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Centralisation of Distribution Systems and its Environmental Effects

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In loving memory
of my mother
Salme Sandberg Kohn

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The process of writing a thesis is like a journey and mine started about three years ago when I commenced my Ph.D. studies at Linköpings universitet. Throughout this voyage I have had many travel companions that have contributed to my journey and the completion of this thesis, and I would like to extent my gratitude to all of you.

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Linköping, May 2005

Christofer Kohn

ABSTRACT

Many believe that the current application of modern logistics solutions in general and centralisation of distribution systems in particular is damaging from an environmental perspective. The reason for this claim is that when a distribution system is centralised, products need to be shipped over greater distances. This causes an increase in transport work, which in turn is believed to cause an increase in emissions. Further, the decision to centralise distribution can be characterised as a structural decision and earlier research has helped illustrate how such decisions have greater impact on the overall performance of a distribution system than decisions taken at subsequent levels (tactical and operative). The reason for this is that structural decisions help create new opportunities to make other logistical decisions that are beneficial for the performance of a distribution system, as measured in terms of costs and service.

It is also acknowledged that there is a lack of research illustrating the actual environmental effects of centralisation. This area is the theme of this thesis and the overall purpose is to describe and analyse how centralisation of a distribution system can affect the environment. This purpose has been divided into two research questions, where the first one reads:

- *How does physical centralisation of a distribution system influence the environment?*

This question aims at investigating what effect centralisation has on the amount of emissions that are caused by transport in a distribution system. One of the main advantages with a centralised distribution system is that emergency deliveries are expected to decrease. This type of transport is often performed by airfreight, which is a mode of transport that is regarded to cause the largest amount of environmental stress among the four most commonly used transport modes. The argument that is made is that even though centralisation causes an increase in transport work, this must not necessarily mean that emissions increase (see *Figure 1*).

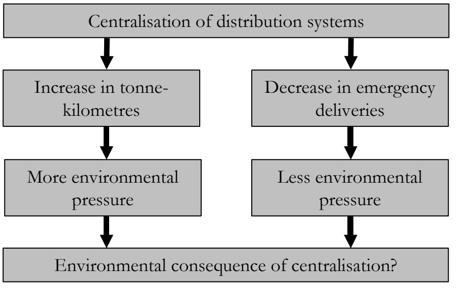

Figure 1: What are the environmental consequences of centralisation?

As indicated above, earlier studies on structural changes in distribution systems have shown that this type of decision creates new opportunities to make other decisions that are beneficial for the performance of a distribution system, albeit in terms of costs and service. The aim of the second research question is consequently to study this issue, but from an environmental perspective. This question therefore reads:

- *How do structural decisions in logistics create new opportunities to improve on the environmental performance of a distribution system?*

The results of the study show that it is not sufficient to only consider transport work and emergency deliveries when the environmental effect of a centralisation is to be evaluated. It has also been concluded that centralisation creates an opportunity to make improvements within the distribution system that can prove beneficial from an environmental perspective. In summary, three characteristics besides transport work and emergency deliveries were identified as being of importance when considering the environmental effects of a centralisation. These included centralised flow, modal change, and bargaining power, and this is illustrated in *Figure 2*.

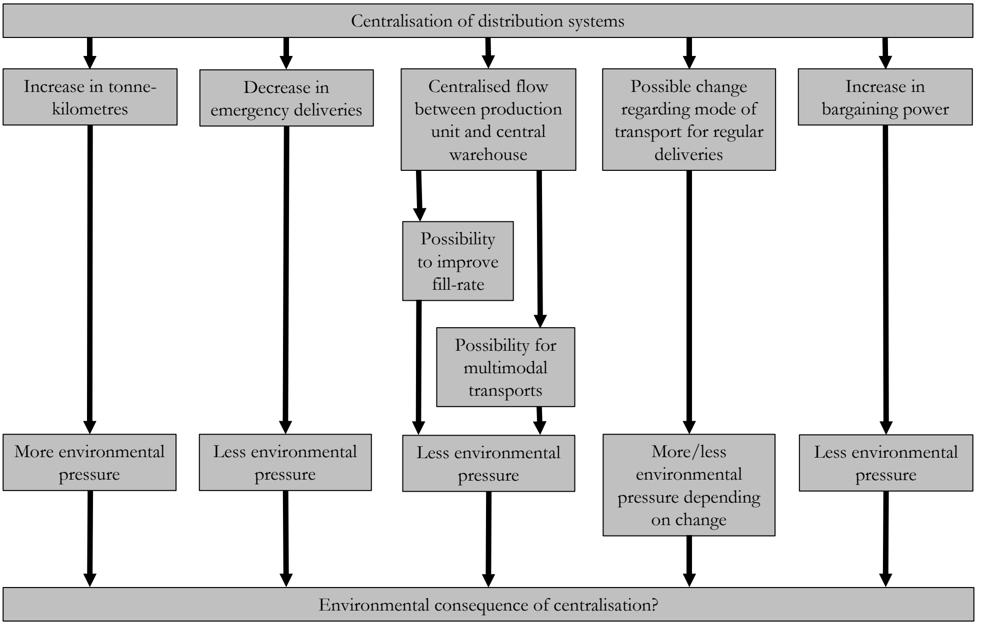

Figure 2: Important characteristics to consider upon evaluating the environmental effects of centralisation

This model does not aim to include all characteristics that can be relevant in an environmental evaluation of a centralisation, but rather those that have been found significant it this study.

However, the model helps illustrate that there are many aspects that need to be considered in such an evaluation and that depending on the characteristics of the distribution system at hand the results can vary quite extensively.

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1 INTRODUCTION

This chapter aims at introducing the theme of this thesis and starts of by introducing how environmental problems have received increased attention over the last couple of years and how many now argue that something needs to be done in order to break the current trend. There are multiple reasons for this decay, but one that is sometimes mentioned is the current application of modern logistics solutions in general and the current industry trend of centralising distribution systems in particular. It is also concluded that there is a lack of empirical investigations on the theme of structural changes in distribution systems and the environmental consequences owing to such changes. From this discussion a purpose and two research questions are derived and the theme of this thesis is presented, which is to study centralisation of distribution systems and its environmental effects. This is followed by a presentation on the scope, focus, and structure of this thesis.

1.1 Background

Over the last couple of years numerous reports have been presented that describe the state of our environment and what role the world's population has had in this degradation. An example of such a report is that of the Intergovernmental Panel on Climate Change (IPCC), which states that the mean temperature for Europe has increased by approximately 1.2 degrees over the last 100 years and that this is the largest increase for about 1,000 years (Houghton et al, 2001). Further, the 1990s was considered to be the warmest decade for over 150 years and the temperature increases are expected to continue. These changes in our climate are accredited to the emission of aerosols and greenhouse gases that in effect are emitted through human activity. In another current report the European Environment Agency (EEA) claim that even though greenhouse gas emissions have in fact decreased by 2.3 % between 1990 and 2001, the targets set for the period 2008-2012 in the Kyoto Protocol will not be met by the European Union and its member states. The main reason for this is the runaway increase in emissions from transport, especially road transport (EEA, 2004-11-08).

During the last fifteen years the volume of transport has increased more than GDP (see *Figure 1*), and this is a trend which the European Union emphasise needs to be broken (European Commission, 2001).

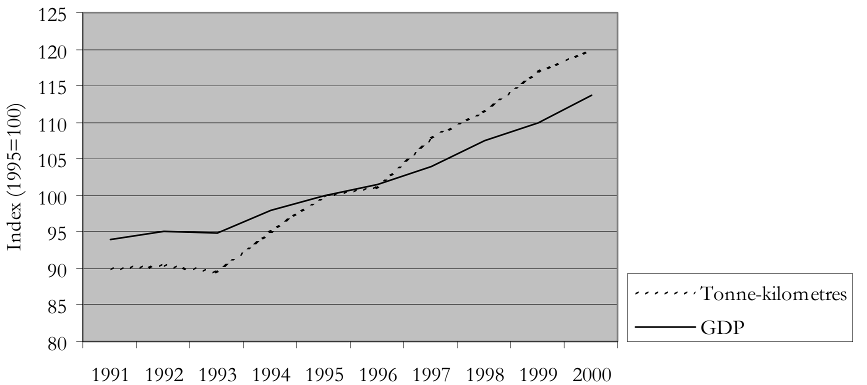

Figure 1: Freight transport demand and GDP for the European Union (Adapted from: www.eea.eu.int, 2004-11-08)

At the same time a functioning and flexible transport system is paramount for the European economy to work and this is also the reason why we have witnessed an increase in transport, which in turn has led to an increase in traffic congestion. Road congestion imposes great costs on companies and studies of the UK market indicate that in 1996 costs for congestion regarding road freight amounted to € 1.7 billion (Dodgson and Lane, 1997). Furthermore, the Freight Transport Association estimate that if there is no action taken to change the current situation, the cost of road congestion on the UK market alone will increase by a staggering € 5.2 billion over the next seven years (Allan, 2003).

As illustrated above, the current transport situation in Europe is alarming and it imposes damages both on the environment and on economic growth of the region. There are numerous reasons for this development, but one reason that is often cited as being partly responsible for this is the current application of logistics solutions. Over the last few decades, companies have sought to find economies of scale in their production and as a consequence production plants have become more dispersed. Simultaneously, customers are demanding better service which for the distribution side of logistics has rendered into demands for shorter lead-times, smaller order quantities, more frequent deliveries, narrower delivery windows etcetera (e.g. Backler, 1991; Ploos van Amstel and D'hert, 1996; Christopher, 1998).

A consequence of these demands has been that many companies over the last couple of decades have changed from a decentralised distribution system to a centralised distribution system (see *Figure 2*).

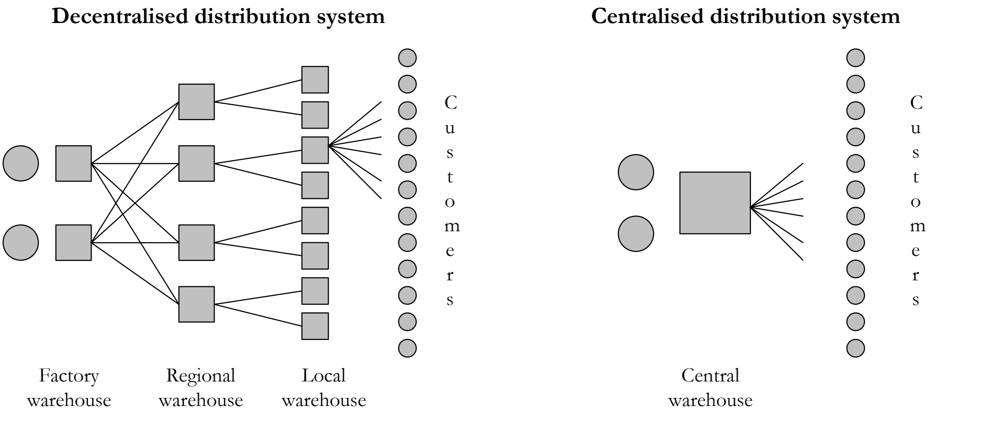

Figure 2: Decentralised distribution system and centralised distribution system (Abrahamsson, 1992, p 2)

Companies typically look to four modes of transport in order to distribute their products across Europe; air, rail, road or ship. Many of the centralised distribution systems are designed to satisfy relatively short customer delivery-times, often times of 24-72 hours (Rodrigue et al, 2001) due to increases in customer demands. This in combination with the current infrastructure in Europe gives companies only two viable transport options, namely road or air transport. Since airfreight is a very expensive means of transportation this is often only used in extreme emergencies and consequently road transport is by far the most commonly used means of transportation, which has become evident with the increase in congestion. The other two transport options, i.e. rail and ship, are not used to the same extent since both of them are not able to fulfil the current demands on delivery times. Hence, due to a combination of an increase in material flow in general, demands on short lead-times, and the current formation of the European infrastructure for transport, the amount of transport on our roads have increased dramatically. A direct result of this is that the EU is expected to increase its commitment to the issue as the problem grows even bigger year by year and there is a consensus that something has to be done in order to break the current overall trend.

At the same time as public policies are developed, companies are also looking at ways to come to a solution regarding the problems that society at large are faced with and during the last decade or so *"green"* gas and environmental friendly lorries have been the main way in which companies have dealt with the problem of emissions. This has had positive effects, as indicated by the 2.3 % decrease in greenhouse gas emissions between 1990 and 2001, but in order to break the overall trend, which indicates an increase in emissions, a more comprehensive analysis is needed, an analysis that deals with structural changes.

According to McKinnon and Woodburn (1996) logistical decisions regarding freight transport can be divided into four different categories or levels, which can be seen as being of a hierarchical character:

- *Physical structure of the logistical system:* This level include those decisions that concern location and number of factories, warehouses and terminals, and in that sense these decisions determine how the physical infrastructure of a company will be manifested.

- *Pattern of sourcing and distribution:* These decisions deal with questions such as how to source products or to who the company should sub-contract parts of its production as well as how to distribute its finished products. These decisions determine what trading links a company has with its suppliers, distributors, and customers.

- *Scheduling of freight flows:* Concerns decisions that transfer the above-mentioned trading links into freight flows through planning and scheduling of production and distribution.

- *Management of transport resources:* The decisions made above define within which parameters transport managers need to work in their day-to-day operations when they make decisions regarding, for instance, what type of vehicle to use.

In a later publication McKinnon goes on to state that:

> *"Many "green logistics" measures have been introduced at the lowest level in this hierarchy, cutting externalities per vehicle kilometre. Often the beneficial effects of these measures, however, have been offset or negated by higher level decisions to centralise warehousing, source products from more distant suppliers and/or more to just-in-time replenishment, which often increase total vehicle kilometres. There is a need therefore for companies to take a more holistic view of the effects of their activities on freight transport and related externalities."*
>
> (McKinnon, 2003, pp 666-667)

McKinnon suggests that the greening of firms' logistical operations at a more fundamental level will require nothing short of a change in management culture and strategic priorities. Even though there are significant possibilities for reduction of emissions in the lower levels of the logistics hierarchy the main potential for reducing transportation volume in production and distribution are linked to higher organisational levels.

In Sweden we have witnessed some studies on the overlapping area of logistics and environmental issues, but these studies could be classified as mainly focusing on the lower three levels in the hierarchy of decisions presented by McKinnon and Woodburn (1996). Bäckström (1999) is one example of such a study, where calculations are made on the emissions incurred when transporting bananas from South America to a community in Småland, Sweden. This study could be categorised as focusing on decisions of an operative character, since the aim is to illustrate the emissions incurred by one transport chain. An example of a study that deals with commercial decisions is that of Björklund (2002) and here focus is on how shippers try and influence carriers regarding environmental considerations. It seems there is a lack of studies illustrating how the environment is affected by decisions relating to the top of McKinnon and Woodburn's (1996) logistics decision hierarchy. This is also emphasised by Abukhader and Jönsson (2004a), who state that there is a need for environmental assessments on various currently known supply chain strategies and centralisation of distribution systems is an example of such a strategy.

Nevertheless, the effects of structural decisions in distribution systems have been addressed within the research field of logistics, but then focus has been on how companies can achieve cost and service advantages simultaneously by changing from a decentralised to a centralised distribution system (e.g. Abrahamsson, 1992; Abrahamsson and Brege, 1995; Abrahamsson and Aronsson, 1999). What these studies illustrate is that by considering distribution systems from a holistic perspective companies can achieve advantages that would not be possible to obtain if each part of the system was in focus. In other words, such studies take on a perspective that is similar to that of the upper level of McKinnon and Woodburn's classification. The exception is that these studies have not undertaken an environmental analysis, but rather a more traditional logistics approach has been used where the structural change is related to cost and service issues.

If we agree with the logic reasoning of McKinnon (2003) and his claim that the main potential for reducing transportation volume, and thus emissions, in distribution systems are linked to higher-level decisions, e.g. whether or not to centralise distribution systems, then it would seem logical to build on the already established knowledge on structural changes, e.g. Abrahamsson (1992) by adding an environmental perspective to the already existing perspectives of cost and service. This is also the theme of this thesis.

1.2 Research questions and purpose

It is believed that the current trend of centralisation is one of the main reasons why we have experienced an increase in emissions over the last couple of years (McKinnon, 2003). Simultaneously, we can also see that there is a lack of empirical research illustrating the actual environmental effects of centralisation (Abukhader and Jönsson, 2004a). This gap allows us to formulate a first research question that is related to centralisation of distribution systems and it reads:

- *How does physical centralisation of a distribution system influence the environment?*

By giving an answer to this question the aim is to contribute to the rather small amount of empirical investigations that illustrate the environmental effects of various logistics strategies.

The description above also helps illustrate how those decisions that could be characterised as structural decisions are believed to on the one hand influence those decisions taken at subsequent levels in the hierarchy and on the other hand have a greater impact on the overall environmental performance of a distribution system than those decisions taken at subsequent levels in the hierarchy of logistics decisions (McKinnon and Woodburn, 1996). Owing to these claims we can formulate a second research question:

- *How do structural decisions in logistics create new opportunities to improve on the environmental performance of a distribution system?*

By answering the second question the aim of this thesis is broadened to also try and illustrate how structural decisions influence other logistics decisions that could have an impact on the environmental performance of a distribution system. These two research questions form the basis for the overall purpose of this study, which is:

To describe and analyse how centralisation of a distribution system can affect the environment

1.3 Scope and focus of this thesis

The starting point for this thesis is that there does not exist research that incorporates the environmental consequences of decisions that have an effect on the design and management of a logistics system. In generic terms a logistics system consists of three subsystems; procurement, operations, and distribution. The focus in this study is on the latter of the three systems, i.e. distribution systems (see *Figure 3*). The reason for this being that much of the earlier research on design and management issues within logistics systems have been focused on the distribution side of logistics (e.g. Coyle et al, 1988; Abrahamsson, 1992). This choice in focus will also give an opportunity to relate the achieved results in this thesis to that of earlier research on structural changes in distribution systems.

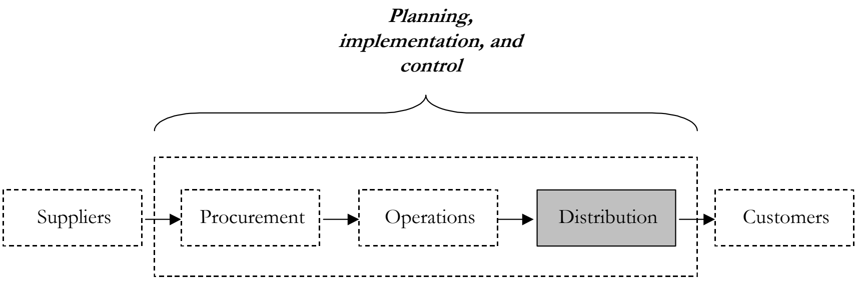

Figure 3: Logistics system (Adapted from Christopher, 1998, p 13)

A distribution system can vary enormously in its characteristics. Imagine, for instance, the difference in characteristics between a system designed to support direct distribution from one production plant to only a few customers compared to that of a system designed to support *"Merge in Transit"* solutions involving multiple production plants and a widespread market of customers. Even though both systems are considered to be distribution systems, they are very different in character and the latter can be considered to be far more complex than the former. According to Coyle et al (1992), one way to analyse a system is to study the nodes and links that constitute the physical structure (see *Figure 4*) of a system. In a distribution system the nodes are typically made up of production plants, warehouses, and customers; whereas the links represents the movement of material, finished goods and the like.

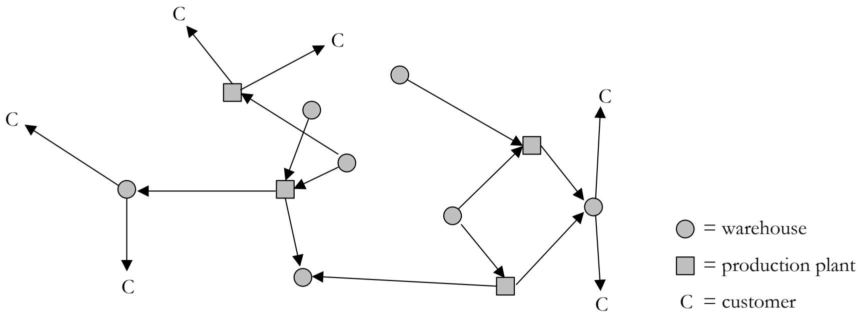

Figure 4: Nodes and links in a logistics system (Coyle et al, 1992, p 25)

The node-link perspective has the advantage that it gives a relatively good overview of the system under study and that the physical structure can easily be illustrated. Therefore this perspective will be used when investigating the environmental effects of the change in physical structure that is caused by a centralisation. According to Blinge et al (2002) however knowledge about those emissions incurred by activities carried out in the nodes are relatively sparse and those studies that have been done on the topic show that these activities only account for 0.5-1.0 % of total emissions. Owing to this the focus in this study will be limited to how the transport situation has changed within the distribution system as a consequence of the structural change and the effect this has on the environment, meaning that the focus is on the links in the node-link perspective.

When companies have changed from decentralised distribution systems to centralised distribution systems it is believed that this has increased the amount of transport on the European roads (Rodrigue et al, 2001). According to Wandel el al (1992) transport can be studied at three different levels (see *Figure 5*).

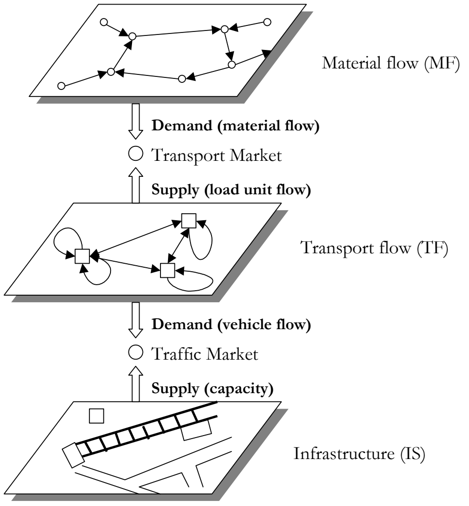

Figure 5: Model relating different levels of transport (Wandel et al, 1992, p 98)

Each level is considered an entity by itself, but simultaneously there exists interfaces between them. The highest level depicts a single company, with production plants and warehouses that make up the physical structure of the distribution system, and the flow of material, goods, and services that are transported between the different nodes in the system. Through material acquisition, production, and distribution a demand for transport is created, which is illustrated by the links in the model. Many companies today do not hold their own fleet of vehicles to carry out these transportations and consequently this demand has to be satisfied through the procurement of transport services on the transport market. Carriers, such as DHL, UPS, and Green Cargo, provide these transport services, but in order for them to achieve economies of scale in their operations they typically consolidate goods from many different customers. This is demonstrated in the middle level of the model, which aims at illustrating how material flows at an aggregated level become transport flows for the carriers on the market. However, carriers also work under a condition of supply and demand, which becomes apparent by adding the third level in the model. The demand carriers have is on that of infrastructure in order to be able to operate the transportations and this is supplied by society at large; or rather by politicians, legislators, and the like.

These levels can also be viewed as being on a macro/micro economic scale, where the higher levels illustrates the micro level of a company while the lower level depicts the macro level of for instance a country or the European Union. The focus in this thesis is on the flow of material or transportations that arise when a company seeks to supply its customers with products. Consequently, the analysis will focus on links in the upper level in *Figure 5*.

1.4 Structure of this thesis

This chapter has set the scene for the continuance of this thesis by introducing the problem at hand as well as the overall purpose of this study and the two research questions that serve as a basis for this study. The aim of the subsequent five chapters is to give an answer to these questions and the structure for how this is done is presented below. In *Chapter Two* an overview of those theoretical areas that have been found to be relevant for this thesis are presented. *Chapter Three* in turn presents the research approach that has been used to conduct this study and such issues as how data has been collected are presented here. Subsequent to this a case description is presented in *Chapter Four*, which illustrates how the company ITT Flygt has centralised its distribution system and the effects this has had on cost and service issues relating to the distribution system. In C*hapter Five* the centralisation of ITT Flygt will be revisited but in this chapter the aim is to add a new perspective to the structural change and an environmental perspective will be added. *Chapter Six* is the final chapter and here the main findings from the study are presented and discussed, and the thesis ends with some suggestions for future research.

