect supply chain design and operations and this has been pursued through three more specific objectives: (1) to analyze transportation structures used in international supply chains, (2) to analyze the employment of different strategies in international supply chains, and (3) to analyze the complexity of decision making in international supply chains. In this chapter, the main findings regarding the individual research objectives are discussed. Finally, the research as a whole is concluded.

5.1 Transportation Structures Used in International Supply Chains

Nowadays, global transportation structures and modes are required, since companies operate on a global basis, that is, their sourcing, manufacturing and distribution operations are dispersed across the world, and their products are sold worldwide. As shown in this research, global transportation structures and modes have become essential in SCM, since increased inventory holdings, quality problems, price falls and lost sales, due to the longer lead-times associated with global sourcing, could erode some or all of the production cost savings. Moreover, this research has shown that globalization has made the utilized transportation structures more complex (increased length, increased number of involved parties, increased and varying lead-times, and high service quality variability), and complicated decision making (e.g. estimation of transportation cost and time along with necessary inventory levels).

Additionally, this research has shown that there is a need for new transportation modes between Asia and Europe, due to increased transportation volumes, and because current transportation services for certain products are either too slow (sea transportation) or too expensive (air transportation). Currently, the majority of the huge volume of goods transported between Asia and Europe is being carried by sea vessels. This mode of transportation can increase the supply chain lead-time up to forty days. Moreover, it contributes to high in-transit costs as well as higher safety stock holdings near the final market to compensate for longer lead-times. Since air transportation is not an option for these types of products – low cost products cannot hold high transportation costs – these factors are limiting companies in designing and managing the supply chain according to lean principles. This can increase supply uncertainty, variability amplification, and overall inventory levels in turbulent and volatile business environments.

As shown in this research, an interesting alternative transportation mode between Asia and Europe is intermodal transportation via landbridge freight services. This alternative has a lead-time advantage compared to traditional sea vessel transportation although costs would not be significantly higher. This implies that the utilization of landbridge freight services could potentially reduce supply uncertainty, variability amplification, and overall inventory levels. However, this research has also identified a number of problems that first need to be solved to fully utilize the landbridge alternative. Firstly, landbridge freight services are not reliable with regard to transportation time and quality. Secondly, there is a lack of infrastructure from the Russian side to final destinations in Asia (e.g. harbors or railways). Thirdly, capacity and equipment are lacking (insufficient numbers of appropriate wagons and containers). Finally, landbridge freight services are not stable enough to maintain continuous service quality with regard to malfunctions of harbors and railway transport. The research and
study of these identified problems should be strengthened. Table 5-1 summarizes the main conclusion and contributions regarding the first research objective.

**TABLE 5-1. MAIN CONCLUSION AND CONTRIBUTIONS REGARDING RESEARCH OBJECTIVE NUMBER ONE**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Globalization &amp; Complexity</th>
<th>Supply Chain Design &amp; Operation</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nowadays global transportation structures and modes are required since companies operate on a global basis.</td>
<td>Global transportation structures have become essential in international SCM due to their impact of overall supply chain performance.</td>
<td>There is a need for more transportation mode alternatives in international SCM and intermodal transportation via landbridge freight services is an interesting alternative.</td>
</tr>
<tr>
<td></td>
<td>Globalization has made the utilized transportation structures more complex, e.g. increased length, increased number of involved parties, increased and varying lead-times and high service quality variability.</td>
<td>There is a need for new transportation structures and modes between Asia and Europe due to increased transportation volumes and since current transportation modes for certain products are either too slow or too expensive.</td>
<td>Current transportation services between Asia and Europe are limiting companies in designing and managing the supply chain according to lean principles.</td>
</tr>
<tr>
<td></td>
<td>Globalization has complicated decision making regarding utilization of transportation modes, e.g. estimation of transportation cost, time and necessary inventory levels.</td>
<td></td>
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</tbody>
</table>

As can be noted the main conclusion is that there is a need for more transportation mode alternatives in international SCM, and that intermodal transportation via landbridge freight services is an interesting alternative.

5.2 Utilization of Different Strategies in International Supply Chains

Globalization has made supply chain design and operation a more complex task, since it provides additional management challenges and new practices in which supply chains are designed and managed. Firstly, globalization allows companies to exploit economies of scale (i.e. specialization, standardization and centralization) by manufacturing and delivering volumes worldwide. Globalization has also made markets more complex and fragmented, due to increased competition, increased demand variability, increased product variety, more customized products, and shortening product life cycles. Consequently, one important issue in developing and managing international supply chains is to increase responsiveness to customer needs while simultaneously achieving cost-efficiency through specialization, standardization and centralization.

In the literature, several classification models for supply chain strategy selection have been offered to guide the choice of an appropriate supply chain strategy. These classification models emphasize that one should select the supply chain strategy that best matches the strategy’s supply characteristics (i.e. efficiency, responsiveness and supply lead-time) with the market’s demand characteristics (i.e. type of product, volume, variety, variability, required lead-time). This research has shown that these classification models are too simplistic, due to three major issues. Firstly, these classification models mediate that it is a question of choosing one supply chain strategy for the entire company (i.e. either a lean, agile or hybrid strategy). However, how many companies sell one type of product (i.e. standard or special) or conduct business in one type of business environment? Secondly, these classification models regard markets as rather homogeneous, that is, they assume that all customers would like to purchase each type of product in a similar way (i.e. similar demand characteristics). However, this research has shown that customers purchase similar products rather differently. For example,
some customers prefer to purchase fashionable, quality clothing at the lowest possible price, while others prefer to purchase the most recent fashion clothing at affordable prices. Both these types of products could be categorized as special, since their demand characteristics are distinguished by high variety, high volume, and high variability. Thirdly, these classification models link each supply chain strategy to a specific business context. However, as shown in this research, certain supply chain strategies could be more suitable in particular business environments. Nevertheless, they are not limited to those environments, since different supply chain strategies can be successfully applied in similar business environments. It is rather a question of how the company would like to conduct its business.

One proposed strategy for dealing with the increased demand variability, increased product variety and customization (i.e. fragmented and complex markets), which also exploit the advantages of globalization, is postponement. Indeed, postponement of certain supply chain activities until orders are received (e.g. switch from MTS environment to ATO) will enable companies to create a cost-efficient and responsive supply chain. However, one type of postponement strategy is certainly not the best option for all markets. Instead, in order to stay competitive in fragmented and complex markets – that is, satisfy differing customer needs in various markets – companies should recognize the need to employ different manufacturing and delivery strategies concurrently (i.e. develop a differentiated supply chain strategy). This corresponds well with current views in the literature. Still, this subject is not well researched, for example, insufficient research addresses how to realize this in practice. This can be seen in the low number of case studies reporting on companies that utilize more than one supply chain strategy (e.g. Christopher et al., 2006).

There are numerous requirements in order to realize a differentiated supply chain strategy. Firstly, the requirement of supply chain collaboration is in this case even higher than normal, since a differentiated supply chain strategy will involve more supply chain partners. Secondly, there is a need for more transportation modes, particularly intermodal, both in supply and distribution operations, due to the fact that differentiation requires alternatives. This research highlights intermodal landbridge freight services as an alternative, which could, potentially facilitate more differentiated supply chains. Thirdly, since the utilization of different postponement strategies concurrently is probably one of the best ways of developing a differentiated supply chain strategy, a flexible supplier network is very important. Finally, more integrated information systems are needed, together with decision support tools. This study has highlighted that agent based simulation and agent based systems (i.e. ABM) offer a potential for developing realistic information systems and decision support tools. Table 5-2 summarizes the main conclusion and contributions regarding the second research objective.
### 5.3 Complexity of Decision Making in International Supply Chains

Globalization has made SCM a more complex task, since it has made the synchronizing of customer requirements and the flow of materials, as well as the handling of different supply chain issues (e.g. demand variability amplification) more difficult.