2 Frame of reference

The frame of reference is divided into four parts and the aim with the chapter is to present a theoretical framework that is relevant to tackle the purpose of this thesis. The first part gives a generic overview of logistics, which leads to a more specific presentation of distribution where it is illustrated how logistics effectiveness and efficiency have mainly been evaluated in terms of costs and service. Subsequent to this an outline of the area of logistics and the environment will follow, where the aim is to show how environmental issues are treated in contemporary logistics research. The third part of the frame of reference refers to how logistics decisions are relevant at multiple levels in a company and how this has an impact on logistics effectiveness and efficiency, from a more traditional cost and service perspective, as well as from an environmental perspective. In the final section the aim is to bring all of these theoretical contributions together and relate them to the research questions and the overall purpose that were presented in the previous chapter.

2.1 Logistics and distribution

In comparison to many other research disciplines within the management area, logistics is quite a young field and as such it has developed a lot over the last few decades. This development has also meant that people, scholars and practitioners alike, relate the word logistics with different things. A quite common association is that logistics is about transportation and warehousing. In fact, in loose terms logistics can be said to concern the efficient flow of material (Persson, 2003) and maybe the goods we see being transported by lorries on our roads from producer to customer, or from one warehouse to another is the most distinct example of this.

Even though transportation and warehousing are important elements of the field, logistics is today typically considered in a wider perspective and quite often seen as a means of competition for companies. One of the more widely acknowledged definitions of logistics today is that of the Council of Supply Chain Management Professionals (CSCMP)[1].

"Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."

(CSCMP, 2005, p 63)

This definition points to several of the more important aspects of contemporary logistics, some of which will be discussed briefly. A fundamental aspect of this definition, which is also prevalent in many definitions today, is that the customer and his/her needs are in focus and that these should be fulfilled. However, there exists a constraint as to in what way a company should intend to meet these wishes. Somewhat differently expressed this means that as a company should meet these customer requirements it should also simultaneously do this in an efficient and effective manner, which traditionally is measured in terms of costs.

According to Christopher (1986) the logistics orientation recognises that in order to improve the performance of the system, as measured by the cost effective provision of customer service, all the interrelated activities in moving materials, goods, and information from source to user must be managed as a whole. This notion of relating costs and service with a holistic perspective is often referred to as the total cost approach, and was initially introduced by Lewis et al (1956). Today there exist various ways of how to relate the total costs of a company's logistics activities with the service it offers, but one of the more widely acknowledged versions is that of Lambert and Stock (1993) illustrated in *Figure 6*.

[1] Previously Council of Logistics Management (CLM)

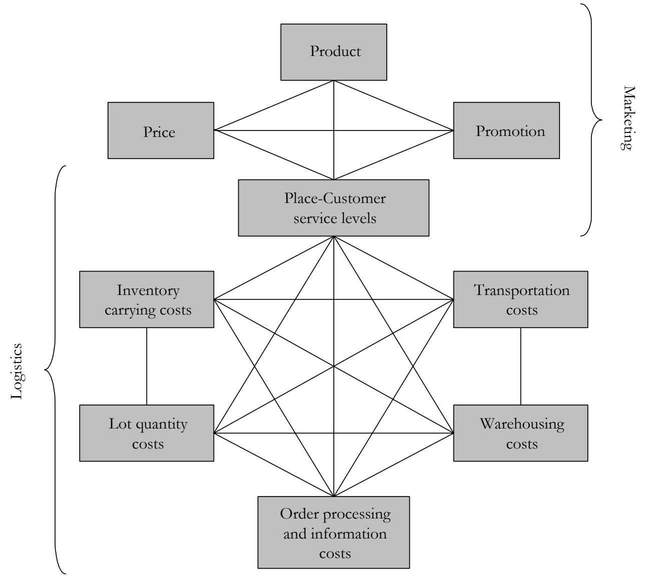

Figure 6: Total cost approach (Lambert and Stock, 1993, p 42[2])

What are to be considered logistical costs can vary, but an important notion is that all costs incurred by a decision that concern logistics activities are to be considered. That is, one must not only think about the effects a decision might have on one specific department or type of cost, but also try to envision what the effects are for the company as a whole or how other cost types are affected. Hence, what the model helps illustrate is the fact that changes made to one of the costs will have an immediate impact on other costs and customer service.

Another dimension of the definition is that logistics does not only focus on the physical forward and reverse flow and storage of goods and services, but also on the associated information. Typically, logistics activities extend from point of origin, i.e. raw materials, to point of consumption, including such activities as inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third party logistics services providers (CSCMP, 2005).

Quite often the term *"logistics system"* is used to describe all of those activities associated with logistics and generally a classification is made where a company's logistics system is divided into three main functions; procurement, operations, and distribution (Christopher, 1998). Besides

[2] The figure presented by Lambert and Stock (1993) is an adaptation from D.M. Lambert (1976) *The Development of an Inventory Costing Methodology: A Study of the Cost Associated with Holding Inventory*

being involved in all levels of planning and execution in the system, strategic, tactical, and operational; logistics also integrates with other functions, such as marketing, sales, manufacturing, finance, and information technology (CSCMP, 2005).

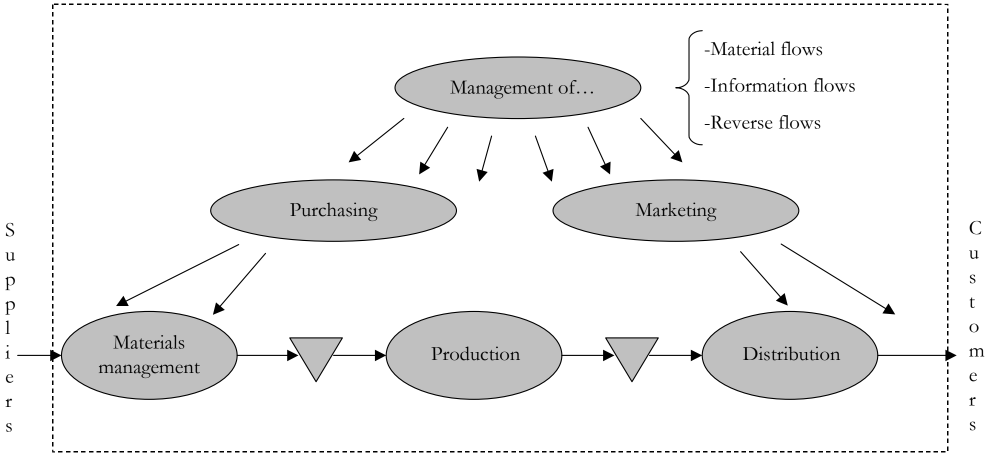

Figure 7: A company's logistics system (Adapted from Aronsson et al, 2002, p 20)

As pointed to earlier, the focus in this thesis is on distribution systems and structural changes of the same and therefore the subsequent section will focus on the distribution side of logistics.

2.1.1 The role of distribution

Logistics has traditionally been viewed as being the equivalent of transportation and warehouses, and since distribution in generic terms is about transferring goods and services from producer to customer it might not be that surprising that logistics and distribution are, at times, viewed as synonymous. The following section focuses on illustrating the role that distribution plays in the logistics system and thus point to some of the differences that exist between the two.

According to Gadde (1980) distribution can be defined in numerous ways and one way of considering distribution is as being synonymous to marketing. This is illustrated by Lewis (1968) who claims that distribution should bridge the gap between the producer of goods and the consumer of the same. By bridging this gap distribution becomes a value-adding activity. Thus, when distribution is considered to add value it takes the role of being synonymous with marketing.

A second view is to regard distribution as one of the four P's in the marketing mix model, namely *"Place"* (Kotler, 1976). According to this marketing perspective a company has four components, which it needs to group in a suitable way in order to become profitable. As such, distribution has a more limited meaning since it is viewed as being a part of marketing instead of being synonymous with it.

The third and final definition takes on an even narrower approach to distribution and views distribution merely as the physical distribution. Traditionally this has been equal to transportation, but over time physical distribution has come to encompass more activities and many authors view physical distribution and logistics as one and the same (e.g. Stern et al, 1996).

In this study distribution is seen as that part of the logistics system that enables a company to supply its customers with finished goods and services, and thus the third definition presented above best reflects how the term is used for the continuance of the thesis. CSCMP presents a contemporary definition that will serve as a basis for this thesis.

"The activities associated with the movement of material, usually finished goods or service parts, from the manufacturer to the customer. These activities encompass the functions of transportation, warehousing, inventory control, material handling, order administration, site and location analysis, industrial packaging, data processing, and the communications network necessary for the effective management. It includes all activities related to physical distribution, as well as the return of goods to the manufacturer. In many cases, this movement is made through one or more levels of field warehouses."

(CSCMP, 2005, p 36)

2.1.2 Cost and service issues in distribution systems

Coyle et al (1988) claim that one of the more important decisions a logistics manager has to make regards how many warehouses there should be in a logistics system, since this determines the costs of distribution as well as the customer service a company can offer. Deciding on the number of warehouses is seen as a cost trade-off between on the one hand warehousing cost and inventory cost, and on the other hand transportation cost and cost of lost sales, as illustrated in *Figure 8*.

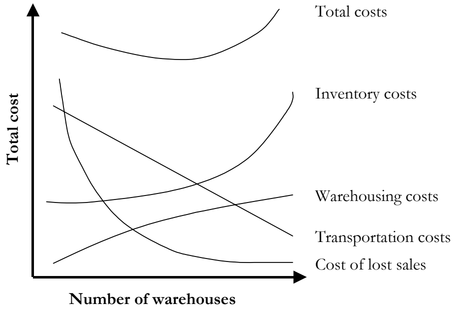

Figure 8: Logistics costs related to the number of warehouses (Coyle et al, 1988, p 277)

The purpose of the distribution system is to bridge the gap between a company and its customers, a gap which is measured as geographical distance. Consequently a company needs to be physically close to the market in order to uphold a high level of customer service and this is achieved by holding inventory at multiple warehouses close to the customer.

Warehousing costs are seen as semi-fixed costs in a shorter time perspective and are a consequence of the number of warehouses in the system as well as the equipment and personnel associated with running the warehouses. Hence, these type of costs increase with the number of warehouses, as illustrated above. The cost of holding inventory is incurred by having products on the shelves in each warehouse and is thus a capital cost. Further, holding inventory at multiple facilities generally implies that each facility must hold slow-moving articles resulting in a larger amount of slow-moving articles for the distribution system as a whole and consequently higher inventory costs. Other costs incurred by holding inventory include insurance, wastage, and obsolescence.

However, as indicated above, an increase in the number of warehouses will also lower transportation costs and this is due to the fact that the warehouses will be closer to the served market and consequently transfers will be shorter in distance. Finally, the cost of lost sales will also decrease with an increase in warehouses and this is connected to the level of customer service a company wishes to offer, since inferior customer service, indicated by lead-times, will cause a loss in the number of customers.

Abrahamsson (1992) illustrates that by changing focus from geographical distance to distance in the form of time, so called Time Based Distribution (TBD), the traditional theories can be turned on their head. Thanks to the development of information technology and a tighter control of its distribution, companies are able to break up the former distribution system and change from a decentralised to a centralised distribution system, as illustrated in *Figure 9*.

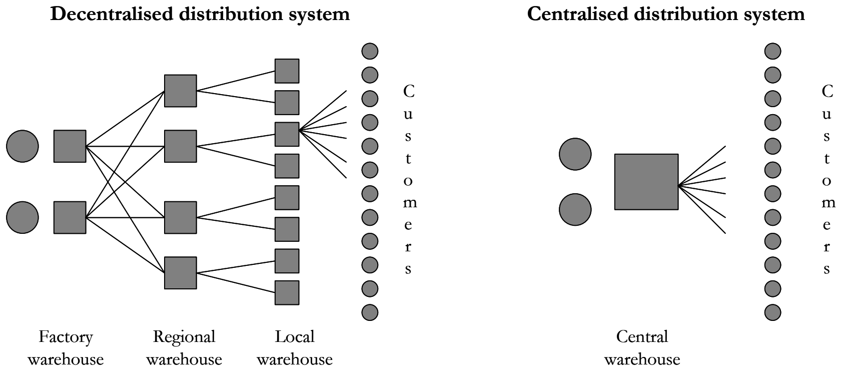

Figure 9: Decentralised distribution system and centralised distribution system (Abrahamsson, 1992, p 2)

Some of the more important theoretical constructs behind these ideas are theories on economies of scale and scope, where economies of scale in generic terms can be described as reductions in average costs attributable to increases in scale (Pratten, 1975). Economies of scope on the other hand relates to the notion that it is less costly to combine two or more product lines in one firm than it would be to produce them separately (Panzar and Willig, 1981). In order to achieve economies of scale, distribution should both physically and organisationally be centralised to a logistics platform and separated from other functions in the channel, e.g. sales, and the reason for this being that logistics can be rendered more effective through this separation at the same time as sales can be more locally adapted to market specific demands (Abrahamsson, 1992; Abrahamsson and Brege, 1995). A logistics platform includes concepts for logistics operations, a physical structure, processes and its activities; as well as the information systems needed for the design, operations, and reporting of the system (Abrahamsson et al., 2003). Further, the objective with such a separation of functions and centralisation to a logistics platform is that it will enable the expansion to new markets or market channels at marginal cost.

Abrahamsson (1992) lists multiple advantages a company can reap from this change in distribution and these are divided into two categories, on the one hand logistical advantages and on the other hand service advantages. The logistical advantages include:

- *Lower fixed distribution costs:* Since fewer resources are needed to run one warehouse as opposed to several, centralisation has a positive effect on costs relating to warehousing activities.
- *Lower variable costs:* Due to the fact that the total amount of inventory decreases at the same time as transport costs can be held at a constant, contrary to earlier theory.

- *Gains owing to integration and separation of activities:* Centralisation of the logistical activities results in lower management costs at the same time as each sales company can concentrate its efforts on marketing measures.
- *Lower learning costs:* As all products are localised to the same warehouse old products can be phased out quicker at the same time as the distribution system can adopt faster to fluctuations in volume.

Whereas the service advantages consist of:

- *Shorter and more secure lead-times:* This applies to all products on all markets.
- *Higher delivery precision:* More deliveries have been carried out correctly, both regarding matching time windows and the number of deliveries that have been made at the same time.
- *Differentiation:* The possibility of customising solutions for different markets or customers increases with a centralised distribution system.
- *Better information:* It is easier to manage inventory levels with all products being centralised and consequently the company can supply its customers with more precise and accurate information on expected delivery times.

In a decentralised distribution system, where inventories are typically stocked at a local warehouse supplying a particular market, it is difficult to hold a full range of products. However, through the implementation of a central warehouse it is easier to hold a more complete product range in inventory that can even out oscillations in demand that occur on the various markets it supplies and consequently a central warehouse can show a higher stock availability. The result of this is that the cost of lost sales changes and the curve illustrating this takes on a new shape and shifts downwards.

Another dimension of a centralised distribution system is that despite that goods are being shipped over greater distances, due to the fact that products need to pass the central warehouse instead of being shipped directly to the market in question, the cost of transportation will not increase in such a radical manner as it is perceived to increase in theories that are not time-based. The logic behind this reasoning is that with a full product range there is also less of a need for emergency transportations. In most cases when a product is not in stock at a local warehouse in a decentralised distribution system the order will be fulfilled by shipping the goods as an express delivery from the production unit. Such deliveries are quite often performed through air transport or express road transport, which either way imposes large costs to the distribution system. In a centralised distribution system these emergency deliveries can be avoided since the central warehouse holds a greater product range than any of the local warehouses are able to offer in a decentralised system and therefore it is expected that the transportation costs can be kept more or less constant, an argument that is in disagreement with earlier theories.

Consequently, Abrahamsson claims that the old theories, e.g. Coyle et al, no longer necessarily hold true and that the total costs do not necessarily increase when the number of warehouses are decreased. This is illustrated in *Figure 10* below, where the curves for cost of lost sales as well as transportation costs tilt downwards resulting in a revised version of the curve illustrating total costs.

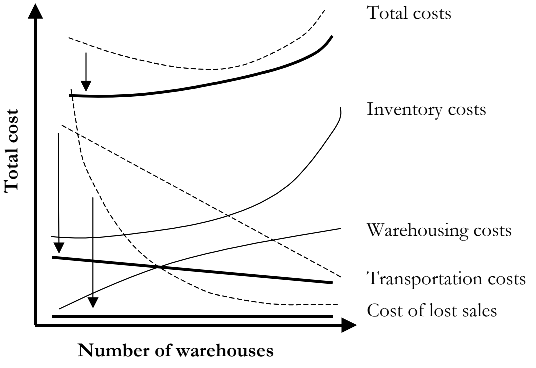

Figure 10: Total costs in a time-based distribution system (Abrahamsson, 1992, p 241)

If we acknowledge this view, i.e. that transportation costs must not increase when a distribution is centralised, then this could also serve as an indication, expressed in relative terms, as to how much emissions each type of distribution system is expected to emit. Expressed somewhat differently, if the cost of transport is not expected to increase when distribution is centralised, why should emissions increase? Does the price of transporting goods one kilometre suddenly change when distribution is centralised? This question is linked to the environmental impact of various transport modes, an area that has not been examined so far. Therefore, in order to discuss this question further the subsequent part of the frame of reference will illustrate how environmental issues have been treated in the field of logistics in general and more specifically the relation between transport work and emissions.

2.2 Logistics and the environment

Over the last few decades focus within logistics has somewhat changed, or rather the focus has been broadened from just being about cutting costs to being about such issues as flexibility, better service, time, increasing revenue, and foremost as a way to compete. This is also evident within the research community where more traditional topics, e.g. location analysis, packaging, and inventory management, receive decreasing coverage; whereas topics covering over larger areas are receiving more and more focus (Stock, 2003). One such area is the combined field of logistics and environmental issues, which in generic terms go under the name of green logistics.

Even though environmental questions were raised already in the 1960s, green issues have not received a great deal of attention within the field of logistics management and these issues seem to take a backseat in comparison to the more traditional issue of relating costs to service. Moreover, despite the 1990s being labelled both as the *"Earth decade"* (Armstrong & Kotler, 2000) and *"The decade of the environment"* (Kirkpatrick, 1990), we still find relatively little evidence of environmental issues receiving a lot of attention in the field of logistics management. Rodrigue et al (2001) even go so far as saying, *"By the end of the 1990s much of the hyperbole and interest in the environment by the logistics industry had been spent"*. An example of this is the fact that during the time-period 2000-2004, less than 3 % of the published articles in four of the more recognised logistics journals dealt with environmental issues (see *Table 1*).

Table 1: Articles in leading logistics journals focusing on environmental issues

Journal	2000	2001	2002	2003	2004
European Journal of Purchasing and Supply Management	1 of 21	1 of 23	0 of 22	0 of 25	0 of 22
International Journal of Logistics	0 of 18	1 of 17	0 of 17	0 of 23	2 of 24
International Journal of Physical Distribution and Logistics Management	1 of 45	1 of 41	2 of 42	0 of 42	1 of 44
Journal of Business Logistics	1 of 21	2 of 18	0 of 13	0 of 19	0 of 8

2.2.1 Introducing environmental awareness in logistics systems

Among these articles issues concerning reverse logistics dominate the environmental focus and it is within this area one can find most of the written material concerning the interface between logistics and the environment, something that has been acknowledged by CSCMP as it has changed its definition of logistics to include *"…and reverse flow…"* in more recent definitions. However, in most definitions of logistics *"effective"* or *"efficient"* still refer to how to relate costs and service to each other in order to become profitable. At the same time increased governmental regulation, the development of international certification standards, and changes in consumer demands (Melnyk et al, 1999) have amplified the pressure for many companies to incorporate environmental philosophies into their businesses.

Nonetheless, environmental issues are of importance for logisticians and, according to Wu and Dunn (1995), one of the main challenges for logistics managers is to determine how to incorporate environmental management principles into their daily decision-making process. Combining environmental issues with efficient logistics systems is by and large referred to as green logistics and, according to Jahre (2003), this is an expansion of the traditional view on logistics in two ways:

- All parts of a supply chain are considered, from the extraction of raw materials through production and distribution, to recycling and other forms of waste disposal.
- Environmental variables are used as complementary criteria in addition to financial criteria to determine the effects of a proposed or followed through solution.

Wu and Dunn (1995) have an analogous viewpoint and state that in order for logistics systems to become environmentally responsible the traditional logistics view of minimising costs and maximising profits needs to be accompanied by a new objective, namely to minimise total environmental impact. Further, the authors view green logistics as an embedded part of Porter's value chain concept, illustrated in *Figure 11* and also discussed below.

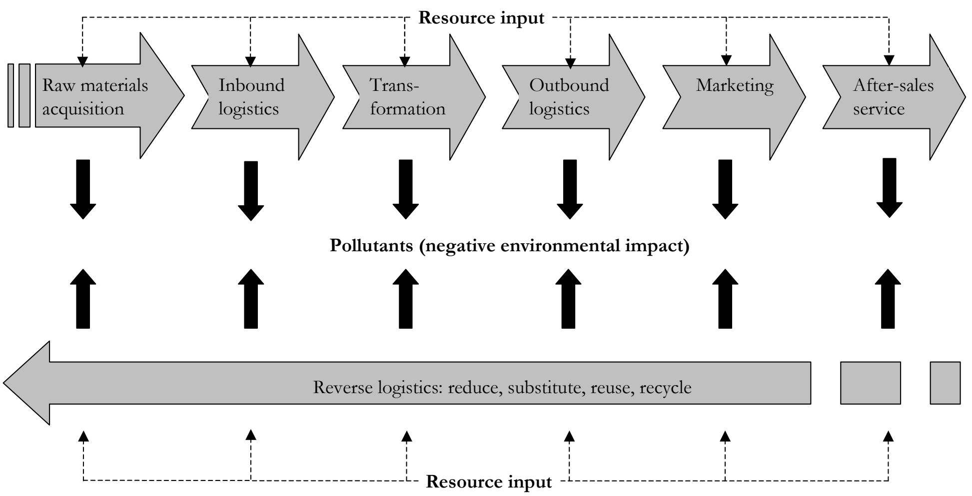

Figure 11: Decisions that affect a logistics system's environmental impact (Adapted from Wu and Dunn, 1995, p 24)

The authors claim that there exists a trade-off between optimal efficiency in a supply chain and environmental goals, and therefore it is required to examine each of the elements in a company's supply chain to see which logistical decisions have an impact on the environmental performance of the system. Raw material acquisition covers those activities associated with purchasing raw materials, and since more and more consumers are becoming increasingly environmentally conscious, companies need to re-evaluate whether to buy from cheaper vendors or to change to vendors offering environmentally sustainable material. International certification standards, e.g. ISO 14000, play an important role and demands vendors to conform to certain environmental guidelines in order to become eligible to supply a buying company.

Inbound logistics refers to how a company receives, stores, and moves the purchased raw material. A potential trade-off a company must consider is to what degree freight should be consolidated. Even though consolidation improves vehicle efficiency, which is good from an environmental standpoint and saves money, it also means longer lead-times and this is not favourable from a service point of view. Other decisions include carrier selection, mode selection, and backhaul management.

In the transformation process inputs are turned into outputs and inventory management and packaging issues are of importance from an environmental perspective. Many companies today operate according to a Just-in-Time (JIT) philosophy with low inventory levels and frequent deliveries, consequently increasing road congestion, which has a negative effect on the environment. However, by internalising the environmental influence of a JIT solution in an inventory decision model companies are open to the possibility of finding a set-up that balances inventory costs and environmental impact.

Activities typically associated with outbound logistics involve collecting, storing, and distribution of goods to customers as well as warehousing, materials handling, network planning and management, order processing, as well as vehicle scheduling and routing. Whereas inbound logistics concerns raw materials, outbound logistics concerns the flow of finished products from a producer to a customer via a distribution system. Trade-off decisions for instance include how the distribution system should be designed so that it fits with overall strategic goals or how third-party arrangements should be handled.

A company's logistics operations is affected by marketing decisions through the choice of market channel and the desired service level that the company aims at fulfilling.

Finally, after-sales service activities include e.g. installation, repairs, returns, and training. These types of activities are important from a marketing perspective since companies today more and more sell their products by means of such value-adding activities rather than just the physical product. For logisticians returns handling has had a great impact over the last decade or so with the design of reverse logistics systems to support the returning flow of products.

Since this study aims at investigating the environmental effects of centralisation of a distribution system it is quite evident that issues relating to outbound logistics are those that will mainly be focused throughout the study. However, one must not forget that distribution systems are often designed to offer a certain level of service towards the customer, which also means that what Wu and Dunn (1995) label marketing also plays an important role in this study. This is because the service level that a company wishes to uphold, e.g. in the form of customer delivery times, has an influence on the mode of transport that the company can employ throughout its distribution system.

2.2.2 The green paradox of logistics

Most logistics systems today however are designed to consider the more traditional logistics trade-offs, such as transport vs. inventory, inbound vs. outbound logistics, transport costs vs. transit time, and customer service vs. logistics costs (Wu and Dunn, 1995). This is also emphasised by Rodrigue et al (2001) who discuss the green paradoxes of logistics in transport systems and point to six different dimensions of how modern efficient logistics systems in fact are designed in a way that is in conflict with environmental responsibility.

The first of the paradoxes, costs, refers to the externalisation of costs. As discussed in previous segments, efficiency of a logistics system is measured by the costs incurred by logistics activities given a certain service level; but improvements in efficiency are often realised at various parts of the supply chain at the expense of a higher burden on the environment and society in general. The authors argue that there is a clear tendency that governments and other policy makers are increasingly trying to make the actual user pay for the costs of using the infrastructure, but the logistics industry have to a large extent managed to avoid these duties. An example of this is the fact that even though lorries are the cause of seven times the amount of nitrogen oxide emissions in comparison to cars and seventeen times the amount of particulate matter, many environmental policies still focus on private cars.

During the 1980s and 1990s the physical structure of transportation networks underwent substantial changes and the hub-and-spoke structure took form, this being the focus in the second paradox. Through the implementation of hubs, costs could be reduced and efficiency increased; but according to Rodrigue et al this solution puts enormous pressure on the environment. As the illustration below (see *Figure 12*) shows a hub-and-spoke structure concentrates the environmental pressure to local areas and furthermore this type of structure occupies vast amount of land, i.e. through airports, seaports and rail terminals.

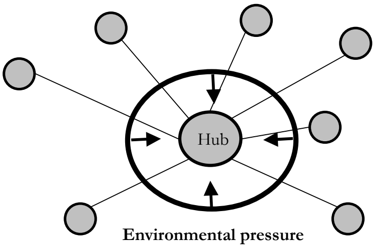

Figure 12: Environmental pressure of a hub-and-spoke system (Rodrigue et al, 2001, p 4)

"Time is money" is a well-known proverb and time, or rather cutting time, has a prominent position in industry, since short lead-times of any kind and efficiency are often seen as going hand in hand (Christopher, 1996). Time is also the third paradox that is pointed to. In order to reduce lead-times in a distribution system, companies often opt for faster modes of transportation. This is proven by the significant increases in air and road traffic, and these modes are often the ones that are the least energy efficient and pollute the most. At the same time new technology provides companies with the opportunity to render more effective logistics solutions, e.g. JIT approaches, in order to reduce time. However, these solutions can only be implemented through the use of air and road transport and these modes are not the best choice from an environmental perspective. Further, if companies have access to fast deliveries this also means that they are less spatially constrained. This is illustrated in the change from a decentralised to a centralised distribution system, where the focus has also changed from geographical distance to distance measured by time (Abrahamsson, 1992). This in turn has led to an increase in the total amount of tonne-kilometres being transported. Rodrigue et al (2001) label this as the *"Environmental vicious circle of logistics"*, as illustrated in *Figure 13*. Both Abrahamsson (1992) and Ballou (1987) also describe this situation, albeit with somewhat different words, when they claim that by offering the customer a higher level of service a company will pave the way for the effect of an increased demand on service, i.e. shorter lead-times with higher accuracy. This demand will eventually spread throughout the industry, resulting in a market condition that could be characterised by time-inflation.

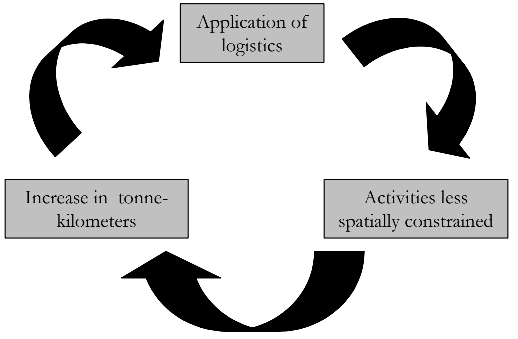

Figure 13: Environmental vicious circle of logistics (Adapted from Rodrigue et al, 2001, p 5)

The fourth paradox concerns reliability. In previously presented definitions on logistics, costs have been related to the objective of providing the customer with satisfying service and this can be measured in a number of ways, as discussed earlier. If a company wants to ensure that its customers receive undamaged products it is likely to choose the mode of transport that presents least likelihood of damaging the products and, as with the discussion regarding time above, air and lorries are the favoured modes of transport for companies when it comes to reliability.

A direct consequence of companies being able to reduce their lead-times and improve on their reliability, thanks to logistics, is that the demand for keeping inventories in warehouses has decreased; this is the fifth paradox. The reason why this is a paradox is that the reduction in inventories that most companies have experienced in their warehouses have not in fact vanished, but rather transformed from being stored to being in transit. McKinnon and Woodburn (1996) claim that between the period of 1978 and 1990 ten major food manufacturers reduced their total number of warehouses by 44 %. This trend has continued and according to a survey by Browne and Allen (1994) warehouses declined by 13.5 % between 1989 and 1992. This change further contributes to the decay of the environment and, as discussed above, these external costs are not compensated for by the logistics industry but rather by society as a whole.

The sixth and final paradox relates to the growth of e-commerce and the changes in physical structure of distribution systems owing to this. According to Rodrigue et al (2001) the traditional supply chain, where consumers visited large stores or shopping malls to buy their products, is being challenged by a somewhat different system. These new systems operate with large warehouses outside metropolitan areas and separate shipments are maid to online buyers, resulting in a disaggregated distribution system. However, in retrospect one can question the existence of these systems, since it has been proven that those companies that already had a functioning logistics concept are those who have ended up on top after the turbulence of the last couple of years. However, e-commerce and its relation to environmentally responsible systems is a topic that needs further enquiry since the former is quite a new occurrence and this is also emphasised by Abukhader and Jönsson (2004a).

All of these paradoxes are of importance for a study like of the environmental impact of logistics. The focal point in this study, however, is on centralisation of distribution systems and this is an example of a modern logistics solution that is believed to cause an increase in transport work, i.e. tonne-kilometres (Rodrigue et al, 2001; McKinnon, 2003). Therefore paradoxes two to five are those that will be focused in the continuance of the thesis, albeit to varying degrees.

2.2.3 Initiatives for greening the logistics system

Although modern logistics solutions may be at paradox with environmentally responsible systems there exists no doubt that initiatives that deal with environmental responsibility are both discussed and realised in the logistics industry. However, many of these initiatives are focused on more operative measures, which are associated with the lower levels of the logistics decision-making hierarchy (McKinnon and Woodburn, 1996). Penman and Stock (1994) claim that this can be attributed to the fact that logistics managers need to translate the fairly broad environmental objectives into specific and more tangible initiatives and *Table 2* depicts some typical logistics measures to tackle environmental impact.

Table 2: Logistics initiatives and their environmental objective (Adapted from Penman and Stock, 1994, p 849)

Logistics initiative	Environmental objective
Use substitutes for chlorofluorocarbons (CFCs) or at least use alternative lower-impact CFCs	Reduce depletion of ozone layer
Use in-vehicle communications to avoid traffic congestions	Reduce congestion
Use routing and scheduling systems	Reduce congestion and air pollution
Utilise backhaul capacity	Reduce congestion and air pollution
Move materials in the largest loads practicable	Reduce congestion and air pollution

Blinge and Lumsden (1996) reason in a similar fashion and claim that most of the work in reducing emissions of transport has been focused on improving vehicle engines and changing to green gas. Further, they make a distinction between two types of improvements, internally related improvements and externally related improvements.

Internally related improvements are those factors that in effect are connected to such issues as the infrastructure, vehicles, and fuel needed to be able to transport the goods. The authors go on to claim that most of the research related to the environmental problems of the transport sector has been focused on that part of the transport process where most emissions are incurred, namely when the actual shipments are carried out. These internally related improvements encompass four areas.

- *Technical enhancements*

The area of vehicle technique level has seen relatively large improvements over the last few decades. For example, legislative demands for various types of engines have become stricter over the years, as indicated by *Table 3* below, which has had a positive effect on the amount of emissions.

Table 3: Legislative demands for Euro class engines (Scania, 2000, p 1)

	Law from	NO_X	PM	HC	CO
Euro I	1993	9.0[1]	0.40	1.1	4.5
Euro II	1996	7.0	0.15	1.1	4.0
Euro III	2001	5.0	0.10	0.7	2.1

[1)] All values are expressed as g/kWh

- *Fuel enhancements*

The second area concerns fuel and, as indicated above, this has been one of the main approaches by which companies have tried to minimise their environmental impact. However, alternative fuels are more expensive and have a lower energy density, which has a negative impact on the driving range of a vehicle. Due to this the authors believe that improvements within this area will not have that great an impact in the future unless effective incentives are put in place by governments or the like.

- *Road enhancements*

The overall flow of traffic as well as the actual condition of the road also has an impact on fuel consumption and the amount of emissions caused by road transport (see *Table 4*). Even though better roads improve vehicle performance it can simultaneously lead to an increase in traffic since accessibility is improved, which in turn would have a negative environmental impact.

Table 4: Fuel consumption and emissions for heavy lorries with trailer (Blinge and Lumsden, 1996, p 14[3])

	Motorway 90 km/h	Two-lane way 90 km/h	City, suburban area 70 km/h	City, suburban area 50 km/h	City, central area 50 km/h
Fuel consumption[1]	0.42	0.45	0.54	1.15	1.03
CO_2[2]	1,106	1,178	1,412	3,009	2,699
SO_X	0.22	0.21	0.25	0.54	0.48
NO_X	18.5	19.0	23.2	48.6	45.5
CO	4.35	4.30	6.49	17.59	16.37
HC	1.55	1.48	2.06	2.40	2.73
Particles	0.45	0.55	0.62	1.09	0.95

1) Fuel consumption: l/vehicle kilometre
2) Emissions: g/vehicle kilometre

- *Multimodal transportation*

The final internally related factor relates to multimodal transportation and the authors see an increased interest in combining rail and road transport. There is great potential in transferring part of the transport work from road to rail, in particular for distances over 500 kilometres (Blinge, 1995), but there is a need for large investments in order to make such solutions feasible for most companies and their European operations.

Through improvements in each of these four areas the overall service level and frequency of deliveries in a distribution system can stay at status quo; but since these improvements are capital intensive, transport costs are likely to increase. Therefore the authors also point to the second category of improvements, which they label externally related improvements and these can be associated to the logistics operations of a company. These improvements concern how well available resources are used within the system and are considered to be the fastest and cheapest way by which the transport sector can improve on its environmental performance. Hence, the goal is to perform a larger amount of transport work without increasing the amount of traffic work carried out.

- *Consolidation*

Consolidation refers to the load factor of vehicles, which is often around 40-60 %. What this implies, at least theoretically, is that the environmental impact of road transport could be cut to almost half of what it is today if more loads were consolidated. An increase in load factor would not only decrease the number of shipments but also total fuel consumption, since fuel consumption only increases by 20 % when the load factor is increased from 50 % to 100 %.

[3] Table is originally published in Eriksson et al (1995) *Transporters miljöpåverkan i ett Livscykelperspektiv*

- *Return loading*

Connected to consolidation is return loading, which focuses on trying to fill empty lorries after they have released what they were first transporting. The focus on return loading has received much attention within the field of logistics due to the interest of reverse logistics.

- *Route-planning*

Another effective way to reduce environmental impact is by route planning and according to Swahn and Söderberg (1992) the number of distribution vehicles can be reduced by 15 % if route-planning systems are used effectively. McKinnon (1995) also claims that by using computer software packages in load planning as well as route-planning, vehicle kilometres can be reduced by 5-10 % in comparison to manual planning.

- *Ordering systems*

Ordering systems, or logistics concepts, is another area where there is room for improvements. The authors stress that there is not sufficient evidence as regards to how Just in Time (JIT), Quick Response (QR), and other logistic concepts influence the environment and that companies therefore should conduct audits to evaluate the environmental consequences when making changes in such logistics concepts. Even though studies have been conducted on the consequences of, for instance, JIT applications there does not seem to exist a unanimous answer to whether or not this has a negative environmental effect (Abukhader and Jönsson, 2004b).

- *Packaging*

The weight and volume of goods being transported are affected by the design and construction of packaging material and therefore this is also considered an important factor. This is also recognised by Tilanus and Samuelsson (1997), who illustrate that only 2.1 % of the maximum load capacity in transport is used.

- *Driving behaviour*

The final factor in relation to external improvements regards driving behaviour, which can affect the fuel consumption for a passenger car by up to 25 % (Laurell, 1985), and therefore driver education can be a quick and effective way to cut fuel consumption and consequently emissions.

In summary Blinge and Lumsden (1996) see a potential for improving on the environmental performance through changes in both categories of improvements, but that the demand of service from the customer plays an important role on the outcome. As discussed earlier, demands on transport has increased and if customers are willing to accept a lower level of service, meaning longer lead-times, a decrease in flexibility, and a decrease in the frequency of deliveries, then there exists a potential in improving on those factors related to external improvements and to simultaneously cut transport costs. However, if the customers will not accept such a decrease in service level then transport costs will increase since improvements will have to be achieved among the externally related factors (see *Figure 14*). All of these improvements are of interest for this study and how they will be used is discussed more extensively in *section 3.6.2*.

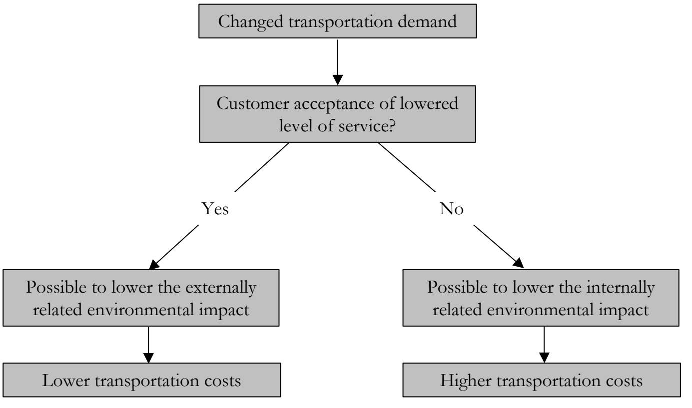

Figure 14: Customer acceptance of lowered level of service (Blinge and Lumsden, 1996, p 9)

2.2.4 How to measure the environmental impact of logistics

It is difficult to depict the impact industry in general and transport in particular has on the environment. According to Aronsson and Huge Brodin (2003) most researchers within the field of logistics take on an approach that implies that measuring the environmental impact is synonymous to measuring the pollution caused by, e.g. transportation of goods (see *Figure 15*).

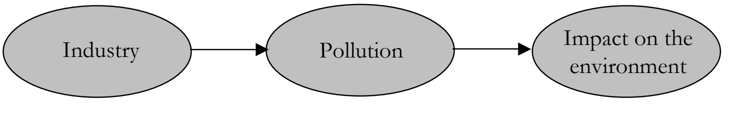

Figure 15: Industrial activities cause pollution, which in turn have an environmental impact (Aronsson and Huge Brodin, 2003, p 2)

The physical effects of traffic in general and transport in particular are the cause of many effects at multiple levels in society. According to Blinge (1995) environmental impact can be studied at three levels: locally, regionally, and globally. Local effects have a direct impact on people living in that particular area, but they are often short-lived and relatively easy to come to terms with through different measures. Regional effects can be the cause of emissions being emitted far from the area of environmental impact and consequently are more difficult to tackle since the ones that cause these problems are often far from the area that is being affected. Also, these effects are generally caused by a longer negative influence, which makes these effects even more difficult to turn around. Thirdly, global effects, which are typically caused by greenhouse gases, are even more difficult to come to terms with since they originate from the social structure of Western society at large. There are three types of effects that can be studied: physical effects, social and indirect effects, and subjective effects (Lumsden, 1998). These effects in connection to the three levels of local, regional and global effects are depicted in *Table 5* below.

Table 5: The effect of transport on the environment (Adapted from Lumsden, 1998, p 635[4])

	Local effects	Regional effects	Global effects
Physical effects	- Air pollution: CO, NO_X, SO_X, HC, PM, and led - Smoke - Smell - Noice - Vibrations - Water contamination - Land usage - Wear of infrastructure	- Air pollution: NO_X, SO_X, and HC - Land usage - Water contamination from NO_X	- Air pollution: CO_2, CH_4, N_2O, and CFC - Deplition of finite resources
Social and indirect effects	- Accidents - Delays and congestion - Local land usage	- Economic growth - Regional investments for land usage - Consumer agreements and costs for products	
Subjective effects	- Fear of traffic - Barrier effects - Visual intrusion	- Style of life - Expectations - Loss in mobility for people without cars	

As indicated above, the effects of transport can be analysed from various perspectives but upon discussing and evaluating the environmental impact of transport emissions is the variable most typically used. According to Lumsden (1998) emissions to air pollution is the dominant form of pollution, where other types of pollution include emissions that affect both land and water as well. When considering total air pollution there are six types of emissions, so called regulated emissions, and these emissions affect the surrounding environment in various ways (Demker et al, 1994; Lumsden, 1998).

- *Carbon dioxide*: Contributes to the green house effect
- *Nitrogen oxides:* Contributes to over fertilising, acidification, affects ozone at near ground level and can cause overall health problems
- *Hydrocarbon:* Affects ozone at near ground level and can cause overall health problems
- *Carbon monoxide: Causes health problems*
- *Particulate matter:* Cause health problems, soiling, and climate changes
- *Sulphur dioxide:* Leads to over fertilising, acidification, corrosion, and health problems

[4] The table presented by Lumsden (1998) is a summary of the effects of transport on its surrounding environment presented by Blinge (1995*) Energilogistikmodell för systemberäkningar av transport- och energiförsörjningssystem*

Carbon dioxide is that type of emission that is most often referred to in environmental reports and the like, and the reason for this is that it is believed that these emissions are the main contributor to the green house effect. This type of emission is caused by each of the most commonly used modes of transport, i.e. air, road, rail, and ship. These modes of transport emit various amounts of carbon dioxide, but in generic terms airfreight is considered to be the worst polluter among the four transport modes; with road being considered the second largest polluter, ship the third largest and with rail being considered to be the most environmental friendly alternative (Lenner, 1993). Besides only considering the amount of emissions that are incurred by transportation, one also needs to consider where these emissions are incurred. For instance, are the emissions caused by jet airplanes at an altitude of 10,000 metres more or less hazardous than those emissions caused by lorries in urban areas?

When regarding the environmental impact of transport it is also important to make a distinction between transport work and traffic work. The former, i.e. transport work, is the product of the amount of goods and the distance these goods travel, and is measured as tonne-kilometres. The latter on the other hand is defined as the product of the number of vehicles and the distance, and is measured as vehicle-kilometres. The demand a company has for road transport is determined by decisions taken at various levels in the company, e.g. strategic and operative, and McKinnon and Woodburn (1996) claim that logistics managers generally have very little say when it comes to those decisions that are taken at higher levels in this hierarchy. At the same time it is decisions at these levels that determine the number of tonne-kilometres generated by a company, whereas it is the decisions at the lower levels, where logistics managers have a greater influence, that translate the necessary volume of tonne-kilometres into road vehicle-kilometres and it is here that we experience the actual pollution of carbon dioxide emissions.

Hence, the actual amount of emissions incurred by day-to-day transportations is in fact determined by decisions taken at higher organisational levels in a company and consequently there is also a need to add another perspective to the discussion on structural changes in distribution systems and their effect on the environment. This will be the focus of the subsequent part of the frame of reference, which will discuss how decisions can be taken at various levels in a company and the consequences owing to this.

2.3 Decisions in logistics systems

The goal of most companies is to gain a competitive advantage and attain sustainable profitability and this can only be achieved if a company can deliver superior value to its customers or create comparable value at a lower cost, or do both simultaneously (Porter, 1996). According to Christopher (1998) logistics has the potential to assist companies in achieving both and thereby leverage their business in relation to competitors, and as such a well functioning logistics system has become a strategic issue for many companies. As illustrated earlier, the role of distribution is to contribute to high sales revenues by providing the customers of a company with a service-level that meets their requirements and that this is carried out in a cost-efficient manner (Virum, 2003). In order to achieve this, logistical decisions must be taken at various levels and McKinnon and Woodburn (1996) divide logistical decisions into four separate levels:

- *Physical structure of the logistical system:* This level include those decisions that concern location and number of factories, warehouses and terminals, and in that sense these decisions determine how the physical infrastructure of a company will be manifested. These decisions are also connected to the overall strategy of a company and as such they are considered relatively fixed in a short-term perspective.

- *Pattern of sourcing and distribution:* These decisions deal with questions such as how to source products or to whom the company should sub-contract parts of its production as well as how to distribute its finished products. These decisions determine what trading links a company has with its suppliers, distributors, and customers.

- *Scheduling of freight flows:* Concerns decisions that transfer the above-mentioned trading links into freight flows through planning and scheduling of production and distribution.

- *Management of transport resources:* The decisions made above define within which parameters transport managers need to work in their day-to-day operations when they make decisions regarding, for instance, what type of vehicle to use.

The decisions taken at these various levels determine the demand a company has for transportation and the authors claim that logistics managers generally have very little say when it comes to those decisions that are taken at the higher levels in this hierarchy. Simultaneously it is decisions at these levels that determine the number of tonne-kilometres that is generated by a company; whereas it is the decisions at the lower levels, where logistics managers have a greater influence, that translate the necessary volume of tonne-kilometres into road vehicle-kilometres. Thus, the authors make the point that the levels should be considered as being of a hierarchical character and that even though changes can be made at each separate level in order to improve the efficiency of the system, the largest benefits can be found higher up in the hierarchy.

We can also find this view upon studying theories on structural changes in distribution systems and their effect on costs and service. For instance, Abrahamsson and Aronsson (1999) discuss the need to measure the efficiency of logistics systems on a structural level as opposed to more local measurements. The reason for this being that by not measuring on a structural level, with the aim of improving the effectiveness of the whole system, companies cannot fully explore the advantages that a structural change may hold.

The authors illustrate that by considering the whole of a logistics system, in this case a distribution system, companies can achieve large improvements in the efficiency of the system. Efficiency is here measured in terms of costs and service, and the authors label these large improvements *"quantum leap improvements"* (see *Figure 16*).

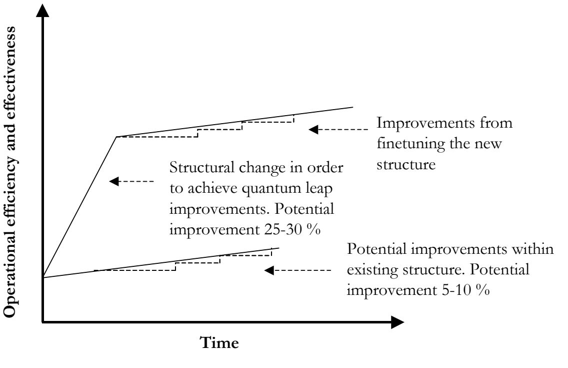

Figure 16: Quantum leap improvements (Abrahamsson and Aronsson, 1999, p 264)

The logic behind this reasoning is that the actual structure of a logistics system is the main driver of both cost and service, which consequently means that in order to radically improve these two variables one must consider how the actual structure of the system is built up. The aim of a structural change is to achieve economies of scale in both administrative and physical activities, something that is achieved through separation and specialisation of activities. When a structural change has been achieved, improvements within the existing system can be achieved; but these are considered to be of an incremental character.

A further example of how logistics decisions can be taken at various levels is that of Aronsson and Huge Brodin (2003), who present a conceptual model that intends to link decisions taken at various levels in the logistics hierarchy to environmental consequences (see *Figure 17*).