This research has shown that to make feasible logistics decisions, in the context of global and complex supply chains, information systems and advanced decision support tools are required, particularly to address different supply chain issues, such as the bullwhip effect. As shown in this research, ABM (i.e. agent based simulation and agent based systems) offers a potential to develop realistic decision support systems to help managers make more feasible logistics decisions in complex and global supply chains. Supply chain managers aided by agent based models and simulations can benefit in several ways. Firstly, they acquire an increased understanding of the impact of unscheduled factors, such as breakdowns, accidents and changes of demands. Such factors are often found in reality, but usually reduced or even ignored when transferred to most traditional models. This implies that the optimized solutions from these traditional models mislead managers into believing in future scenarios which do not reflect reality well enough. Secondly, agent based simulation and systems can guide managers’ instincts, since interactive agents generate an emergent pattern which can be explained and understood, and can therefore benefit the improvement of decision-making in companies. Thirdly, agent based simulation and systems can help managers find where the highest leverage can be gained among improvement alternatives. This is based on the fact that agent based simulation and systems allow models to encompass several business functions that can affect each other. Finally, there are, at times, even opportunities to improve predictability based on the scenarios generated. However, much work remains in order to clarify the usefulness of ABM. This research has only established an understanding of agent based SCM by developing a framework of multi-agent based SCM from case study findings. Since much of the ABM literature lacks case company based models and industrial applications, this constructive research approach is justified. Table 5-3 summarizes the main conclusion and contributions regarding the third research objective.
TABLE 5-3. MAIN CONCLUSION AND CONTRIBUTIONS REGARDING RESEARCH OBJECTIVE NUMBER THREE

<table>
<thead>
<tr>
<th>Objective</th>
<th>Globalization &amp; Complexity</th>
<th>Supply Chain Design &amp; Operation</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>To analyze complexity of decision making in international supply chains</td>
<td>Globalization has made the synchronizing of customer requirements and the flow of materials a more complex and difficult task.</td>
<td>To make feasible logistics decisions in the context of global and complex supply chains require information systems and advanced decision support tools.</td>
<td>Information systems and advanced decision support tools are required to make feasible logistics decisions in the context of global and complex supply chains.</td>
</tr>
<tr>
<td></td>
<td>Globalization has made the handling of different supply chain issues (e.g., demand variability amplification) a more complex and difficult task.</td>
<td>ABM offers a potential to develop realistic decision support systems to help managers make more feasible logistics decisions.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply chain managers aided by ABM can benefit from improved understanding and decision making.</td>
<td></td>
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</table>

As can be noted, the main conclusion is that information systems and advanced decision support tools are required to make feasible logistics decisions in the context of global and complex supply chains.

5.4 Conclusion

In this research, it has been concluded that there is a need for more transportation mode alternatives in international supply chains, and intermodal transportation via landbridge freight services has been highlighted as an interesting alternative. Moreover, it has been concluded that globalization has made markets more fragmented and complex, and therefore companies need to utilize different supply chain strategies concurrently, that is, develop a differentiated supply chain strategy. Finally, it has been concluded that information systems and advanced decision support tools are required in order to make feasible logistics decisions in the context of complex global supply chains. Thus, the overall conclusion of this thesis is that companies, in order to cope with more complex and fragmented markets, need more differentiated transportation structures, modes and supply chains (i.e. a differentiated supply chain strategy), and, to effectively manage this, information systems and advanced decision support tools are required (Table 5-4).