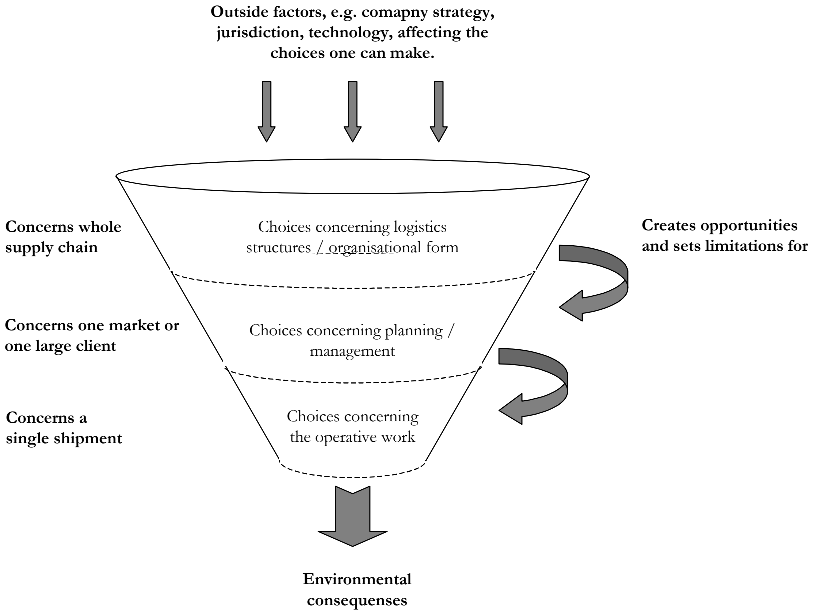

Figure 17: Linking decisions to environmental consequences (Adapted from: Aronsson and Huge Brodin, 2003, p 3)

A distinction between three types of decisions is made: strategic, tactic, and operative, and as with the theoretical contributions presented earlier strategic decisions are linked to those areas that are relevant further up in the hierarchy, e.g. decisions on the structure of the distribution system or whether to outsource production or not. In turn tactical and operative decisions are linked to those choices one has to make further down in the logistics decision hierarchy. Also, the funnel-like shape of the model helps illustrate that decisions at higher levels of the hierarchy are those that in effect on the one hand create opportunities, but on the other hand also set the boundaries for decisions taken at subsequent levels. As such, the model is reminiscent to both that of McKinnon and Woodburn (1996), and Abrahamsson and Aronsson (1999), who also claim that there exists a decision hierarchy and that it is those decisions taken further up the hierarchy that have the largest impact on the overall logistics performance.

Further, Aronsson and Huge Brodin (2003) have studied a few companies that were in the process of implementing or had already implemented a structural change and found that such a change is also interlinked with changes made at other levels in the hierarchy. What constitutes a structural change varies and examples are given on what could be labelled as common changes, as well as changes that have led to the possibility to change transport mode or changes that have been more of a virtual kind. In summary the empirical findings demonstrate solutions that simultaneously have had a positive impact on costs and the environment, meanwhile the service levels have not decreased and in some cases even increased. This leads the authors to formulate the following hypothesis:

"Structural changes in logistics systems can simultaneously lead to reduced costs, reduced pollution and to improved customer delivery service."

(Aronsson and Huge Brodin, 2003, p 9)

The authors also make a call for investigations that in greater detail illustrate how decisions at different levels in the hierarchy associate to one another and how this is linked to the environmental outcome of a structural change. This call together with the theoretical contributions that have been presented in the last section also serve as the foundation for the second research question of this study, which is to illustrate how structural decisions in logistics create new opportunities to improve on the environmental performance of a distribution system.

2.4 Bringing it all together

It is evident that the state of our environment has steadily deteriorated and voices are being raised claiming that something needs to be done in order to break the trend (European Commission, 2001). The causes of this downfall are many, but one example that is sometimes put forward is the application of modern logistics systems, which is the consequence of increasing customer demands and companies striving for sustainable financial profitability (Rodrigue et al, 2001). However, with the emergence of green logistics has come a call for incorporating environmental awareness into the field of logistics and according to Jahre (2003) this expansion of the traditional view has two distinct ramifications for the logistics community. First, all parts of a supply chain should be considered; from the extraction of raw materials through production and distribution, to recycling and other forms of waste disposal. Within this area we have witnessed progress over the last decade or so and terms such as "*Life Cycle Analysis*" and "*Reverse Logistics*" have become well known, in industry as well as academia.

Regarding the second condition, i.e. that environmental variables should be used as complementary criteria to that of financial criteria, there is still a long way to go. Initiatives for incorporating environmental issues as criteria can nevertheless be found and efforts to improve the environmental performance of logistics systems have been undertaken. These efforts however have mainly focused on technical solutions, such as improving fuel efficiency or changing to cleaner types of petrol, but it is believed that these measures have been more than offset by decisions taken at higher organisational levels (McKinnon and Woodburn, 1996; McKinnon, 2003). Expressed somewhat differently, even though technical advancements have improved the environmental performance for individual vehicles whereby emissions related to traffic work have decreased, the common view is that this in many cases these positive effects have been eradicated by increases in the overall transport work, which is a consequence of changes in the overall set-up of logistics systems.

In fact, if one studies what constitutes an environmentally friendly distribution system in theory (Wu and Dunn, 1995; McKinnon and Woodburn, 1996; Rodrigue et al, 2001) and the trend of centralising distribution systems it becomes obvious that there exists a mismatch between the two (see *Table 6* below).

Table 6: Environmentally friendly distribution systems vs. current practice

Environmentally friendly distribution systems	Observed trends in distribution systems
- Shorter transportation distances	- Longer transportation distances due to centralised distribution systems
- Fewer transports	- Larger growth in transports than in GDP
- Less handling	- More handling of goods
- More direct shipping routes	- Shipping routes via central distribution points
- Better utilisation	- Low utilisation of space due to JIT deliveries and the like

Despite this mismatch there does not exist much research on the impact logistics has on the environment and the research that does exist seem to focus on questions that can be regarded as being of either an operative or a tactical character (e.g. Penman and Stock, 1994; Bäckström, 1999; Björklund, 2002). This is emphasised by Abukhader and Jönsson (2004a) who point to the fact that research focusing on the environmental impact of logistics operations have fallen into slumber over the last couple of years and that there now is a need for a new focus and direction within the area. The authors articulate a call for environmental assessments of different logistics strategies, where the area of decentralisation vs. centralisation is seen as an area that is in need of empirical investigations in order to shed some light on the issue.

There does however exist studies claiming that the total amount of tonne-kilometres will increase as distribution systems are centralised (e.g. Rodrigue et al, 2001; McKinnon, 2003). Since tonne-kilometres is considered a common way to depict the environmental impact resulting from transportations in a distribution system, the only logic conclusion that can be made is that even though centralisation of distribution systems is advantageous from the perspectives of cost and service it is inauspicious from an environmental perspective.

The underlying assumption in this thesis, however, is that the relationship between tonne-kilometres and environmental impact might not be quite that simple, and if centralisation is studied from a company perspective then the results may be quite different in relation to the general opinion. According to Abrahamsson (1992), one of the main advantages with a centralised distribution system is that emergency deliveries are expected to decrease since a central warehouse can offer a higher level of service than is possible in a decentralised distribution system. Emergency deliveries are often performed by airfreight, a mode of transport that is very costly for a company. This is also the reason why transport costs can be kept at a relative constant level even though total transport work increases as a consequence of centralisation. What occurs is that the ratio for how much it costs to transport a certain amount of goods a certain distance decreases for the distribution system as a whole when it is centralised.

The same logic should also be possible to apply when analysing the environmental impact of centralisation. Even though total transport work (i.e. tonne-kilometres) increases, this must not necessarily mean that the emissions caused by the transportations that are performed within a distribution system increase as a consequence of centralisation. The reason for this being that emergency deliveries are substituted by regular deliveries, which are most of the time performed by modes of transport that cause less emissions than airfreight. This logic relates to the first research question that was posed in *section 1.2*, which concerns how physical centralisation of a distribution system influences the environment and this is also illustrated in *Figure 18* below.

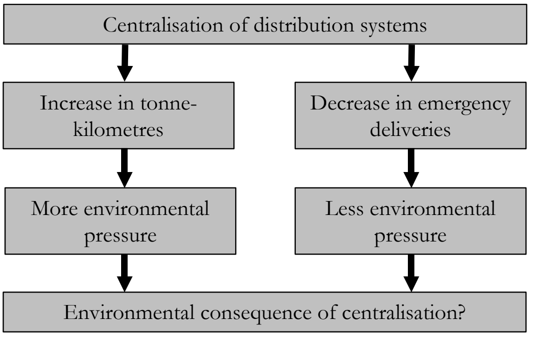

Figure 18: What are the environmental consequences of centralisation?

The frame of reference has also helped illustrate how the environmental impact of transportations within a distribution system can be lowered by undertaking various measures within the context of a given distribution system (Blinge and Lumsden, 1996). A distinction between internally related improvements and externally related improvements was made, where the former focused more on technical enhancements and the latter focused more on operating more efficiently within the logistics system. What is not discussed is what effect a structural change could have on the possibility of making improvements in these areas, since decisions taken at structural level in a distribution system can affect decisions at other levels (e.g. McKinnon and Woodburn, 1996; Abrahamsson and Aronsson, 1999; Aronsson and Huge

Brodin, 2003). This is the focus of the second research question, which aims at investigating how a decision to centralise a distribution system can influence other decisions relating to the environmental performance of a distribution system.

How these two questions are to be investigated and analysed is presented in the subsequent chapter, which portrays the research approach of this thesis.

3 RESEARCH APPROACH

The purpose of this chapter is to describe the research process that is the foundation of this thesis. Initially the methodological approach is discussed in brief terms, which is then followed by a more detailed description of the research design and how data has been collected as well as analysed.

3.1 Introduction

According to the French mathematician, physicist, and philosopher of science Jules Henri Poincaré (1952) science is facts, but a collection of facts is not necessarily science. What this means is that it is not sufficient to only collect data, or facts, and then make statements in accordance to the observations one has made for this to be called science. Rather, science is about making conscious decisions on how the empirical evidence is to be collected. According to Arbnor and Bjerke (1997) there exist various approaches as to how a researcher or scientist can go about collecting data and the results of a study are to a large extent determined by the approach that has been chosen, i.e. the methodological approach. According to the authors the methodological approach is what connects theory of science and methodology (see *Figure 19*). Theory of science relates to questions such as *"What is the goal of science?"*, *"What is a theory?"*, and *"What can be considered to be a scientific problem?"*. How such questions are to be answered are highly dependent on the ultimate presumptions of a specific researcher or maybe a whole science, e.g. logistics, and as a consequence there exist various scientific paradigms, each with its own scientific ideals and views on how reality is constructed. Methodology on the other hand relates to the creation of knowledge, or rather how methods are constructed in order to create knowledge. The authors view methods as an operative paradigm, which consists of two important parts; methodological procedure and methodics. The former refers to how the researcher in question incorporates, develops, and/or modifies any given technique within the realm of a specific methodological approach, whereas the latter, i.e. methodics, refers to how this adaptation is applied during the actual study.

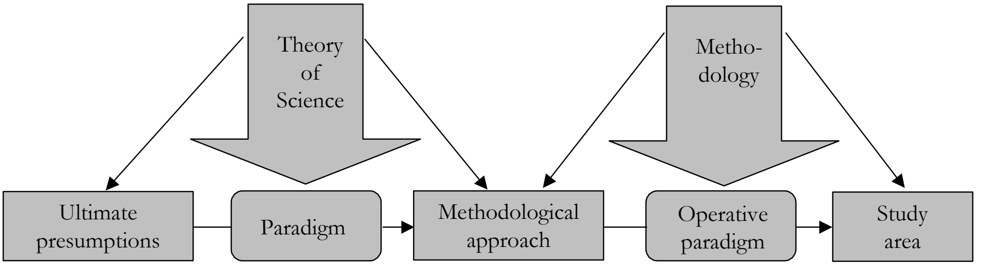

Figure 19: Methodological approach (Arbnor and Bjerke, 1997, p 15)

I believe that it is more or less impossible for a researcher not become affected by the surrounding community, which in turn is likely to shape the methodological shape of any study. According to Persson (1982) the field of logistics has chosen a systems approach as the basic methodological approach. In generic terms the systems approach views reality as objectively accessible and that the parts of a system are explained, and sometimes understood, by the characteristics of the whole (Arbnor and Bjerke, 1997). It could be argued that the statement by

Persson (1982) was made over two decades ago and it does not necessarily hold true today, but a more recent study by Vafidis (2003) shows that during the time-period 1994-1998 just over two thirds of all Swedish and Finnish logistics dissertations applied a systems approach. I also believe that the methodological approach applied in this thesis can best be described in terms of being a systems approach. However, the aim with this chapter is not so much to discuss theory of science within the field of logistics management and methodological approaches, but rather to discuss the methodological considerations I have had to deal with during my research process; this being the theme for the continuation of this chapter.

3.2 Identifying a research problem

The research presented in this thesis is part of a larger research project at the department of Logistics Management at Linköpings universitet. The project's duration is three years and it is financed by the Swedish Agency for Innovation Systems, Vinnova, and it was initiated during the summer of 2002. The project aims at identifying and explaining environmental drivers in logistic systems and tries to explain the balance between the three variables of cost, time, and the environment in an analysis of such systems.

During the same summer I conducted a first literature review to find out what had been written on the combined area of logistics and the environment and I soon came to the conclusion that there existed many unexplored topics that could serve as the basis for my research. However, some of the research that had been done on logistic systems and environmental issues referred to various journal articles and book chapters written or co-written by McKinnon. What many referred to in McKinnon's research was how he classifies logistics decisions into various organisational levels and how logistic decisions taken at these levels affect the environment in different ways, something which has also been presented both in *section 1.1* and *section 2.3*. However, I also found that much of the research that had been conducted on the effect logistics has on the environment is concerned with questions that could be characterised as having more of a tactical or operative character. Within my research department however there exists a strong tradition of studying structural changes in logistics systems, but then with a focus on cost and service issues. Structural changes are linked to decisions taken further up the hierarchy than tactical or operative decisions. This does not imply that these decisions are more important than those taken at a tactic or operative level, but previous research, e.g. Abrahamsson and Aronsson (1999), illustrate how these decisions are likely to have a greater impact on the logistic system as a whole than those decisions taken at subsequent levels.

Thus, given what I had found during my first literature review and the research tradition within my department I quickly zoomed in on an overall purpose of my research, which was to study how structural changes in distribution systems affect the environment and its relation to costs and service. During the following year I presented a thesis proposal as well as presented a *"Work in progress"* paper, which I had co-written, at the annual Nofoma conference in order to present the overall ideas of my research and receive important feedback on my research. I also searched for more literature and started to form a frame of reference that would be aligned with the purpose of my research. It also came time to decide what type of study I wanted to conduct, since there exists a vast number of possibilities as to how one can design a study, and this is the theme of the subsequent section.

3.3 Deciding on type of study

A study can be conducted in numerous ways and according to Yin (1994) there exists three conditions that a researcher should consider when choosing how to conduct his or her research (also see *Table 7*):

1) The type of research question that is posed
2) The extent of control a researcher has over actual behavioural events
3) The degree of focus on contemporary events as opposed to historical events

Table 7: Relevant situations for different research strategies (Yin, 1994, p 6)

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
experiment	how, why	yes	yes
survey	who, what, where, how many, how much	no	yes
archival analysis	who, what, where, how many, how much	no	yes/no
history	how, why	no	no
case study	how, why	no	yes

The first of these conditions is seen as paramount, since the research question should help determine the research strategy. In other words a researcher should not reason in terms of *"I would like to conduct a survey and therefore I have to pose a research question that is in accordance with this preference"*, but rather look at the formulated research question, which most of the time is based on personal presumptions and the problem at hand, and apply a research strategy that is in accordance with this. It is also important to remember that different strategies are not mutually exclusive, meaning that one can use multiple strategies within the same study.

Given the purpose of my research and associated research questions I found that a case study would most likely be the most appropriate way to design my research. Not only were my questions formulated as *"how"* questions, but my aim was also to study a contemporary event, i.e. a structural change, where I would have no control over the behavioural events associated with the phenomenon that I wanted to investigate. There are five issues that are important to consider when designing a case study (Yin, 1994):

1) A study's questions
2) Its propositions (if any)
3) Its unit(s) of analysis
4) The logic linking between collected data and the propositions
5) The criteria for interpreting the findings

The purpose and research questions have already been discussed earlier and it was in formulating them that I decided that a case study would be the most apt type of study for me to conduct, so this will not be discussed further.

With propositions Yin refers to statements or hypotheses that illustrate more precisely what it is that should be examined within the scope of the study. Propositions also illustrate how the researcher has reasoned regarding issues that are of relevance for the study. For me these propositions were stated while formulating the frame of reference. For example, a fundamental proposition throughout the study has been that an increase (or decrease) in tonne-kilometres does not necessarily give an equal increase (or decrease) in carbon dioxide emissions, since tonne-kilometres alone does not indicate what mode of transport has been used. This is because the amount of emergency deliveries should decrease with the implementation of a centralised distribution system (Abrahamsson, 1992). This proposition and others have together with the overall purpose of the study as well as the two research questions been the guiding light for what is to be studied.

Quite often it can be difficult to pinpoint what the actual case is and Yin claims that it is important to know the unit of analysis when conducting a case study. In this study the unit of analysis, or the case, are structural changes in distribution systems and the effect this has on the environment. Hence, the case could be a description of how one single company has undertaken a structural change in its distribution system and the effects of this change, or the case could include multiple descriptions. In this study the focus has been on one company and its structural change, which will be discussed further in *section 3.4* below.

According to Yin *"linking data to propositions"* and *"criteria for interpreting the findings"* are those elements that have been discussed and developed the least in case studies. These two elements refer to how a researcher plans to structure the analysis of the gathered data and how the data should be analysed. These issues will also be discussed below.

3.4 Preparations for data collection

Within the research project multiple companies had been approached, companies with the common denominator that they had all conducted or were about to conduct some form of structural change in their logistics system. The companies were Ericsson, IKEA, Stora Enso, ICA, and ITT Flygt. Initial interviews were made with all companies to see what these changes manifested and what the results had been, and these interviews were presented as smaller case descriptions illustrating the main characteristics of each structural change. Given the scope of the purpose and research questions the conclusion was made that it would be better to focus on one company and go deeper into the empirical data than to focus on multiple companies and maybe only scratch the surface for each of them.

From the set of companies ITT Flygt was chosen as the most suitable company to contact for further studies and there were two main reasons why the company was chosen. The first was that through the initial interview it had become apparent that the process that ITT Flygt had gone through upon changing its distribution system displayed many of the more characteristic traits of a structural change. Expressed differently, in theory a company that decides to change from a decentralised to a centralised distribution system should experience large improvements in the service it can offer its customers at the same time as it succeeds in cutting its costs related to logistics activities. Hence, even though the study only focused on one centralisation it could be argued that ITT Flygt's centralisation would serve as a fair representation of the consequences of such a structural change. Second, ITT Flygt had kept the preferred mode of transport constant throughout the change, which in this case was road freight. The reason why this is of interest is that by keeping the normal means of transportation constant it should be possible to isolate the environmental effect of the structural change itself. This would not be possible if the structural change also implied a change regarding the main mode of transport used within the distribution system.

Besides deciding to conduct the empirical investigation at ITT Flygt I had also, in parallel, started to form a frame of reference. Through the knowledge that was acquired by building a frame of reference a plan was formulated stating the type of data that needed to be gathered in order to be able to fulfil the purpose of the study. In generic terms the empirical part of the study was divided into two parts, one where interviews were carried out and one where calculations describing the change in emissions due to the structural change were made. The logic behind this plan was to use multiple sources of evidence and try and converge these in order to build a strong case study from the data that could be gathered from ITT Flygt.

3.5 Data collection

The basis for the data collection has been interviews with various respondents at ITT Flygt that in one way or another could give relevant input to the process the company had gone through. A list of respondents (see *Appendix A*) was compiled by my contact person at the company and a cover letter was written explaining who I was and why I wanted to come in contact with them (see *Appendix B*). This cover letter was sent by email by my contact person, where the respondents were notified that they were going to be contacted by me for an interview, subsequent to which I contacted the respondents in order to book an interview.

The respondents were also given the opportunity to prepare themselves for the interview, since they received the interview guide in advance via email. The interview guide (see *Appendix C*) served as a basis for a conversation between the respondent and me. At the start of each interview I informed the respondent that the intention of my interview was to obtain their picture of what comprised the structural change and that I would write one portrayal; describing the company, why the structural change came about, what this implied for the company etc. The respondents were therefore asked if it would be all right if the interview was recorded so that I could go back and listen to the interview afterwards, a question to which none of the respondents said no.

In general the interviews lasted between one and two hours. At the end of each interview the respondent was asked if they were of the opinion that I should interview someone else besides those personnel that were listed as respondents in the cover letter. On two occasions the respondents came up with suggestions on additional personnel to interview. I then discussed this with my contact person to obtain his view on the issue and in both instances a contact was made, thus adding two interviews. When the interviews were done they were listened to again and those parts that were relevant were transcribed. Since these transcriptions did not represent the interviews in their full version they were not sent back to the respondents for revision and approval. The reason for this being that the interviews that were carried out were done so in order to obtain a comprehensive portrayal of what the structural change implied for ITT Flygt. Thus, the intention has not been to contrast opinions from various respondents against each other, but rather to use the answers given to me to build the case description. However, in order to ensure the quality of the case description it was sent to ITT Flygt for revision, a revision that was done by personnel with extensive knowledge about the structural change that had been carried out.

Besides conducting interviews with personnel at ITT Flygt, data has also been collected from the two carriers, DHL and Wincanton, that operate the transportations in the company's current distribution system. This information has been gathered in order to be able to conduct the calculations that serve as the basis for analysing the environmental effects of the structural change. How this has been done is explained in greater detail in the next section.

3.6 Processing and analysing the collected data

After conducting the interviews and also receiving additional information, e.g. internal reports and shipment data for the distribution system, I started to process all of this data. The data that has been gathered serves two purposes. First it has been the basis for the case description that is presented in *chapter 4* and second it has been used to construct the calculations that are presented in the analysis in *chapter 5*. This process of working with the gathered data is closely linked to the two last components of a case study and that is how the collected data should be linked to the research questions, or propositions, and what criteria is used to interpret the findings (Yin, 1994). The analysis that has been carried out is divided into two separate parts, one part that could be labelled a quantitative analysis and a second part that is has more of a qualitative character.

3.6.1 Quantitative analysis

This part of the analysis refers back to the first research question of this study:

- *How does physical centralisation of a distribution system influence the environment?*

This question is focused on quantifying the environmental effects of the structural change in ITT Flygt's distribution system. As discussed in the frame of reference environmental effects in this case refer to two things, effects expressed as changes in the amount of tonne-kilometres as well as effects expressed as changes in the amount of carbon dioxide emissions. The focus in the quantification of the environmental effects is on how the transport situation has changed as a consequence of the structural change. Expressed differently, centralisation of distribution systems implies that the number of warehouses will decrease in number, which inevitably will affect how transportations are carried out within the system. Thus, the focus in this case is on the physical structure of the distribution system and according to Coyle et al (1992) a node-link perspective is a good way to analyse the physical structure of a distribution system, where nodes represent the warehouses and links represent the transportations. Environmental impact can be caused by the actual transport work as well as the activities that are performed in the nodes of a system. According to Blinge et al (2002), however, knowledge about those emissions incurred by activities carried out in the nodes are relatively sparse and those studies that have been done on the topic show that these activities only account for 0.5-1.0 % of total emissions. Therefore the analysis is only focused on how the structural change has affected transportations within the distribution system.

In order to isolate the effects of the structural change itself other variables than the actual physical structure have been kept constant. ITT Flygt has supplied shipment data for 2003 and this data has then been used to calculate the amount of transport work and carbon dioxide emissions that were generated by the centralised distribution system in 2003 on the one hand and by a recreated version of the decentralised distribution system on the other hand. This implies that even though ITT Flygt has experienced a change in the amount of goods in its distribution system over the years, as measured by weight, this is not taken into consideration. Such issues as the technology level of the lorry that performs the transfers have also remained constant in the comparison of the two distribution systems. The procedure for how the calculation model has been designed and how the analysis has actually been carried out is explained in greater detail in *Appendix D*, whereas the analysis itself is presented in *section 5.2*.

3.6.2 Qualitative analysis

The qualitative analysis is focused on illuminating those effects of the structural change that could be argued to be of a more indirect character. This analysis relates to the second research question, which reads:

- *How do structural decisions in logistics create new opportunities to improve on the environmental performance of a distribution system?*

Indirect effects refer to how the decision to centralise the distribution system has made it possible for ITT Flygt to make other decisions, or changes, in its distribution system that are considered beneficial from an environmental perspective. Differently formulated this analysis examines whether or not structural decisions do have an effect on other decisions in the logistics decision-making hierarchy.

For this part of the analysis the framework of Blinge and Lumsden (1996) was used where the authors list ten categories of opportunities for environmental improvements that are related to transportations within a logistics system. The case of ITT Flygt has been compared to each of these categories in order to see whether or not the centralisation has led to an improvement or has created an opportunity to make changes in the future that can be favourable from an environmental perspective. This analysis is presented in *section 5.3*.

3.7 Validity and reliability of the study

According to Yin (1994) the quality of all research designs needs to be judged and tested and there are four commonly used tests to establish the quality of any case study; these are construct validity, internal validity, external validity, and reliability.

Construct validity refers to how well the researcher manages to establish correct operational measures for the concepts that are being studied, and according to the author a researcher must be able to cover two steps to meet this test:

1) Select the specific types of changes that are to be studied
2) Demonstrate that the selected measures of these changes do indeed reflect the specific types of change that have been selected

For this study the type of change that has been chosen is that of a structural change in a distribution system, more specifically a change from a decentralised distribution system in favour of a centralised distribution system. There are also two types of changes that are studied as a consequence of the structural change, where one is how the environmental impact has changed due to the transformation in the physical structure of the distribution system. The other concerns how changes at a structural level create new opportunities to make improvements in the distribution system that have a positive effect on the environment (also see research questions one and two). The tactic that has been used to ensure the construct validity of this study has been to use multiple sources of evidence, e.g. interviews, archival records, as well as quantification of emissions; converging these to construct the case and also structure the analysis. Also, the intention has been to ascertain a chain of evidence by first studying theory to see how environmental impact of logistics is portrayed and to find what the main drivers of emissions are believed to be. It was found that the amount of transport work, indicated as tonne-kilometres, is the main driver of emissions in a distribution system and this measure has therefore been used throughout the study, in quantitative as well as qualitative parts. A third tactic has also been employed is to allow ITT Flygt to view and respond to the case description and give comments accordingly.

The second test, i.e. internal validity, concerns to what extent the researcher is able to establish a causal relationship, whereby certain conditions are shown to lead to other conditions (Yin, 1994). Internal validity is inapplicable to descriptive or exploratory studies, regardless of the employed research strategy, since such studies do not involve making causal statements. The aim of this thesis has been to describe and analyse the environmental consequences of a structural change rather than to find causal relationships, whereby internal validity becomes less of an issue.

External validity is focused on whether or not it is possible to make generalisations that go beyond those results that have been obtained through the case study at hand. Yin points out that this is the test where case studies generally receive the most criticism, especially from advocates of a survey approach. The question that is often raised is *"How is it possible to generalise from a single* *case?"*. The mistake that is often made, Yin claims, is that many confuse statistical generalisation, which is used in surveys, with analytical generalisation, which is used when conducting case studies. Within the scope of this study some generalisations have been made, but these do not aim at drawing conclusions that are applicable for other cases besides the one that has been presented here. Rather, the generalisations that are made refer to earlier theory within the area of structural changes in logistics systems and they aim at confirming that the case at hand confirms earlier theories.

The final test concerns reliability and refers to whether or not a researcher would come to the same results as a previous researcher, given that he used the same procedures as the earlier researcher. In this study the aim has been to ensure the reliability by using the same interview guide during those conversations that were held with respondents that were providing information for the build up of the case description. Also, the final draft of the case description has been sent to ITT Flygt for final confirmation, thus ensuring that this is a description that represents the change process that took place and the results of this. In order to ensure the reliability of the calculations a sample country has been used throughout the analysis in order to ensure that another researcher would be able to perform corresponding calculations given the same input of data.

4 STRUCTURAL CHANGES AT ITT FLYGT

In this chapter ITT Flygt, a world-leading manufacturer of submersible pumps and mixers, is introduced. During the second half of the 1990s the company launched its operation of a new Supply and Distribution Centre in Metz, France. This was one part of a strategy to change the structure by which the company distributed and supplied its customers on the Western European market with products, accessories, and spare parts. In generic terms the change can best be described as a centralisation of the company's distribution system. From a logistics viewpoint this change, i.e. that of changing from a decentralised to a centralised distribution system, was by no means a revolutionary change and many companies, amongst others Atlas Copco and Sandvik Coromant, had undertaken similar projects with great success during the 1980s and early 1990s.

The case description aims at illustrating why this change came about and how the new distribution system was put in place, as well as the results ITT Flygt accomplished through the change. Before these issues are presented a brief overview of the company ITT Flygt will be made, subsequent to which a more detailed description of the structural change and its consequences is presented. The case description also serves as a foundation or basis for what is to be presented in the subsequent chapter, i.e. the analysis.

4.1 ITT Flygt – an overview

4.1.1 Company history

In 1901 the blacksmith Peter Alfred Stenberg established a glass mould factory, Lindås Glasformsfabrik, in the small village of Lindås in the southern parts of Sweden. This area in Sweden is well known for its many glassworks and Peter Alfred Stenberg specialised in producing ironmoulds and equipment for the many surrounding companies. Just over a decade later the company was restructured and given the new name Lindås Gjuteri & Formfabriks AB (Lindås Foundry & Mould Factory) and a few years later Peter Alfred Stenberg transferred the responsibility for the factory to his children.

Later on, in 1929, an engineer from Stockholm named Hilding Flygt advertised in the daily newspaper in order to find a company that was able to manufacture the products his company developed, namely pumps. The Stenberg brothers responded to the advert and the cooperation between Hilding Flygt and the Stenbergs in Lindås saw the light. About a year later the company was able to introduce its first pump, the *"universal pump"* (see *Figure 20*).

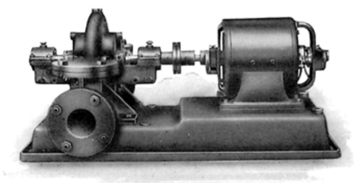

Figure 20: The company's first pump, the "universal pump"

Almost two decades later, in 1947, Hilding Flygt decided to retire and AB Flygts Pumpar was sold to the Stenberg brothers in Lindås. In the same year the company introduced the world's first submersible pump thanks to the engineering knowledge of Sixten Englesson, an employee of the company. Over the subsequent years the company introduced new pumps, started an export company, and established foreign subsidiaries. In 1968 the American multinational company International Telephone & Telegraph Corporation, better known as ITT, acquired the company through an exchange of shares, and the following decade the Lindås plant grew tremendously as an expanding range of products were introduced. Later on, in 1991, the company name was changed to ITT Flygt AB, a name that the company holds to this day.

Today ITT Flygt is the world's largest manufacturer of submersible pumps and mixers, and is renowned for producing efficient and versatile products of the highest quality. ITT Flygt's vision is to be recognised as the leading supplier of solutions and services in fluid handling with submersible products worldwide. In trying to live up to this reputation as a market innovator the company has recently released the N-pump, which promises to revolutionise submersible pumping, much in the same manner as the first submersible pump did just over half a century ago.

4.1.2 Facts and figures

With its 44 wholly or partly owned sales offices, representation in over 130 countries around the world, production plants in Sweden, Germany, the Netherlands, Argentina, and China, and distribution centres in Sweden and France, ITT Flygt can truly be considered an international company. The company has over 4,000 employees, of which over 2,500 are stationed outside of Sweden. The corporate headquarter is located in Stockholm, as well as the departments of Research & Development, Marketing, Flygt International, and the Swedish sales company. The largest production plant is located in Lindås, where the company has its roots, and in 2003 approximately 78,000 out of the company's total production of 130,000 pumps were manufactured here, as well as 8,500 out of 8,600 mixers. The departments of Finance, Quality, and Shipping are also located in Lindås; whereas Purchasing, Human Resources, and IT/IS are functions that are divided between Lindås and Stockholm. *Figure 21* below shows an organisational chart of the ITT Flygt Group.

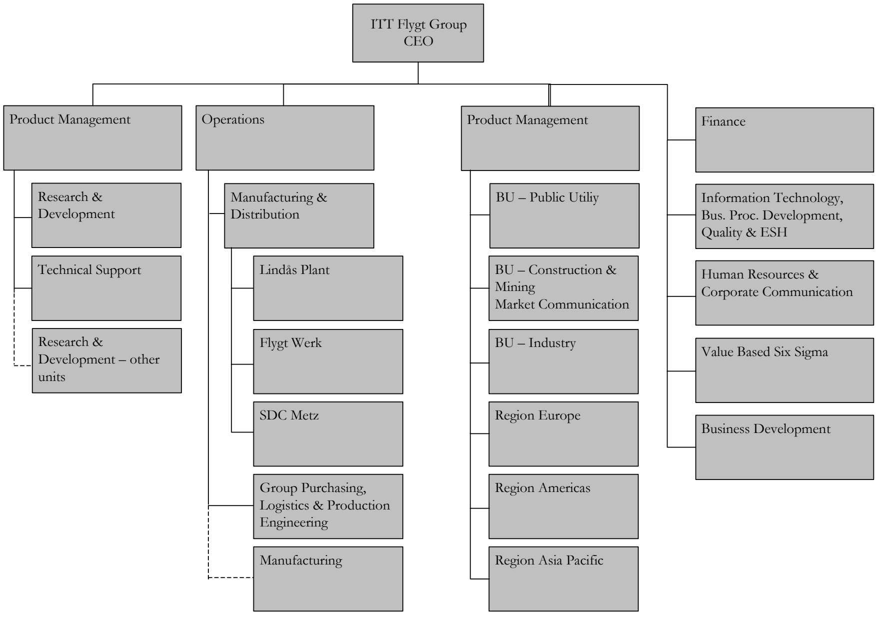

Figure 21: Organisational chart of the ITT Flygt Group

Today, ITT Flygt is the flagship of the ITT Fluid Technology division, which is a business segment of ITT Industries where all companies in the group are active in developing fluid systems and solutions in order to move and control water and other fluids. Fluid Technology is one of four business areas, where the other three areas include Electronic Components, Defense Electronics & Services, and Motion & Flow Control, and represents 40 % of total sales for ITT Industries. The corporate headquarter of ITT Industries is located in White Plains, New York and the company employs about 38,000 people all over the world. It is noted on the New York Stock Exchange as well as on the stock exchanges US Midwest, US Pacific, London, Paris, and Frankfurt.

4.1.3 The market

In 2003 ITT Flygt had a turnover of approximately US$ 763 million, where the European and US markets make up for almost 90 % of total revenues (see *Figure 22*). Just over 50 % of these sales can be attributed to the waste-water segment, with industry and construction making up other large segments, and 20 % and 18 % of sales come from these respective segments.

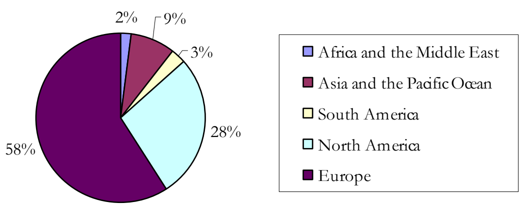

Figure 22: Sales per region for ITT Flygt

ITT Flygt is considered to be a premium brand on the submersible pump market and the pumps are used in various settings and environments. For instance they are used to pump waste-water in the London Docklands, to drain mines in South Africa from water, or to create man-made surfing waves in Texas. Just as with most other industries ITT Flygt has a number of companies with whom it needs to compete over market shares and currently some of the larger competitors include Grundfos and ABS Pumps.

Earlier ITT Flygt considered the market in a somewhat narrow manner, or rather the market was defined as just selling pumps, and with this view the company considered itself to have a market share of approximately 25 %. Today, the company defines the market in a broader fashion and the goal is not only to supply a submersible pump, but instead to supply a complete system including installation and other services. When the market is defined by using these criteria, then ITT Flygt instead considers its market share to be approximately 5-10 %. However, the company has presented an offensive strategy for the coming years, a strategy where the company shall grow substantially over the coming years and increase its overall market share. This expansion shall be achieved through extensive acquisitions as well as increases in sales on markets outside of Europe and the U.S.

4.1.4 The pump

Even though many of the pumps ITT Flygt in fact sell look and operate in a similar fashion, the company does not have a standard or pre-specified product that the customer can pick out from a catalogue in the same manner as they could do if they bought something from Elfa or IKEA. This is because a product can come in more or less a million different configurations, since cables, voltage for motors, or material for the sealing jointing and the like can vary depending on the preference of the customer in question. *Figure 23* below illustrates typical products of ITT Flygt.

Figure 23: Typical ITT Flygt pumps

Until the 1960s ITT Flygt was a rather small company and it was not that difficult to specify what components each of the products were to have as they were ordered, since volumes were not that large and therefore the workload was manageable. Sales representatives went out into the field and sold pumps to the customers through the use of brochures, technical specifications, effect curves etcetera and could quite easily specify the characteristics that described a certain product. These were then transferred to the factory where personnel translated these orders into specific articles so that the customers received the pump they actually requested. These lists could contain, depending on the type of pump, between 50 and 100 articles.

When ITT Flygt started expanding on new markets and the volumes started to grow, this way of working was no longer feasible since this would be too time consuming. Therefore, the company in the 1970s introduced an identity system, a system that had the purpose of making it possible to identify all objects, e.g. single parts, components, or a complete unique product. This system can be seen described as an *"identity pyramid"* and *Figure 24* below gives an example of what this may look like.

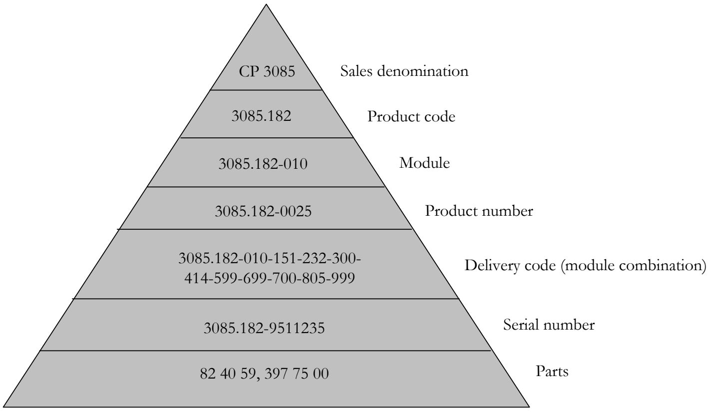

Figure 24: Example of the ITT Flygt "Identity pyramid"

When a customer today sees a pump, the sales representative sees a product code according to the identity rules that the company have decided upon in the technical administration system. The order is then handled by the order personnel, who for that particular product group match customer requirements with the matching articles in each of the module groups, e.g. motor module group, cable group, or pump wheel group. The final product then is actually a configuration of various modules. This way of describing the products has turned out to be a very efficient way of describing all the parts, components, and modules, and it has become clear and easy to see all available product combinations.

4.1.5 Environmental policies and initiatives at ITT Flygt

Besides having the vision of being recognised as the leading supplier of solutions and services in fluid handling with submersible products worldwide, ITT Flygt also wants to contribute to a better environment. The company is dedicated to being a leader in environmental protection and management is responsible for making this an integral part of the company and in line with this dedication the company is certified according ISO 14000 standards. The company sees third party certifications as a push for continuous improvement of quality and environmental control and its environmental performance can be described with a comprehensive set of different categories, aspects and indicators.

However, even though environmental issues have always been a question at heart for the company, random tests performed by ITT Industries during the first half of the 1990s showed that ITT Flygt could not claim to be working in a proactive manner with respect to these issues. Therefore, in 1996 a plan was presented on how the company could improve on its performance and today environmental and sustainability issues are an integral part when business decisions are evaluated. Further, life cycle analyses are performed on all products and all new products have an environmental declaration. All subsidiaries undergo substantial training in Environment, Safety, and Health issues, and all 44 sales companies have their own ESH coordinator. Moreover, each year the company introduces a sustainability agenda, where a risk assessment is made for all processes. Another initiative that has been taken is that management annually meet and discuss situations that have arisen, or are likely to arise, which could be considered to be of a questionable nature, i.e. cases in which it is hard to judge whether or not the company has acted in a sustainable manner even though laws and regulations have in fact been met.

In 1999 ITT Flygt released its first Sustainability report and in 2001 the company joined a UN project headed by Kofi Annan labelled Global Compact which is a programme with the aim of setting standards within the areas of human rights, labour rights, and anti-corruption as well as environmental issues. In the latest top 100 ranking of sustainability reports done by SustainAbility Ltd on behalf of United Nations Environment Programme (UNEP) the company was ranked number nine, which the company views as recognition of their environmental work. The company is also a frontrunner within other environmental projects, for instance Nordic Partnership, and is also one of the co-founders of the Stockholm Water Prize.

4.2 Changing distribution systems

The intention of the previous section has been to give a brief overview of ITT Flygt, its history, the type of products that are sold and the like. The following section instead focuses on that which is the empirical foundation of this study and that is the structural change which ITT Flygt undertook in its distribution system during the latter part of the 1990s. In brief terms the change came about because management at ITT Flygt was of the opinion that the company needed to become more efficient in its operations in order to secure its margins on its most important market, namely the European market. As mentioned before, this change was not original from a logistics viewpoint since many companies, amongst others Atlas Copco and Sandvik Coromant, had undertaken similar projects with great success during the 1980s and early 1990s.

The portrayal is based on interviews conducted with various personnel within ITT Flygt who in one way or another have, or have had, an association with the structural change and the aim is to present a plentiful depiction of the series of events that occurred rather than to present contrasting views of various actors within the company. The structure for this case description is such that it begins by presenting the former decentralised distribution system and its characteristics, which is followed by a section illustrating how and why ITT Flygt came to the conclusion that a decentralised distribution system would not suffice in the future. Subsequent to this a description of the actions that were taken to change the structure of the distribution system and the way it was managed are presented. In the final section of this portrayal the new centralised distribution system and its main characteristics are presented, as well as the results of the change.

When ITT Flygt decided to change its distribution system this was done in order to improve the efficiency of the distribution system. In this case this referred to cost and service issues, meaning that the company wanted to lower the cost of operations and simultaneously improve on its service performance towards the final customer by means of centralising the distribution system. Even though environmental considerations were also taken into consideration during this process they were not a prominent feature, at least not from a logistics perspective. What was considered from an environmental viewpoint instead were issues such as whether or not the ground at the building site for the new central warehouse was contaminated. The environmental issues related to the structural change itself are instead introduced in the subsequent chapter, i.e. the analysis.

4.2.1 The distribution system prior to 1999

Ever since ITT Flygt established its first international subsidiary in 1956 it has expanded onto the European market either by setting up its own subsidiaries or by acquiring suitable companies. Along with this expansion also grew a distribution system that could be characterised as being of a decentralised character and there are multiple reasons for this, which will become evident below.

Prior to the development of the European Union it was more difficult than today to transport goods across the borders in Europe and as a consequence of this it had been a natural decision for ITT Flygt throughout the years to keep pumps and accessories in stock at each of the local sales companies throughout Europe. Also, quite often, the directors of the subsidiaries were of the opinion that the customers had very market specific demands and consequently there was a need for all sales company to customise their sales and logistics operations to suit the respective markets. Out of this mentality one can say that a strategy emerged, a strategy implying that every subsidiary was its own small company in most respects, but with the common denominator that they all had the same supplier of pumps, namely the factory in Lindås (see *Figure* 25).

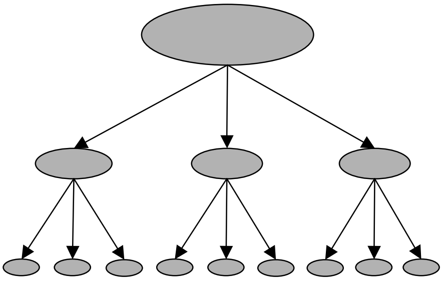

Figure 25: Generic illustration of ITT Flygt's decentralised distribution system

The directors of the sales companies often argued that the factory had a production lead-time that was too long in comparison to what the customers generally demanded. In other words there existed a perceived gap between the demand of the customers and what the production unit in Lindås could offer. The consequence of this was that local sales companies felt they had a need to store pumps locally in order to guarantee a high degree of service towards the customer and since each subsidiary, or sales company, controlled its own market this also implied that they could decide on the inventory levels necessary to guarantee a certain level of service towards the customers. A consequence of this was that there were a vast amount of pumps, spare parts, and accessories being held in stock at multiple places throughout the European market.

This lead-time gap also had a direct impact on how the sales companies typically handled an order. Even though the intention was that all orders should be passed on to the production unit in Lindås, this was not however what occurred in most cases. The situation that often appeared instead was that the order was *"short circuited"* by the sales company, meaning that the order was not passed on to the production unit. Instead a sales company typically fulfilled an order in one of two ways. One way was to simply supply the customer with a standard pump that they had in stock at that moment in time. Since the sales companies argued that there existed a lead-time gap they tried to forecast the demand for standard pumps and order these pumps in speculation and therefore in many cases the order could be met in this fashion.

However, there also existed instances when a standard pump did not fit the requirements that a customer had, but even so these orders were still fulfilled by the local sales companies without having to pass them on to the production plant in Lindås. The reason for this being that there existed personnel at most sales companies that had vast technical knowledge as well as experience about the assortment of pumps that ITT Flygt sold and thanks to this knowledge they managed to rebuild standard pumps to suit customer specifications. In other words all sales companies typically worked according to a production system where they themselves could decide when to order a new batch of pumps from the production unit. For the production unit in Lindås this meant that the demand could be quite uneven over the year and that it was quite difficult to forecast the production.

Each sales company received their products from Lindås and the number of deliveries was dependent on the size of each sales company, as measured by sales volume. Accordingly Austria, Belgium, Ireland, and the Netherlands were to receive shipments once a week, whereas Germany, France, Italy, and Great Britain were scheduled for deliveries twice a week. Since each local subsidiary functioned as a separate entity they were also able to decide on what carrier to use and they also had full budget responsibility for all transportations. A direct consequence of this was that there almost existed as many carriers operating throughout Europe, as there were sales companies since each sales company often closed contracts with carriers that suited their particular demands. This also implied that there were many different carriers picking up the products at the production plant in Lindås, each potentially working in a somewhat different manner regarding how the pumps should be loaded onto the lorries.

Besides this normal flow of transportations there also at times existed a demand for emergency deliveries, which was used when a customer needed a product urgently that the sales company could not offer due to not having it in stock at the moment. The decision whether or not to use this type of delivery was also a decision that was completely in the hands of the sales companies since they carried the cost of this transport themselves. When measured by number of deliveries, this type of delivery accounted for a rather large amount of total transportations; but even though emergency deliveries were large in absolute numbers most of the time they comprised of smaller products and spare parts, meaning that the total weight that was sent this way was not in proportion to the amount of deliveries. Nevertheless, these deliveries were typically handled by means of airfreight, which meant that they were costly for the sales companies.

Besides these emergency deliveries there also existed another type of express delivery, a type that could be labelled service related express deliveries. This type of delivery was common for products being shipped from the sales company to the customer and was used when the customer so requested. However, in the case of Flygt Great Britain this type of express delivery was also used to ship products from Lindås. Under normal circumstances a product destined for the UK market would first be transported by road from Lindås to Gothenburg, which would then be followed by a ship transport and then another road transport within Great Britain. Flygt Great Britain argued that this transport procedure was too slow in many cases and that their customers demanded faster deliveries. For this purpose a constant express solution was set up for this market, a solution that entailed a road delivery service that guaranteed 48 hours delivery time. This was accomplished by transporting the goods from Lindås down to France and then through the channel tunnel. These transfers were quicker than the regular road transport but also less expensive than emergency deliveries and it was a solution that Flygt Great Britain used for a large portion of its shipments.

When the German, French, and Italian sales companies placed an order to the production unit they did this through an EDI interface, whereas communications between Lindås and the other sales companies was either handled through fax, telephone, or mail; which of course meant that the information lead-time could also vary in the supply chain. If a sales company wanted to change an order they had placed to Lindås they could do this until two weeks before the goods were to be shipped, since otherwise there would not be sufficient time to change the order.

A lot of the times a sales company does not merely supply the customer with a pump, but rather a complete function that suits a specific demand. In order to be able to achieve this, sales companies sourced accessories locally and this type of procurement made up approximately half the worth of what a sales company bought in a year. Given that every market was considered to be a market with unique customer demands this of course resulted in every sales company having their own local suppliers of accessories. The effect of this of course being that for the system as a whole there existed a variety of accessories that in fact had the same function.