TABLE 5-4. MAIN CONCLUSION REGARDING THE RESEARCH OBJECTIVES AND OVERALL CONCLUSION

<table>
<thead>
<tr>
<th>Objective</th>
<th>Conclusion</th>
<th>Overall conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>To analyze transportation structures used in international supply chains</td>
<td>There is a need for more transportation mode alternatives in international SCM and intermodal transportation via landbridge freight services is an interesting alternative.</td>
<td>To cope with more complex and fragmented markets companies need more differentiated transportation structures, modes and supply chains (i.e. a differentiated supply chain strategy) and to effectively manage this, information systems and advanced decision support tools are required.</td>
</tr>
<tr>
<td>To analyze the employment of different strategies in international supply chains</td>
<td>Globalization has made markets more fragmented and complex and therefore companies need to utilize different supply chain strategies concurrently, i.e. develop a differentiated supply chain strategy.</td>
<td></td>
</tr>
<tr>
<td>To analyze complexity of decision making in international supply chains</td>
<td>Information systems and advanced decision support tools are required to make feasible logistics decisions in the context of global and complex supply chains.</td>
<td></td>
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</tbody>
</table>
Furthermore, it has been concluded that current taxonomies for supply chain strategy selection are too simplistic due to three major problems: they mediate that it is a question of choosing one supply chain strategy for the entire company, they regard markets as rather homogeneous, and they link each supply chain strategy to a specific business context. Instead, it has been argued that it is increasingly necessary to utilize different manufacturing and delivery strategies concurrently (i.e. develop a differentiated supply chain strategy) to satisfy all major customers/markets in a better way. Thus, there is a need for new taxonomies for supply chain strategy selection which recognize that the markets are becoming more fragmented and complex, that customer preferences differ across customer/market segments, and that there is a need to differentiate the supply chain strategy.

Moreover, it has been concluded that there are several requirements of a differentiated supply chain strategy. Firstly, a differentiated supply chain strategy requires extended supply chain collaboration, since this type of strategy will involve more supply chain partners than a traditional supply chain strategy. Secondly, there is a need for more transportation mode alternatives, particularly intermodal, both in supply and distribution operations, due to the fact that differentiation requires alternatives. In this thesis, intermodal landbridge freight services have been highlighted as one interesting avenue which could potentially facilitate a more differentiated supply chain strategy. Finally, more integrated information systems are needed, as well as advanced decision support tools. An ERP-system integrates all necessary business functions within an enterprise, such as product planning, purchasing, inventory control, sales, financial and human resources, into a single system with a shared database. This system is the central part of any attempt to create an information system for the whole supply chain. Moreover, this study has highlighted that agent based simulation and systems (i.e. ABM) offer a potential to develop realistic decision support systems to help managers make more feasible logistics decisions in complex and global supply chains.
6. FUTURE RESEARCH

From a broad and comprehensive approach on how complexity and globalization affect supply chain design and operations in this licentiate thesis, forthcoming research will focus on the employment of different manufacturing and delivery strategies concurrently, in international supply chains.

In this thesis, it has been argued that companies, in order to cope with more complex and fragmented markets, need to differentiate their supply chain strategy by utilizing and combining different manufacturing and delivery strategies concurrently. The overall purpose of the forthcoming research is to investigate how different manufacturing and delivery strategies can be used concurrently, in international supply chains. This topic is pursued through three more specific objectives (Figure 6-1).

**FIGURE 6-1. FURTHER RESEARCH TOPICS**

Firstly, forthcoming research aims to investigate how different manufacturing and delivery strategies are used concurrently, in international supply chains. The main objective is to provide an increased understanding of how different manufacturing strategies, such as Make-To-Stock (MTS), Assemble-To-Order (ATO), Make-To-Order (MTO), and Engineer-To-Order (ETO), are used in contemporary manufacturing related supply chains. However, it is also interesting to investigate how these manufacturing strategies are combined with different delivery strategies, such as factory direct, self collect and home delivery, to truly differentiate the supply chain strategy.

Secondly, forthcoming research aims to investigate what the requirements are for the utilization of different manufacturing and delivery strategies concurrently, in international supply chains. As highlighted in this thesis, there are several requirements, and the research and study of these needs to be strengthened. The importance of supply chain collaboration, as well as information systems and decision support tools when different manufacturing and delivery strategies are utilized concurrently, particularly need to be further investigated.

Finally, forthcoming research aims to investigate what the opportunities are for the utilization of different manufacturing and delivery strategies concurrently, in international supply chains. This is interesting, since there is a trend towards commoditization in many
industries, resulting in customers perceiving little difference between products. This implies that brand loyalty dwindles and competing through logistics (i.e. customer service) becomes a major determinant of success. Furthermore, this suggests that companies, in order to stay competitive, must enhance customer value by making the product worth more in the eyes of the consumer by adding value to the core product through the inclusion of customer desired customer service. If companies utilize different manufacturing and delivery strategies concurrently, they would probably increase their competitiveness.
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