The situation described above held true for almost all of the pumps that were being produced in the Lindås plant. These were pumps of a more or less standard character, albeit the local sales company often reconfigured them before they were shipped on to the final customer. There also existed a second category of pumps, namely pumps that were produced for larger projects, pumps that can weigh up to ten tonnes. These larger pumps were usually shipped directly to the customer without stopping at the local sales company since they were often built for a particular project. Also, these pumps are so large and heavy that personnel tries to avoid lifting them off the lorry if it is not absolutely necessary to do so. In these cases the customer received two different shipments, one with the larger pump coming directly from the factory in Lindås and one shipment with all the accessories that were required to install the pump, and then these two flows were joined at the installation site.

In summary the decentralised distribution system could as a whole be considered as somewhat complex and demonstrated the following characteristics:

- Local sales company acted independently and saw their markets as unique.
- Large amounts of capital were tied up in the distribution system in the form of local inventory due to a perceived lead-time gap between the demands of the customers and what the factory in Lindås could offer.

- Orders were not directly passed on the production units, which meant that the demand at the production unit in Lindås could be quite uneven.
- Only the larger sales companies had an EDI interface with the production plant, whereas the smaller sales companies communicated via telephone, fax, or mail.
- A vast amount of carriers were employed since each sales company handled the procurement of transport services for their respective markets.
- Emergency deliveries were used quite extensively as well as service related express deliveries, such as the case with the UK market.

Even though a decentralised distribution system had been seen as a natural way of handling the distribution part of the logistics process for ITT Flygt, it was from a central viewpoint starting to be realised that this type of system was not beneficial from a holistic perspective, as will become evident in the following section.

4.2.2 A changing market gives birth to the idea of a new distribution system

In the early 1990s ITT Flygt realised that the market for submersible pumps in Western Europe was starting to become saturated since almost the whole of the European Union, or at least what used to be the European Union back then, had been connected to some kind of waste-water system. The company comprehended that this would change the European market into more of a replacement, or spare parts, market. This, along with an increased pressure on prices due to competitors, and the fact that the market in question made up for most of the company's sales, meant that the company saw its margins starting to decrease and this was worrying. Management drew the conclusion that it would not be sufficient to try and cut costs and make small adjustments in the regional sales companies in order to break this trend, but rather there was a need for larger, more comprehensive changes. Upon reviewing what could be changed it was concluded that there were some areas in close relation to the customers where the company felt that they did not want to make any changes, since such changes could affect the relation to the customers in a negative manner. Instead ITT Flygt's logistics operation was highlighted as an area in which the company could improve and excel in the future by changing the design of the distribution system.

Actually, there where discussions being held within the company already during the 1980s on whether or not logistics activities should be centralised. Although these plans were not put into action, these discussions could be said to have been the embryo to the intensified discussions that were to be held about a decade later. In the early 1990s it was being realised that many things would change on the European market in the years to come, especially from a Swedish perspective with the prospect of entering the European Union. A pre-study was launched with the aim of presenting whether or not it was actually possible to do things differently regarding how operation of the European market was managed. The European Director headed the study at that time, whereas the directors of all subsidiaries were excluded from this process. This had the consequence that the presented ideas were not met with open arms when they were presented. Instead of embracing the idea of a centralisation of the distribution system it was concluded that the company was not mature enough to make such changes in its operations since all the local sales companies operated in an independent and uncoordinated manner.

However, these general ideas of restructuring the European logistics operations were kept in the organisation and three years later a new pre-study was initiated. This second pre-study was launched in 1994 and ran until 1996, and quite early on the conclusion was made that if ITT Flygt was going to remain competitive in Europe in the long run, there was a need to change the way in which the company acted logistically and operationally. By this time Sweden had already held a general referendum with the result that Sweden was going to join the European Union on January 1st 1995. Hence, now there was, from a Swedish perspective, an opportunity to start sending lorries from one country to another without having them stop at various custom controls and without worrying about import/export declarations.

This time around the Operations Director of ITT Flygt oversaw the study with a group staff of about ten. Directors of all the subsidiaries, as well as logistics personnel, were also invited to participate in the discussions, which meant that this time around management was able to anchor the overall ideas in the company in a better way. However, there were still many sceptics. The idea of a centralised distribution system was discussed, since many companies had been successful in implementing such a logistics solution during the 1980s and early 1990s. Issues such as standardisation of assortment and number of shipments were discussed from a theoretical perspective to see what could be achieved by introducing changes within these areas.
Out of these discussions, as well as through an overview of the decentralised distribution system, two important conclusions were made. First, an alarmingly large portion of the pumps being sold actually came from the group of pumps each sales company had stored in their warehouses instead of coming from the factory. Second, even though sales companies were close to the market they could not offer a high and consistent level of service towards the final customer.

4.2.3 A project plan is presented

The pre-study ended in 1996 and a Project Appropriation Request (PAR) was compiled for, what was to be called, Project Europe and presented to ITT Industries. The project was an attempt to improve the company's overall performance on the European market and it was divided into five different sub-projects: standardisation, centralisation of inventory, finance, sales, and IT/IS. For the centralisation project, which is the focus here, the aim was to change the previously described decentralised distribution system to that of a centralised distribution system.

In the Project Appropriation Request management of ITT Flygt presented an overall objective, which was to give savings in sales company logistics costs and inventory, while simultaneously improving on the delivery service to the final customer. Also a number of targets were posted that were to be reached in order for the project to be considered a success. A time plan was set that stated that the project should be completed by year-end 2000, meaning that by this date all eight sales companies should be connected to the new central warehouse. In order to carry out the project a rather large financial investment had to be made; but it was estimated that the savings the company would make, through lowered inventories and burden costs, this investment would be paid back rather quickly.

Even though these financial objectives were important, the paramount object for the whole change was to improve the service offered to the final customer. It was emphasised that in the ITT Flygt world, *"Business is Local"* and therefore the relation to the final customer was in no way to be jeopardised by the change; meaning that during the change process the customers should not be affected in any way. The general consensus was that the company needed to offer a high degree of service towards its customers, not only on the European market but also on other markets. In line with this reasoning it was assumed that there was a need to standardise the way the company acted in its logistics activities and a centralised distribution system was one step towards this vision. If the company was able to fulfil both the service objectives and the financial objectives described above then this would mean that the margins needed from the European market could be secured for the foreseeable future.

4.2.4 Preparing to put the new distribution system in place

In July 1997 ITT Industries approved the Project Appropriation Request that had been presented and staff belonging to the corporate logistics function started working on getting the new central warehouse in operating condition for the planned opening of January 1st 1999.

Quite early on an important question arose, which the logistics function group had to find an answer to. What they needed to know was how fast a pump needs to be delivered from the central warehouse to a local sales company or final customer. From a theoretical perspective it was concluded that each sales company could probably deliver a pump faster than a central warehouse since each sales company kept its own inventory. However, this would often be offset by the fact that each sales company could not store all pumps locally and consequently a sales company could only offer a short lead-time for those pumps presently held in stock. Thus, it was argued that a central warehouse could improve on the service performance seen from a more holistic perspective of the distribution system. The reason for this being that a central warehouse can hold a greater range of products in stock and also balance out oscillations in demand from the various markets.

The group went out to all the sales companies and discussed this issue in order to obtain their point of view on the topic. What many of the sales companies declared were unreasonable demands and scenarios for what the customer required of them. For instance, the Dutch sales company argued that all of their customers, irrespective of them being located on the mainland or on one of the smaller islands outside the coastline, typically needed a delivery within 24 hours from the time of the order being placed. Even though it was questioned whether or not this was actually reasonable, representatives of the sales company were sure that this was what the customers demanded from them and this was the level of performance they needed to show in order to be competitive. As a consequence it became necessary to go through saved order data in order to see if this was really the case and thereby it was proven that it was not the case that all customers needed to be supplied within 24 hours. In fact, all customers were not even being supplied in 24 hours or less as had initially been claimed.

Overall, many sales companies insisted that they could show a fairly high degree of service towards its customers and statements suggesting that a service level of 100 % was held at all times were not that uncommon. However, after scrutinising such statements it turned out that what the companies actually managed was to offer its customers a delivery time of 24 hours on the specific pumps that were held in stock. For all other occasions when the pumps needed to be ordered from the factory in Lindås the lead-time was considerably longer than the manifested 24 hours. In other words the sales companies did not live up to the statement of holding a service level of 100 %, which they had put forward as an argument for not changing to a centralised distribution system. In fact the sales companies were in most cases not able to present any figures indicating how they performed regarding service. However, investigations made by external consultants indicated that the average sales company offered the customers a service level that was well below 100 %.

In conclusion it was found that the sales companies could not offer the level of service ITT Flygt felt it needed to achieve in order to secure its financial margins on the European market. It was also concluded that customers very seldom required having a pump delivered to them within 24 hours, as it had been stated by some of the subsidiaries. However, it was agreed upon that swift deliveries were important and therefore the central warehouse needed to be geographically located in such a manner that it should be possible to deliver the standard assortment of pumps within a time frame of 24 to 72 hours with the normal means of transportation. Since the company's largest markets in Europe were, and still are, France, Germany, and Italy it was important for the warehouse to be located somewhere in the heart of Europe. The Benelux region and the southwestern parts of Germany were seen as possible locations, but finally the decision was taken to locate the new warehouse in Metz, France. The reason for this could be said to be two-fold. First of all this location fulfilled the criterion of being in the heart of Europe from an infrastructural perspective. Besides having good road connections Metz had another advantage and that was the presence of a rail connection, and this was seen as a clear benefit since regulations in the future could force companies to convert some of the shipments from road to rail in order to salvage the environment.

A second reason why Metz was chosen was more political. France had some of the most strict laws and regulations regarding redundancy, which meant that it would be more difficult to dismiss personnel in France than in other countries and, given that it is one of ITT Flygt's more important markets in Europe, the local sales company had a lot of personnel employed and dismissing many of them could prove difficult. Also, the region surrounding Metz had rather high unemployment rates and the company was promised grants by the French government if the new warehouse was to be located there.

Besides solving such issues as where to place the new warehouse that was to replace the eight local warehouses, there also existed other important issues that were investigated during this time. One important issue was which pumps were to be stored in the new warehouse in comparison to the overall product range. Earlier it was briefly described that ITT Flygt has, what at best can be explained as, two categories of pumps. The first category includes those pumps that each sales company quite often would order in speculation from the production unit in Lindås and then reconfigure to fit certain customer demands and this category accounts for most of the sales, as measured by units. The second category of pumps is that where the pumps are specially designed to fit customer demands already at the production unit in Lindås. These are pumps that are typically manufactured for larger projects and the planning horizon is generally longer than for the first category of pumps. When the idea of a central warehouse was discussed it was never the intention to centralise warehousing and distribution of the second category of pumps, since they were produced according to specific customer demands and therefore it was already known where they were to be shipped upon completion. Instead it was the first category of pumps, those that could be described as the standard assortment of pumps, which were to be the object of centralisation. However, there also existed variances within this group of pumps. Some pumps were not sold that often by the sales companies and therefore a limit was set stating that those pumps that were to be stored at the new warehouse in Metz needed to reach a certain level of turnover, whereas pumps with a lower inventory turnover rate were to be stocked locally. Hence, the centralisation of warehousing and distribution was only going to affect certain parts of the product assortment. *Figure 26* below illustrates the change that ITT Flygt wanted to conduct for the standard assortment of products.

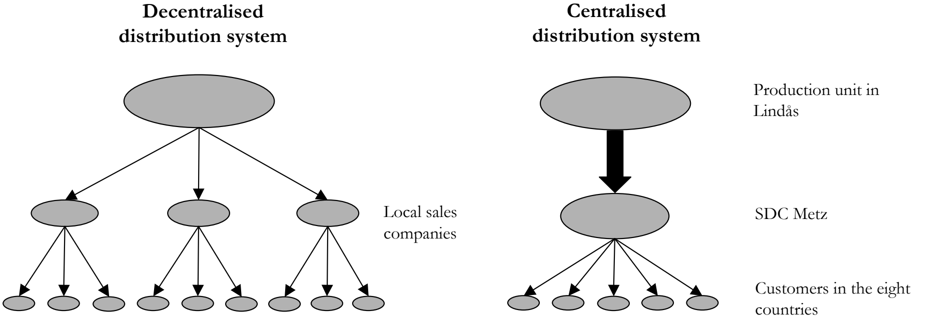

Figure 26: Depiction of generic distribution flows in ITT Flygt's centralised distribution system

Another issue that was investigated during this time was how transportations were to be handled in the new system. Previously all sales companies were within their own rights to select the carrier that best suited their needs and consequently there was a vast amount of carriers executing transfers within the ITT Flygt distribution system. From a central viewpoint it was argued that instead it would be more beneficial to sign centrally negotiated contracts for the whole of Europe with various carriers, contracts that were then to be used by the local sales companies. The logic behind this was that even though each sales company claimed they had their own specific demands on a carrier, the service the various carriers provided did not in fact not differ that much. There also existed a will to decrease the number of carriers and in the future only turn to one or two carriers in order to obtain better prices due to having a larger portfolio to bargain with. This issue was later added to the project and the goal was to ensure that transport costs should at least not increase through the implementation of the new central warehouse. However, the budget responsibility for the transport costs was to be maintained by the local sales companies.

All in all there were many issues that had to be solved before the shovel could be put to the ground and many were the sceptics that did not believe that the site could open its doors on the date presented in the Project Appropriation Request. However, on January 1st 1999 operations were initiated and the roll out plan of connecting all of the sales companies to the new distribution centre was put into action.

4.2.5 The new Supply and Distribution Centre is launched

During the pre-study and the work leading up to the launch of SDC Metz a schedule had been laid out for when and in what order each an every sales company should be attached to the new system. The idea was to start of with one or two of the smaller sales companies in order to get the momentum going and then change over to the largest sales companies in order to achieve some so called quick wins. The Austrian and British sales companies were attached to the site in SDC in January and March respectively, and this was done without any larger problems occurring.

However, halfway through the first year it became time for the French sales company to be connected to SDC Metz and problems arose. The situation ITT Flygt faced acts as a good example of how even though it in theory sounds like an easy task to pack up a local warehouse and ship the parcels to another location and have these unpacked there, this might not be the case in real life. A problem that had not been anticipated was that among all of the articles that were shipped to SDC Metz there were pieces already allocated to a certain customer. This meant that instead of these pumps and accessories being shipped out by the local sales company to the end customer they were on their way to Metz in order to be stored there. To further enhance this problem there were no bills or packing notes on any of the pallets to indicate which parts were packed where, so in effect there was no way of knowing which pallet to look for in order to find already customer-allocated pumps and accessories. Besides these items, pumps and accessories of a non customer-allocated character were also coming in to the SDC. Among these products were articles that there was not necessarily a market demand for, in other words the SDC received a lot of articles that had a low turnover rate and the consequence of this was an initial increase in stock levels. These circumstances led to the SDC having a breakdown and it was decided that the phasing in of further sales companies would be put on hold. This was done because it was of paramount importance that the end customers should not notice anything of the change, albeit that the decision had the implication that the timetable for the overall connection of sales companies to the SDC was delayed. In other words, from the customers' point of view everything was running smoothly and each sales company was able to offer the same level of service as they had done previously.

Another problem that SDC Metz faced in its infant stages was related to changes in the IT/IS system. Before the decision to centralise distribution was taken many of the sales companies only communicated with the factory in Lindås through fax, telephone, and mail, but with the initiation of the new distribution centre it was decided that all sales companies should handle their orders to SDC Metz by EDI communication. However, in a similar fashion to the description above this change also caused some turmoil and there were two reasons for this. First, the internal system in Metz was at first relatively slow and it could take minutes from when a picking order was executed in the system until the request arrived to those who were actually going to pick the products in the warehouse. Hence, if the orders are received at two in the afternoon and they need to be ready for shipment two hours later every minute is of the essence in order to be able to finish picking and packing all the goods that are to be shipped that day. Second, at first the rules of the IT/IS system were configured so that orders that had not been picked were granted priority over new orders coming in. Thus, even though a sales company had managed to put in an order before its cut-off time this order could get stuck in the system and not surface until hours later and consequently the order could not be shipped as promised initially.

Instances as those described above meant that the initial start-up phase for SDC Metz was quite hectic and many issues that were not thought of earlier emerged, and the abbreviation C in SDC was by many jokingly considered to mean *"clean up"* instead of *"centre"*. Today, however, operations run smoothly.

4.2.6 Description of operations in the new distribution system

Earlier it was described how in its infant stages the centralised distribution system faced some problems upon phasing in all of the sales companies, but once those problems were handled much of the work has revolved around making the new distribution system function even better. One such area has been that of transport agreements. In the decentralised distribution system, where all sales companies could independently choose what carrier to use, there existed numerous carriers. With the centralisation came a change that meant that more of a corporate approach was taken regarding transport agreements and this change was completely finalised in 2003 when the transport contracts were renegotiated. Today there are two main carriers operating within the ITT Flygt distribution system, DHL and Wincanton.

The former is responsible for all shipments leaving the production unit in Lindås and the arrangement is such that DHL has at least one dedicated lorry leaving for Metz every workday and on average SDC Metz receives six to seven shipments each week. DHL is also responsible for those shipments destined for a sales company or a final customer, i.e. that flow of products that was to the object of centralisation; for this type of shipments goods are picked up on more or less a daily basis and then transported through the DHL transport network. For the shipping unit in Lindås this change, i.e. to that of only working with one carrier, has meant that the daily working routine has been simplified due to the fact that there now only exists one interface instead of multiple ones, which was the situation in the old distribution system.

The new unit in Metz employs approximately 74 employees and the facility measures 9,200 square metres and has the capacity to store 14,000 pallets. SDC Metz is considered to be the internal logistics dedicated tool to provide all customers with the best delivery conditions on new or existing needs. Besides being supplied with goods from the factory in Lindås, SDC Metz also receives shipments from ITT Flygt Werk and ITT Lowara, factories that are located in Germany and Italy respectively. The latter is a company that belongs to the ITT Fluid Technology division, where ITT Flygt is responsible for distributing these products to ITT Flygt sales companies and customers. Originally the facility was planned to measure 7,000 square metres, but a decision to include the Lowara assortment meant that the original project plan was revised.

SDC Metz supplies four major types of products, construction and mining pumps, waste and process water pumps, mixers, and industrial pumps. Every day shipments leaving SDC Metz are split among eleven different lorry departures that are handled by Wincanton and with its geographical location in the heart of Europe it is possible to supply all of the eight sales companies within 72 hours of acknowledged order confirmation.

In addition to this the distribution centre also receives goods from many external suppliers of accessories in ten European countries, which amounts to vast numbers of receptions every week. Before the idea of a SDC was converted into concrete actions ITT Flygt had already during the 1990s made attempts at standardising some of the accessories for the pumps and this standardisation was completely separated from the SDC concept. Earlier each sales company sourced this locally, but central management at ITT Flygt saw an opportunity to standardise some of these accessories. This change was a hard battle since many sales company directors in this case as well argued that their customers had particular demands and that consequently it was vital to source the accessories locally. However, today some portions of the accessories are standardised and these are stored in Metz and consequently shipped together with the pumps to either the sales company or the final customer.
Today, much of the work with SDC Metz revolves around increasing the operational efficiency and leveraging the full potential from the concept of centralisation. In their quest to become more efficient in how transportations are handled the company has undertaken a project aimed at improving the fill-rate for all incoming as well as outgoing transfers in relation to the production unit in Lindås, from which the latter are of interest from a distribution perspective. The personnel involved asked themselves what could be done better in order to improve on the efficiency in relation to transportation and the conclusion was made that there existed a number of areas where improvements could be achieved.

One area concerned transport scheduling, especially from Lindås to Metz. Prior to 2003 ITT Flygt employed Wincanton for this flow, but it was realised that even though Wincanton was a good partner for the European market the carrier did not have the same presence on the Nordic market as some of its competitors. In order for Wincanton to carry out the transportations between Lindås and Metz they needed to know the amount of goods that were to be shipped at least 48 hours before dispatch. This was due to the fact that they did not have their own transportation network for the Nordic market and therefore sourced these services from other carriers. In 2003 ITT Flygt instead started to use DHL, which through various acquisitions had a more profound presence on the Nordic market than Wincanton. A consequence of this was that ITT Flygt could work with a time horizon of only 24 hours when planning their shipments to Metz. This change has had the result that ITT Flygt today has been able to streamline the way they handle their work in dispatch due to the fact that the planning horizon has been cut by one day. At present ITT Flygt has a dedicated lorry on a daily basis between Lindås and Metz as well as two to three extra lorry deliveries per week when so needed.

Besides changing carrier for some of their flows ITT Flygt also found a number of operative areas where improvements could be made, which mostly concerned packaging and loading. It was found that some of the packaging was carried out in a somewhat inefficient manner and that some parts could in fact be packed and shipped in a more space efficient method than earlier. ITT Flygt are themselves responsible for planning what should actually be shipped each day and therefore personnel were educated on how various products can be loaded in different ways in order to improve on the overall fill-rate. All in all these changes have had the result that ITT Flygt has been able to improve on its overall fill-rate for the flow between Lindås and Metz. This is illustrated in *Figure 27*, which shows comparative figures for 2003 and 2004.

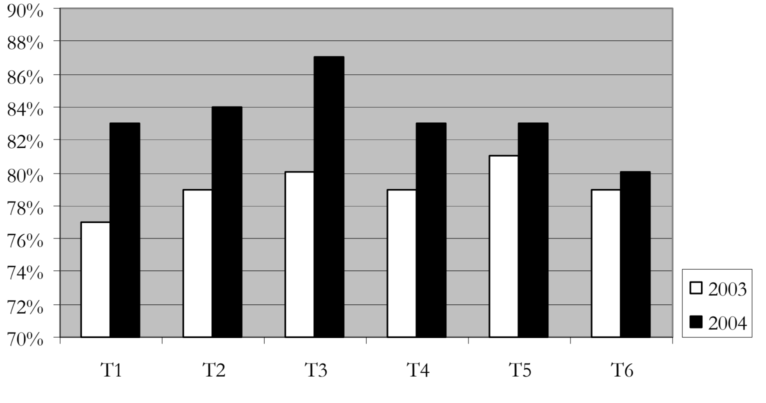

Figure 27: Fill-rate comparison between 2003 and 2004 for transfers between Lindås and Metz[5]

The fill-rate project has not been exclusive only to the flow of goods between Lindås and Metz, but has also involved the flow of goods between Lindås and the sales companies/final customers. However, a comparison between 2003 and 2004 (see *Figure 28*) show that the improvement that

[5] The time-period that is used has been indexed for reasons of confidentiality.

has been achieved for every time-period for the flow between Lindås and Metz has not been achieved for other outgoing flows to the European market.

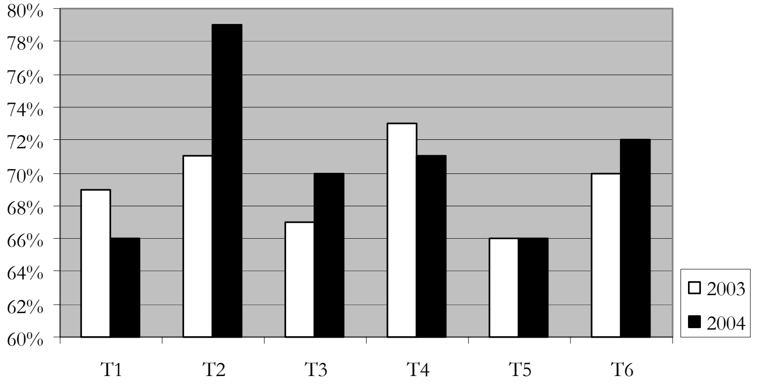

Figure 28: Fill-rate comparison between 2003 and 2004 for transfers between Lindås and sales companies/final customers

Prior to as well as subsequent to the implementation of SDC Metz the preferred mode of transportation within the distribution system has been road transport. When the geographical location of the new distribution centre was discussed an important aspect that was considered was how well the transport infrastructure could support ITT Flygt's operations today as well as for the future. An aspect that favoured Metz was that it had the presence of a rail connection, thus enabling future rail transport. Since SDC Metz has been put into operation there have been tests carried out where goods have been shipped by train from Lindås to Metz. The results of these tests show that transfers have ended up taking more than double the time to get to Metz and the cost of transport has turned out to be more expensive than if they had been carried out by road transport. In addition to this a larger proportion of the goods were damaged during the transport and in summary it has been concluded that currently the European railway infrastructure does not support the demands ITT Flygt face regarding service and therefore it has been decided that for the foreseeable future road transport will continue to be the preferred mode.

4.2.7 Results of the structural change from an ITT Flygt perspective

Earlier it was described how a number of targets were set in order for the centralisation project to be considered a success, all of which in generic terms were related to cutting costs associated with logistics activities and improving on the service the company were to offer its customers.

In the Project Appropriation Request it was claimed that the project should have been completed by year-end 2000, but with the complications that arose during initial launch phase of SDC Metz the actual completion date was delayed by two years. This of course has also had an effect on how well the project has performed regarding the two most important financial measures, namely inventory costs and burden costs, which both were to be cut substantially. Since the final customer should not notice anything of the change the initial problems caused a short-term increase in inventory levels during 1999. However, by the end of 2003 these figures were better than budget, which is illustrated in *Figure 29* that shows the inventory development in detail for ITT Flygt.

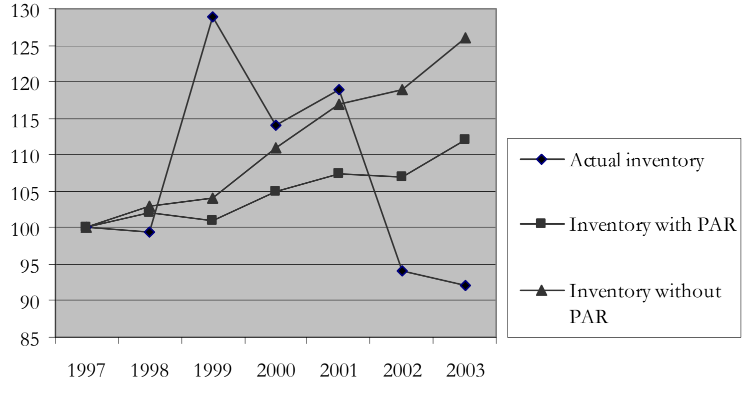

Figure 29: Inventory development between 1997 and 2003[6]

The figure aims at illustrating two things. First it illustrates actual inventory development over the time-period 1997-2003, as well as two different scenarios regarding inventory development for the same time-period. The figures presented are indexed and what the curve *"Actual inventory"* depicts is the development of overall gross inventory for ITT Flygt between 1997 and 2003 by using 1997 as a basis, thus having an index number of 100. The curve *"Inventory without PAR"* shows the amount of inventory it would have been necessary to hold, given real increases in sales volumes and the scenario that the decentralised distribution system had still existed; whereas the last curve, i.e. *"Inventory with PAR"* depicts inventory development as it was anticipated to develop in the Project Appropriation Request.

[6] Indexed values have been used due to confidentiality reasons.

Second the figure also illustrates how sales have changed in relation to gross inventory levels, which is illustrated by the figures next to the curve *"Actual inventory"*. These figures are also indexed and show that the ratio of inventories through sales have decreased over the seven-year period.

Further, the curve showing how actual inventory has changed during the time-period illustrates some interesting aspects. One is that it quite clearly shows how the distribution system was affected by the initial problems that occurred upon phasing in the sales companies, resulting in a peak in overall inventory levels in 1999. Another aspect it helps demonstrate is that by 2002, when these problems had been overcome and all sales companies were connected to SDC Metz, the centralised distribution system started to show its potential, even surpassing the initial targets set in the Project Appropriation Request.

The figures on actual development of inventory levels also point to another interesting occurrence, one that in part took place prior to the launch of SDC Metz. During the final pre-study there existed many that did not view the centralisation project as something positive and in some ways therefore tried to persuade central management not to follow through with the plans, since there existed a need for a decentralised distribution system due to perceived variations in customer demands for the concerned markets. However, once the decision was taken to go through with the change many of the sales companies started to adapt to what was to come in 1999, i.e. the connection to SDC Metz, and consequently they slowly started to decrease their inventories to quickly adopt to the new system and this is why overall inventory levels initially decreased slightly.

The second type of cost that was important was burden costs or local logistics costs for such areas as material handling, warehouse rent, and personnel. These costs were also targeted to decrease by a substantial amount and, just as with inventory costs, this target was met but the procedure did not follow the project plan. In an opposite manner to inventory saving, burden costs were decreased faster than projected early on, whereas figures later on showed that burden costs decreasing at a slower rate than anticipated in the Project Appropriation Request. The reason for this development is coupled to the previous discussion. When it became evident to the sales companies that ITT Flygt would go through with the project they started to adapt their operations accordingly. The initial results that were better than planned could thus be explained by the fact that sales companies that had personnel that were anticipated to go into retirement in a year or so were not replaced by new personnel. The latter results can in turn be attributed to the fact that the connection of all sales companies was delayed due to the initial problems.

Another cost issue that was of relevance during the structural change was that of transport costs. During the discussions leading up to the centralisation the sales companies argued that they could obtain better transport prices through local negotiations since they knew their respective markets. However, just as it was with the situation regarding the service levels each sales company could offer its customers, very few of the sales companies could show any reliable data. Some sales companies did not even have a cost of transport according to themselves. After the centralisation was carried through and the procurement of transport services was centralised there have been many discussions and the sales companies have time and again claimed that they would be able to obtain better transport prices if they were allowed to procure these services themselves. However, various inquiries made to carriers have shown that this would not be the case and today the sales companies are satisfied with the transport situation. As described above it is difficult to make a 100 % accurate assessment of how the transport costs have changed due to the structural change, but it is believed that they have not increased even though the amount of transport has increased.

There are three reasons for this. First ITT Flygt has been able to negotiate better overall transport prices due to an increased leverage since the procurement of transport services are now handled centrally. Second, the amount of emergency deliveries have decreased and these are generally more expensive that regular deliveries. Finally, the cost of service related express deliveries have decreased as a consequence of the structural change. The best example of this is Flygt Great Britain, which earlier had a constant express solution in place, a solution that is no longer needed in the centralised distribution system.

Even though the financial objectives described above were important in order for ITT Flygt to secure its margins on the European market, the paramount objective for the whole change was to improve on the service offered towards the final customer. When the group belonging to the corporate logistics function prior to the inauguration of SDC Metz had discussions with the affected sales companies the intention was to try and measure what level of service each sales company could offer its customer. However, this proved to be a tedious task and it was very difficult to obtain any useful performance data on this issue due to the fact that every sales company had their own way of defining what service entailed. However, the conclusion that could be made was that the sales companies did not live up to the degree of service that they themselves claimed they offered their customers. Therefore, although it has been difficult to measure the improvement in service, the service level has without a doubt increased with the new centralised distribution system. Today SDC Metz keeps records on the level of service that ITT Flygt offer all sales companies and final customers, and in 2003 a service level of approximately 95 % was achieved (see *Figure 30*).

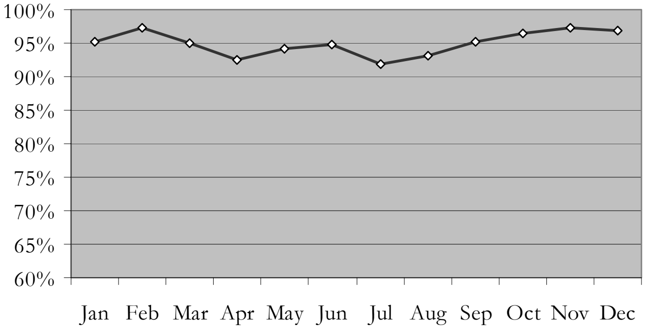

Figure 30: Monthly delivery performance for SDC Metz 2003

This measurement refers to how many of the orders SDC Metz has been able to ship so that a sales company or a customer has this order within the requested time window, which generally is 72 hours, from the time the order has been placed and accepted. It is also important to point out that today SDC Metz is evaluated on whether or not it can deliver a product on the requested day, whereas previously the sales companies were evaluated on whether or not they could deliver a product on the requested week.

Besides these figures SDC Metz can also show off a low level of claims due to issues, such as when the wrong product is picked and shipped, and this figure has steadily been improved so that for 2003 claims only amounted to 0.5 %.

In summary the project has turned out to be a success for ITT Flygt and today efforts are directed towards streamlining the new system and making more incremental changes in order to improve on the overall performance. However, there still exists one aspect of the structural change that has not been presented yet, which at the same time is of great importance for this thesis, and that is the environmental consequence of the change. This is the theme for the subsequent chapter, i.e. the analysis.

5 Analysis

The previous chapter presented how ITT Flygt conducted a structural change in its distribution system, but there was no mentioning of the environmental effects of this change. This is the focus in the analysis that follows in this chapter, an analysis that takes on an environmental perspective. The analysis is divided into two parts. The first part is focused on illustrating how the structural change conducted by ITT Flygt has affected the amount of tonne-kilometres and also carbon dioxide emissions that are generated by the distribution system. The second part aims at illustrating how the structural change itself has also given ITT Flygt an opportunity to make environmental improvements in its logistics operations as a consequence of the structural change.

5.1 Introduction

Prior to the implementation of the new distribution system ITT Flygt had a decentralised distribution system and, as indicated by the case description, the customers were supplied with most of the products by the local subsidiary for that particular market. These sales companies were more or less considered to be autonomous companies, but with the common denominator that they all received their products from the same supplier, namely the production unit in Lindås.

The goal with the structural change was to transform the way the customers were being supplied with ITT Flygt products, or rather in more specific terms how they were supplied with the standard assortment of products. The overall idea was to short-circuit the sales companies in the physical distribution process, which was accomplished by setting up a Supply and Distribution Centre (SDC) in Metz, France. With the new distribution system all of the products that are classed as standard assortment, meaning that they have an inventory turnover rate that exceeds a certain value, are kept in stock at the SDC and the customers are supplied directly by the SDC, rather than by each sales company (see *Figure 31*).

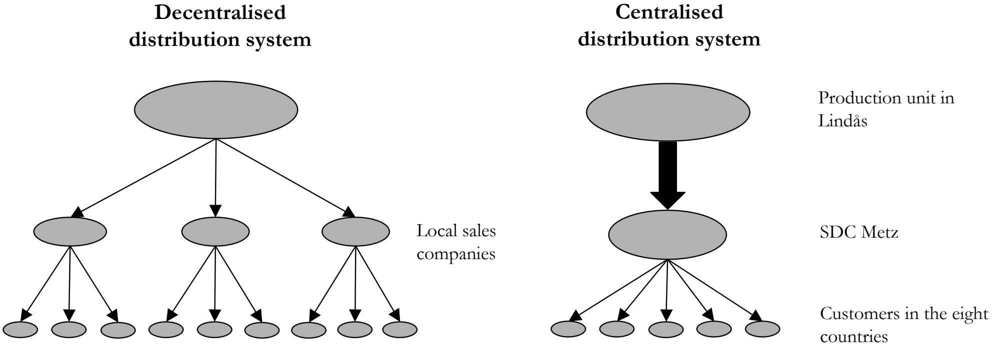

Figure 31: Generic illustration of ITT Flygt's structural change

When the structural change is presented with such a generic illustration one might think that the transport situation, and consequently also the environmental impact, might not have changed that much. Throughout the analysis it will become evident that this is hardly the case. In fact, the structural change that ITT Flygt has carried out has had a significant impact on the physical structure of the distribution system. However, the structural change has not only affected the set-up of nodes and links in the distribution system, but also ITT Flygt's possibility of making logistic decisions that are considered beneficial from an environmental perspective.

Figure 32 below illustrates the structure of the analysis and the starting point is that the analysis will add an environmental perspective to the structural change that ITT Flygt has conducted to the already existing perspectives of costs and service. If an analysis of these latter effects had been the focus of this thesis it would have been argued that ITT Flygt has achieved what Abrahamsson and Aronsson (1999) label *"quantum leap improvements"*, since it has been proven that the company has made large improvements in both of these areas.

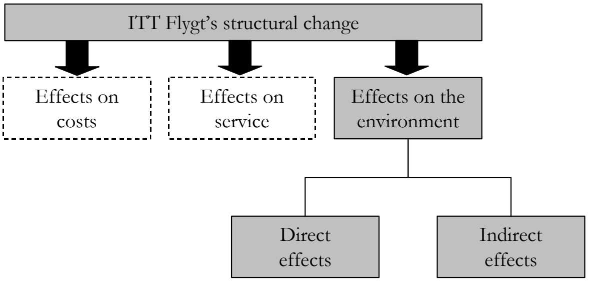

Figure 32: Structure of the analysis

As indicated by the figure above the analysis is divided into two parts, where the first part pays attention to the direct effects of the structural change and the second part is focused on the indirect effects of the structural change.

The first part compares the physical structure of the two distribution systems and an analysis is made regarding the effect the structural change has had on the amount of tonne-kilometres and carbon dioxide emissions generated by transportations in ITT Flygt's distribution system. The analysis only presents the results of the calculations that have been conducted, whereas *Appendix D* gives a more thorough description of the calculation procedure.

The second part focuses on aspects that are of a more qualitative nature in comparison to that which is presented in the first part of the analysis. Here an analysis is made of how the decision to centralise the distribution system has given ITT Flygt opportunities to make environmental improvements in its logistics operations, opportunities that did not exist in the decentralised distribution system.

At the end of each of the two analyses a summary is made presenting those findings that are of relevance for the continued discussion in the subsequent chapter where the conclusions from this study are presented.

5.2 Direct effects of the structural change

When ITT Flygt decided to centralise its distribution system this was partially done in order to improve on the service the company could offer its customers. As the case description illustrates ITT Flygt found that even though the sales companies are located closer to the final customer than a central distribution centre in most cases, thus implying shorter distances and quicker transport of goods. This geographical closeness to the customer was often offset by the fact that the local sales company could not hold a full assortment of products in stock. Hence, even though the sales companies had a theoretical lead-time of 24 hours to the customers in their respective countries it was only possible to maintain this level of service for a relatively small part of the product assortment. With a central distribution centre ITT Flygt has the opportunity to hold a wider assortment of products in stock and the company can today in most cases guarantee its customers delivery within 24-72 hours for the standard assortment of products. These results coincide with earlier research, e.g. Abrahamsson (1992).

It was important for ITT Flygt to have the new distribution centre located in the heart of Western Europe so as to ensure that the customers on its most important markets, i.e. Germany, France, and Italy, could receive fast and secure deliveries. This is not an issue only for ITT Flygt. Many companies that have taken the decision to centralise their distribution systems have done so by setting up a larger distribution centre in south-western Germany, the Benelux region, or the northern parts of France. This is also the reason why many claim that a centralised distribution system in most cases cause a greater environmental impact in comparison to a decentralised distribution system, since the products need to be transported over greater distances in a system of a centralised character (Rodrigue et al, 2001; McKinnon, 2003).

Evidence of this is also found when the structural change of ITT Flygt is examined more closely. In the decentralised distribution system the standard assortment of products, i.e. those products that were the object of centralisation, were transported from the production unit in Lindås to any of the eight sales companies and then onwards to the final customer. In the current distribution system on the other hand all of these products are first transported to the distribution centre in Metz and then to the final customer. This is illustrated in *Figure 33*.

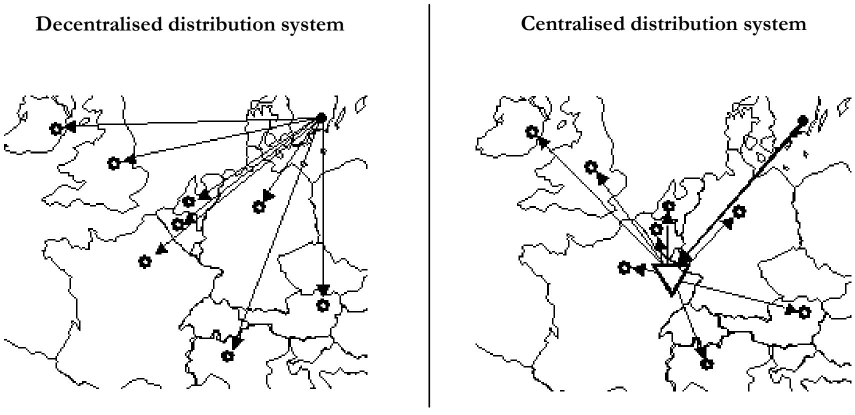

Figure 33: Principle transport situation in the two distribution systems

A direct effect of the change in the physical structure of ITT Flygt's distribution system is that the average length of haul for regular transport has increased from 1,512 kilometres to 2,153 kilometres[7]. This increase has in turn also affected the amount of tonne-kilometres that is caused by transport that are carried out within the distribution system and the calculations that have been made indicate an increase from just less than 2.2 million tonne-kilometres to just over 2.9 million tonne-kilometres, thus implying an increase by approximately 34 %. The analysis also shows that the amount of transport work has increased for each of the eight countries that constitute the distribution system (see *Figure 34*).

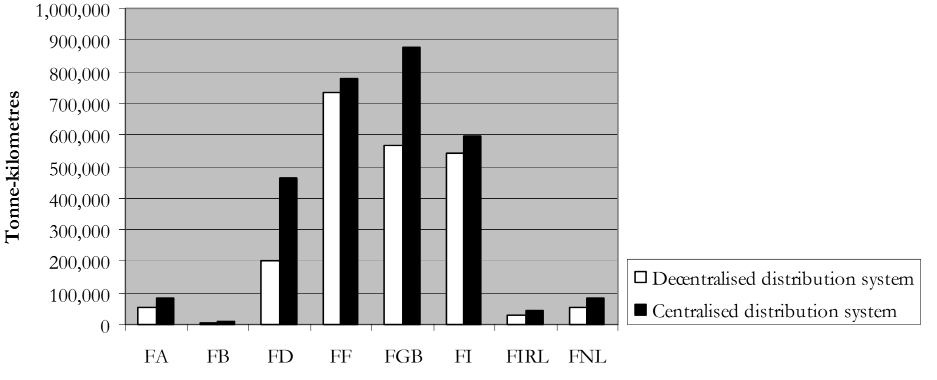

Figure 34: Amount of tonne-kilometres generated by the two distribution systems for each of the eight countries

[7] The average length of haul in the centralised distribution system has been calculated to be between 2,145-2,153 kilometres. The deviation in distance is dependent on the weight of a shipment when it leaves SDC Metz. This is further explained in Appendix D.

These results coincide with the claim made by McKinnon (2003) stating that higher-level decisions, e.g. a decision to centralise distribution, will most likely increase the amount of transport work generated by the distribution system.

The claim made in this study though is that an analysis of how the amount of tonne-kilometres is affected by a centralisation is not sufficient evidence as to indicate whether or not the structural change has had a negative or a positive impact on the environment. Rather, there is also a need to analyse how the actual transport work is performed within each of the two distribution systems in order to give an answer to whether carbon dioxide emissions have increased or decreased due to the structural change.

An analysis of carbon dioxide emissions indicates that these emissions have increased from approximately 92,200 to just over 131,000 kilograms, or by 42 % for the whole distribution system. *Figure 35* also illustrates how carbon dioxide emissions have increased for all of the countries in the distribution system.

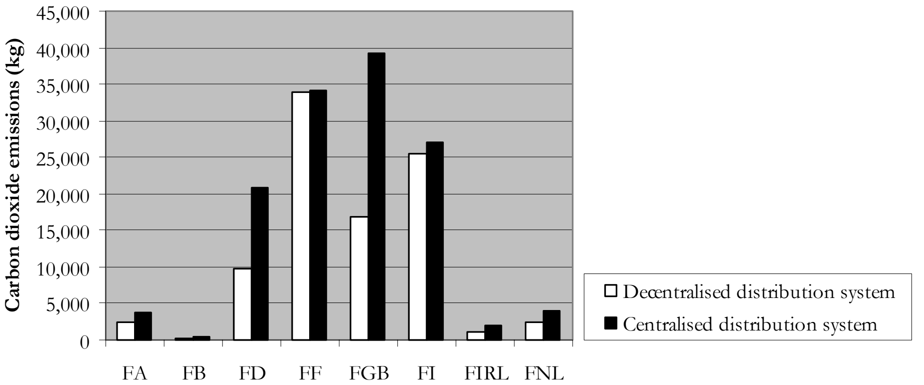

Figure 35: Amount of carbon dioxide emissions generated by the two distribution systems for each of the eight countries

The increase in carbon dioxide emissions is not surprising considering that transport work is generally regarded as an indication of the environmental impact of transport. However, these results do not only indicate that structural change has caused an increase in tonne-kilometres and carbon dioxide emissions respectively, but also that ITT Flygt has experienced a worsening in the ratio of carbon dioxide emissions per tonne-kilometre. This is illustrated in *Table 8* below, which shows that carbon dioxide emissions per tonne-kilometre, as measured for the whole distribution system, has increased from 0.042 kilograms to 0.045 kilograms.

Table 8: Carbon dioxide emissions per tonne-kilometre for the two distribution systems

	Decentralised distribution system	Centralised distribution system
Tonne-kilometres	2,186,146	2,928,666
Carbon dioxide emissions (kg)	92,185	131,149
Carbon dioxide emissions per tonne kilometre (kg)	0.042	0.045

What is then the cause of this deterioration? A closer analysis of the calculations reveals that there are three areas that need to be analysed further in order to give an answer to this question. These three areas are:

- The effects of emergency deliveries
- The effects of the centralised flow
- The effects of a modal shift

5.2.1 Analysis of emergency deliveries

According to Abrahamsson (1992) one of the main advantages with a centralised distribution system is the fact that the need for emergency deliveries should decrease. The decrease in emergency deliveries is also the reason why transport costs can be kept at a relative constant level even though the amount of transport work increases through centralisation. Since emergency deliveries are often performed by use of airfreight, a mode of transport that causes greater amounts of carbon dioxide emissions per tonne-kilometre in comparison to road transport (Lenner, 1993; NTM, 2005), a decrease in this type of delivery should therefore not only enable a company to keep the cost of transport at a constant but also improve the ratio of carbon dioxide emissions per tonne-kilometre for the whole of a distribution system.

In the case description it was illustrated how ITT Flygt has managed to keep the transport costs relatively stable despite an increase in transport work and there were three reasons for this, of which a decrease in emergency deliveries was one.

Data from ITT Flygt seem to support the view that the structural change has indeed led to a decrease in the amount of emergency deliveries. In the decentralised distribution system emergency deliveries caused approximately 3,500 tonne-kilometres of transport work, whereas the centralised distribution system generated a total amount of just over 1,200 tonne-kilometres of emergency deliveries. The corresponding figures for carbon dioxide emissions are about 2,000 kilograms for the decentralised distribution system and roughly 700 kilograms for the centralised distribution system. Hence, the results show that emergency deliveries have in fact decreased by

64 % as a consequence of the structural change, which has also had a positive effect regarding carbon dioxide emissions.

This decrease in emergency deliveries has only had a marginal effect on the distribution system as a whole (see *Table 9*) and the reason for this is that the amount of transport work that was generated by emergency deliveries in the decentralised distribution system accounted for such a small part of total transport work.

Table 9: Comparison of emergency deliveries in the two distribution systems

	Decentralised distribution system	Centralised distribution system
Total tonne-kilometres	2,186,146	2,928,666
Tonne-kilometres caused by emergency deliveries	3,491	1,209
Percentage	0.16%	0.04%
Total carbon dioxide emissions (kg)	92,185	131,149
Carbon dioxide emissions caused by emergency deliveries (kg)	2,048	730
Percentage	2.22%	0.56%

In the case of ITT Flygt this decrease in carbon dioxide emissions of just over 1,300 kilograms has actually meant that the company has been able to increase its transport work of road transport by more than 25,000 tonne-kilometres[8] without causing any additional environmental stress.

In summary the results in the case of ITT Flygt support the claim made by Abrahamsson (1992) regarding the effect centralisation is expected to have on emergency deliveries. They also give support to the argument put forward in this thesis, which is that a decrease in emergency deliveries should not only have a positive effect on the cost of transport but also on the environment. However, the results from this analysis do not give an answer to the question why carbon dioxide emissions per tonne-kilometre have increased in the case of ITT Flygt and consequently the reason why the ratio has increased must be attributed to either of the two remaining effects.

5.2.2 Analysis of the centralised flow

A main characteristic of a centralised distribution system is the fact that all products need to be transported from a factory to a central warehouse. This is also the root cause as to why

[8] Assuming a lorry with a cargo capacity of 26 tonnes and standard diesel.

centralised distribution systems generate more transport work than do decentralised distribution systems, since products are transported over greater distances.

This is also the case with ITT Flygt, where the centralised flow of products runs between Lindås and Metz. This centralised flow is by far the largest generator of transport work as well as carbon dioxide emissions in the current distribution system. In fact, this flow accounts for approximately 65 % of total tonne-kilometres, whereas it causes 60 % of all carbon dioxide emissions. The reason why these transportations, in relative terms, cause less environmental impact in comparison to transport work is because ITT Flygt has managed to achieve a higher fill-rate for this centralised flow, 79 % compared to that of 70 %. This positive environmental effect of centralisation is discussed in greater detail in *section 5.3.2* where the positive effects of consolidation are analysed.

Nevertheless, given that carbon dioxide emissions caused by this flow account for a smaller percentage for the whole distribution system in comparison to tonne-kilometres, the same logic as for emergency deliveries can be applied to these transportations. Expressed differently, an improvement in the fill-rate for this flow should improve the ratio for carbon dioxide emissions per tonne-kilometre, rather than to worsen it. Hence, the effects of the centralised flow cannot help explain why the overall ratio has increased as a consequence of the structural change. The answer to this conundrum is instead explained by the third area, which concerns how the structural change of ITT Flygt has also caused a modal change for regular deliveries in parts of the distribution system.

5.2.3 Analysis of a modal change

When ITT Flygt decided to centralise its distribution system a principle was that the preferred mode of transport for the whole of the distribution system was not to be changed, which in this case was transfers by road. This has had the consequence that ITT Flygt has in parts of its current distribution system come to employ a mode of transport for its regular deliveries that cause greater environmental stress, as measured by carbon dioxide emissions, than was the case in the decentralised distribution system. That part of the distribution system that has experienced this modal shift concerns Ireland and Great Britain, and therefore a closer analysis of these two countries will be made.

In the decentralised distribution system all regular deliveries that were destined for Ireland and a approximately 80 % of the deliveries that were destined for Great Britain[9] were transported from Gothenburg to the east coast of Great Britain by ship and then transported onwards by road. In

[9] As measured by weight.

the case of Ireland a second transport by ship was also necessary to get from Great Britain to Ireland, which was then followed by road transport. Thus, a rather large amount of the total transport work arising from regular deliveries was generated by ship transport.

In the current distribution system all regular deliveries to these two countries first go to the central distribution centre in Metz. From this point they are transported by road to the Eurotunnel from where they are transported by rail[10] in order to get from mainland Europe to the British Isles. Products destined for the British market are then only transported by road, whereas products that are transported to Ireland also need a ship transport to get from Great Britain to Ireland. What has occurred is that in the centralised distribution system a much larger part of the total transport work for regular deliveries is generated by road transport in comparison to the situation in the decentralised distribution system (see *Table 10*).

Table 10: Comparison of the modal split for Great Britain and Ireland in the two distribution systems

Flygt Great Britain		**Decentralised distribution system**		**Centralised distribution system**	
		Tonne-kilometres	**Carbon dioxide emissions (kg)**	**Tonne-kilometres**	**Carbon dioxide emissions (kg)**
Regular deliveries	**Ship**	315,083	4,096	109,584	1,425
	Road	248,839	12,614	742,249	36,326
	Rail	4,071	0	23,743	0
Total		567,994	16,710	875,577	37,750

Flygt Ireland		**Decentralised distribution system**		**Centralised distribution system**	
		Tonne-kilometres	**Carbon dioxide emissions (kg)**	**Tonne-kilometres**	**Carbon dioxide emissions (kg)**
Regular deliveries	**Ship**	18,312	449	6,771	166
	Road	13,073	663	35,920	1,768
	Rail	0	0	1,016	0
Total		31,385	1,112	43,708	1,934

Since road transport inflicts a larger amount of carbon dioxide emissions per tonne-kilometre than does ship transport (Lenner, 1993; NTM, 2005) this has had the consequence that Ireland and Great Britain have experienced much larger increases in carbon dioxide emissions compared to that of tonne-kilometres, thus worsening the ratio indicating carbon dioxide emissions per tonne-kilometre. In fact, Ireland has only experienced an increase in tonne-kilometres of 39 % arising from regular deliveries, but an increase in carbon dioxide emissions of 74 %. For Great Britain the results are even worse and carbon dioxide emissions have increased by 133 % despite transport work only increasing by 54 %.

[10] The assumption has been made that trains driven by electricity have been used for transfers in the Eurotunnel.

Since these two countries account for approximately 30 % of the total transport work within ITT Flygt's distribution system this is the root cause as to why carbon dioxide emissions per tonne-kilometre have increased for the whole distribution system as a consequence of the structural change. Thus, this modal shift has outweighed the positive environmental effects, in relative terms, ITT Flygt has experienced through the decrease in emergency deliveries and consolidation improvements that are the positive effects of the centralisation. This is also emphasised when an analysis regarding regular deliveries for the rest of the distribution system is carried out, which shows that carbon dioxide emissions per tonne-kilometre have decreased from almost 0.046 kilograms to roughly 0.045 kilograms. The improvement that has been made is attributed to the improvement in consolidation factor for the centralised flow.

5.2.4 Summary of the direct effects of the structural change

The analysis has shown that when ITT Flygt changed from a decentralised distribution system to that of a centralised system tonne-kilometres as well as carbon dioxide emissions have increased significantly. These results support earlier research that claims that the trend of centralisation is harmful from an environmental perspective (e.g. Rodrigue et al, 2001; McKinnon, 2003).

However, it was also found that ITT Flygt has managed to decrease the amount of emergency deliveries by centralising its distribution system and that the emissions incurred by these transportations have decreased by 64 %. Further, ITT Flygt has managed to achieve a consolidation factor of 79 % for the centralised transport flow between the production unit in Lindås and the distribution centre in Metz, something that has also had a positive environmental effect. This is illustrated by the fact that this flow accounts for 65 % of the total transport work within the centralised distribution system, but only 60 % of the carbon dioxide emissions.

Despite of these improvements the results also indicated that the amount of carbon dioxide emissions per tonne-kilometre had increased from 0.042 to 0.045 as a consequence of the structural change, thus indicating that even though emergency deliveries had been decreased and fill-rate improvements had been achieved there was another attribute of the structural change that had caused this deterioration. For parts of the decentralised distribution system ship transport constituted a large part of total transport work and that the centralisation had led to a modal shift to road for Ireland and Great Britain, which had a substantial negative impact on carbon dioxide emissions.

5.3 Indirect effects of the structural change

Whereas the previous section analysed those effects of ITT Flygt's structural change that could be labelled direct effects, i.e. the change in tonne-kilometres as well as carbon dioxide emissions, the analysis in this section will instead focus on effects that have been categorised as indirect effects.

In the frame of reference it was explained how logistics decisions can be taken at various levels and McKinnon and Woodburn (1996), Virum (2002) as well as Aronsson and Huge Brodin (2003) claim that decisions taken at one level will have an effect on decisions taken at subsequent levels. All of the authors view a decision to structurally change a distribution system as being of a high-level character. Such a decision has in this study been denoted as a structural decision and the purpose of this section is to analyse in what way ITT Flygt's decision to centralise its distribution system has also affected the company's ability or possibility of making changes in its distribution system that have proved or could prove advantageous from an environmental perspective. For this intention the framework of Blinge and Lumsden (1996) is used and consequently the analysis is grouped into two categories of improvements; internally related improvements and externally related improvements.

5.3.1 Internally related improvements

This category includes four types of improvements; technical enhancements, fuel enhancements, road enhancements, and multimodal transportation. There is no evidence in the case description to support that the structural change ITT Flygt has carried out has led to any improvement for either of these aspects. However, the change has paved way for potential future developments regarding three of these issues; technical enhancements, fuel enhancements, and multimodal transportation.

In a decentralised distribution system the logistics function is typically handled at each subsidiary, but in a centralised distribution system the logistics function should be centralised and also separated from the sales function which should be handled locally (Abrahamsson, 1992; Abrahamsson and Brege, 1995). This will have the positive effect that each subsidiary can focus on its core activity, namely to market and sell products to the customers. Also, the logistics function will become increasingly specialised and thereby more effective for the company as a whole. The case of ITT Flygt can be related to theory in this respect. Through the structural change has also come a change in how, for instance, the procurement of transport are handled within the company. Prior to the change a sales company would typically choose the solution that best suited the perceived demands of that particular market. This of course meant that there were almost as many carriers operating within the distribution system, as there were sales companies.

Also, from a central viewpoint ITT Flygt was for a long time of the opinion that there did not exist any pan-European carriers that could offer a solution that was feasible for all sales companies.

With the Swedish entry into the European Union the conditions changed and when new discussions were launched on whether or not to centralise the distribution system the carrier market had also changed so as to facilitate a change in how ITT Flygt procured its transport services. Through the structural change the company not only transformed the physical structure of the distribution system, but some of the organisational responsibility was also changed. In the current distribution system the centralised logistics function is responsible for negotiating and procuring the transport services for the whole of the European market, an issue that was previously handled by each sales company individually. From a central viewpoint it was argued that the services provided by the carriers would in fact not vary that much and that the customers on the eight European markets did in fact not have variation of demands after all.

Today the sales companies are content with the transport situation, despite the fact that they at first were opposed to the idea of centralising the procurement of transport services. By turning over the responsibility to a centralised logistics function, the possibility of finding a solution that suits the whole of the eight markets has increased since a more holistic approach can be used. This holistic approach has inevitably also had the effect that the central function today procures transport services for a much larger financial amount in comparison to what was done by any of the sales companies. In other words the centralised function today has a greater portfolio to bargain with when negotiations are held with carriers. This increase in leverage is also one of the reasons why ITT Flygt have managed to keep the cost of transport at more or less a constant.

Besides achieving leverage this could also prove advantageous from an environmental perspective. If a company increases its bargaining power towards a carrier, then the company can also demand that the carrier is to supply more environmentally friendly transport solution. Or rather, the buying company can in a *"Request for Proposal"* ask the carriers to specify, for instance, what type of engine is most typically used in their fleet of vehicles or whether they use low sulphur diesel or regular diesel. In this manner, environmental aspects can be incorporated into the process of choosing a carrier. This line of reasoning is also relevant in the case of ITT Flygt. The company does not have its own fleet of vehicles distributing its goods across Europe, but instead employs a carrier to carry out this activity. Consequently, ITT Flygt cannot directly influence the technological level of the fleet of vehicles by which their products are transported as could a company owning their own fleet, but by centralising the amount of transport work that is going to be procured on the transportation market the company has increased its possibility of influencing the carriers to make improvements in their operations. Hence, the case illustrates that an indirect effect of centralisation is that ITT Flygt has facilitated a future improvement regarding the environmental performance of its distribution by centralising the procurement of transport services, which gives the company greater leverage vis-à-vis a carrier.

Besides the enhancements of a more technical nature that have been discussed above, Blinge and Lumsden (1996) also see great opportunities in improving the environmental performance of a distribution system by applying more multimodal transport solutions, especially by moving some of the transport work from road to rail. There are considerable environmental advantageous to be reaped by making such a change, especially for transport distances over 500 kilometres. However, with today's high demand on short lead-times train freight is not always a viable option. This is also illustrated in the case of ITT Flygt, where one of the benefits with placing the new central warehouse in Metz was the fact that there existed a railway connection. However, the tests carried out by the company have shown that in its current state, the European railway infrastructure does not allow the company to transport its products with this mode of transport, given current demands on lead-time. Also, these tests turned out to cause more damage to the goods than road freight and they also proved to be more expensive. Hence, the only remaining incentive to use rail freight over road freight would be that of environmental impact, since the former mode of transport is considered to be more environmentally friendly than the latter (Lenner, 1993; NTM, 2005). From an ITT Flygt point of view this positive effect is currently more than outweighed by other factors, i.e. costs and service, and therefore rail freight is currently not a viable transport solution. Nevertheless, through centralisation ITT Flygt has opened up the possibility of transfering a large portion of the transport work to a multimodal solution including rail transport, something that was not possible prior to the structural change.

5.3.2 Externally related improvements

Blinge and Lumsden (1996) categorise consolidation, return loading, route planning, ordering systems, packaging and handling, and finally driving behaviour as externally related improvements. Some of these improvements are found when studying the case of ITT Flygt, whereas others are not.

The first of these improvements, i.e. consolidation, is that improvement which is most evident when studying the ITT Flygt case. One of the areas that was centralised during the structural change was the procurement of transport services, something that had previously been handled by each sales company. Today the company only employs two carriers; DHL who is responsible for all transportations from the production unit in Lindås to all of the concerned sales companies and Wincanton who operates all of the distribution from SDC Metz. In 2003 the shipping department in Lindås undertook a project in order to improve the fill-rate in all transport. Some results from this project were presented in the case description and these indicate that for the flow between Lindås and Metz the company has been able to achieve a higher fill-rate than would be expected if this flow had not been managed by the company.

This improvement is attributed to one of the advantages of a centralised distribution system. By establishing a central warehouse in a distribution system the total amount of inventory within the distribution system can be lowered (Abrahamsson, 1992). The reason for this is that a central warehouse can even out oscillations in demand for various markets. For ITT Flygt this was one of the reasons why the company opted to go through with the structural change and the financial results indicate that the company has managed to substantially cut those costs associated with keeping inventory.

In ITT Flygt's decentralised distribution system each sales company managed their own inventory levels and in many cases the actual demand from customers was not communicated continuously to the factory in Lindås. Instead the standard assortment of products was ordered in turns and this had the consequence that Lindås could experience quite an uneven demand, which influenced the workload for both the production unit and the shipping department. In today's system sales companies pass on their orders to the central warehouse in Metz, who in turn replenish products on a daily basis from Lindås. From the perspective of the shipping department in Lindås this has had the effect that the workload regarding the standard assortment of products is much more stable and this has had the result that it is easier to plan the outgoing shipments to Metz.

According to NTM (2005) a fill-rate of 70 % is a good indication of the fill-rate carriers manage to uphold for long-haul freight in their transport networks. ITT Flygt's two carriers have also confirmed that this fill-rate serves as a fair representation of the fill-rate they can achieve for long haul transport within their respective transport networks. For the centralised flow between Lindås and Metz however, ITT Flygt is not dependent on the carriers' ability to plan the transfers. The reason for this being that ITT Flygt have at least one dedicated lorry operating this flow every day, meaning that the fill-rate that is achieved for this particular transport linkage is solely dependent on ITT Flygt's ability to plan these shipments that serve as replenishment of products to the distribution centre. During 2003 and 2004 ITT Flygt has managed to uphold a fill-rate that surpasses that of 70 % for this centralised flow and regarding the time-period that serves as basis for this analysis the average fill-rate was approximately 79 %.

A higher degree of consolidation, or fill-rate, will have a positive effect on the environmental impact of transport (Blinge and Lumsden, 1996) since an increased fill-rate, as measured by e.g. weight, of 5 % does not result in an increase in fuel consumption of 5 %. This can be illustrated by using the figures from ITT Flygt.

With an average fill-rate of 79 % the average fuel consumption is 35.69 litres per 100 kilometres, whereas the fuel consumption for a fill-rate of 70 % is only 34.70 litres per 100 kilometres (NTM, 2005). However, with a higher fill-rate more goods can be shipped during each transport, which should mean that fewer shipments are needed to transport the same amount of goods. In the case of ITT Flygt a total amount of 1,430,129 kilograms of goods were shipped between Lindås and Metz for the eight concerned sales companies during the chosen time-period. Given that these goods are transported by a lorry with trailer that has a cargo capacity of 26 tonnes it would have taken 70 shipments to transport the total amount of goods, given a fill-rate of 79 %. If the same amount of goods had instead been shipped with lorries that had a fill-rate of only 70 % it would have taken 79 shipments to transport these products from Lindås to Metz. The result of this is that even though the fuel consumption has been increased by a better fill-rate the decrease in total number of shipments has led to a decrease in total fuel consumption by approximately 9 % (see *Table 11*).

Table 11: Total fuel consumption depending on fill-rate

	Fill-rate = 70 %	Fill-rate = 79 %
Fuel consumption (l/100 km)	34.70	35.69
Fuel consumption per shipment	357	367
Number of shipments	79	70
Total fuel consumption	28,208	25,708

Given then that the same amount of goods are transported the same distance a decrease in the total fuel consumption by 9 % also indicates that the amount of carbon dioxide emissions should decrease by the same percentage. The improvement in fill-rate that ITT Flygt has managed to achieve due to the character of the centralised flow between Lindås and Metz has also had a positive impact from an environmental perspective. Having in recollection that the centralised flow between Lindås and Metz accounts for 65 % of the total transport work that is generated within ITT Flygt's centralised distribution system, an improvement in the fill-rate for these transfers also has a large effect for the distribution system as a whole.

The case also shows that a centralised flow in fact creates a better opportunity to make consolidation improvements. Besides the outgoing flow of products to Metz, ITT Flygt has also tried to improve the overall fill-rate for other outgoing flows. The results indicate that it has not been possible to achieve the same type of constant fill-rate improvements for these shipments as it has been for the centralised flow. From this we can draw the conclusion that another indirect effect of centralisation is that a larger and more stable flow of transport between the production unit and the central warehouse is an important enabler for improvements in consolidation.

Regarding packaging and handling ITT Flygt has in Lindås sought to change how goods are packed and shipped during the fill-rate project. As illustrated above progress has been made regarding how products are handled and shipped, but the results indicate that there has not been any significant decrease in the amount of packaging material that is needed in order to ship the products. Instead there is now an increased knowledge regarding type of products which can be packed together with other products so as to improve the efficiency and thereby in the long run also improve the fill-rate.

There is no evidence to support any of the other categories of improvements listed by Blinge and Lumsden (1996), i.e. driving behaviour, return loading, route planning, and ordering systems. However, as with the internally related improvement, ITT Flygt has through a centralisation of the logistics function created an opportunity to impose more strict environmental demands on the carriers that wish to become a partner of ITT Flygt. This is especially important regarding driving behaviour, since this can affect the fuel consumption considerably (Blinge and Lumsden, 1996). With an increase in bargaining power, owing to ITT Flygt now procuring transport services centrally, the company has the opportunity to demand that the carrier of choice should be able to prove that the drivers have been trained in such schemes as eco-driving.

5.3.3 Summary of the indirect effects of the structural change

The second part of the analysis has focused on the indirect effects of ITT Flygt's centralisation, where indirect effects refer to effects other than those that are a direct consequence of the change in nodes and links within the distribution system. In the analysis two important areas were identified.

The first of these concerns bargaining power. The case clearly demonstrates that by not only centralising the physical structure but also, for instance, the procurement of transport services, the company has created an opportunity to make decisions in the future that could be beneficial from an environmental perspective. The reason for this being that with a larger amount of transport work ITT Flygt can pose greater demands on the carriers, regarding such issues as the technology level of the engines, type of fuel that is used or eco-driving education than would be possible if each sales company acted independently.

A characteristic trait of a centralised distribution system is that the products need to be shipped from a factory to a central warehouse, thus creating a centralised transport flow, and this is the second important area that was identified. In the case of ITT Flygt this flow accounts for approximately 65 % of the total amount of transport work, which makes it by far the single largest flow in the distributions system. The flow itself is relatively stable in its character, meaning that there are no large daily fluctuations in the amount of goods that are shipped from Lindås to Metz. The occurrence of this centralised flow has had two effects for ITT Flygt.

First, due to the character of the centralised flow ITT Flygt has managed to achieve a fill-rate for this transportation that exceeds those consolidation factors generally achieved by carriers. Second, the structural change has also created an opportunity for ITT Flygt to change to an multimodal transport set-up for this part of the distribution system and has carried out feasibility tests in order to see whether or not such a change would be advantageous for the company. Even though these tests have proven not to fulfil ITT Flygt's current demands, such a set-up could prove to become a reality in the future. In any case, the structural change has opened up this opportunity, an opportunity that was not present in the decentralised distribution system.

6 CONCLUSIONS

In this, the final chapter, the main findings from the conducted study are presented and discussed. This will be done in two parts, where the first part presents the results of the study by answering the two research questions that were posed in *section 1.2*. These were:

- *How does physical centralisation of a distribution system influence the environment?*
- *How do structural decisions in logistics create new opportunities to improve on the environmental performance of a distribution system?*

The second part presents a wider discussion that is based on the results of the study. Subsequent to these two parts some suggestions for future research will be presented.

6.1 Results of the study

The current trend of centralisation is by many believed to increase the amount of transport work that is generated by a distribution system and that this increase has a negative impact on the environment (e.g. Rodrigue et al, 2001; McKinnon, 2003). The reason for this increase in transport work is due to products needing to be transported over greater distances in a centralised distribution system in comparison to that of a decentralised distribution system, thus increasing the total amount of tonne-kilometres that is generated by transport within the system.

In earlier research on the effects of centralisation on costs and service we have witnessed how transport costs can be kept at a relative constant level owing to a decrease in the number of emergency deliveries that are needed to guarantee the customers a high level of service (e.g. Abrahamsson, 1992; Abrahamsson and Brege, 1995; Abrahamsson and Aronsson, 1999). In these cases emergency deliveries have been performed by means of airfreight, which is a mode of transport that emits more carbon dioxide per tonne-kilometre than do those modes of transport that are used for regular deliveries.

The argument that has been made in this study is that it is not sufficient to only consider the amount of transport work that is generated by a distribution system, but we also need to regard how this transport work is performed. The reason for this being that various modes of transport emit different amounts of carbon dioxide, which is the type of emission that is most often used to illustrate the environmental impact of transport. So, even though centralisation causes an increase in the amount of tonne-kilometres this must not necessarily imply an increase in carbon dioxide emissions (see *Figure 36*).

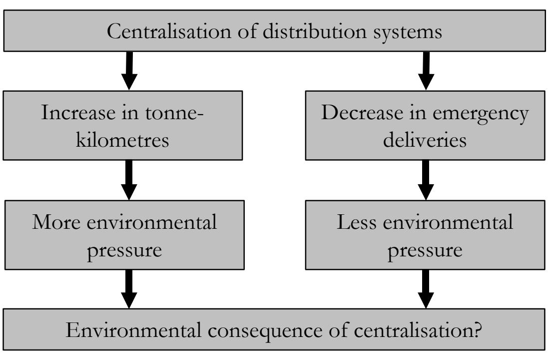

Figure 36: What are the environmental consequences of centralisation?

In the centralisation that was analysed it was found that tonne-kilometres increased at the same time as emergency deliveries decreased and that carbon dioxide emissions overall had increased as a consequence of the structural change. This could cause us to claim that the results relating to the first research question, which was to study how physical centralisation of a distribution system influences the environment, show us that centralisation is unfavourable from an environmental perspective.

However, the analysis also showed that the ratio of carbon dioxide emissions per tonne-kilometre had increased from the centralisation as well. This is a somewhat surprising result given that emergency deliveries are generally performed by means of airfreight and this is a mode of transport that emits more carbon dioxide than does those modes of transport that are used for regular deliveries. Thus, if emergency deliveries decrease at the same time as transport work increases then we should expect the ratio of carbon dioxide emissions per tonne-kilometre to decrease not increase.

The results relating to the first research question therefore show us that it is not sufficient to only consider the amount of transport work and emergency deliveries in a distribution system in order to make a statement regarding the environmental outcome of a structural change. Two additional characteristics were identified as being of importance when considering the effects of a physical centralisation and these were:

- The effects of a centralised flow
- The effects of a modal shift

These characteristics are also to a great extent linked to the second research question, which aimed at investigating how structural decisions in logistics help create new opportunities to improve on the environmental performance of a distribution system. Three opportunities have been identified, all of which relate to some of the fundamental advantages of having a centralised distribution system.

One of the main ideas of changing to a centralised distribution system is to decrease the total amount of inventories in the distribution system by consolidating these into a central warehouse instead of having them stored locally at many subsidiaries. This change has a direct effect on the transport situation in the distribution system, which is that the outgoing flows of products from a factory or a production unit are also consolidated into one larger flow since all products need to be transported to the central warehouse. Because of this it becomes easier to plan these transfers, whereby it is possible to improve the fill-rate and this in turn will have a positive environmental effect. A second opportunity that comes with having a larger centralised flow is that it creates an opportunity to change from road transport to a multimodal transport set-up including, for instance, a combination of road and rail transport, which is beneficial from an environmental perspective.

The third opportunity concerns how a centralised distribution system is organised and managed. In a decentralised distribution system the logistics function is typically handled by each subsidiary, or the like, whereas this function should be handled centrally in a centralised distribution system. This will, amongst other things, have the benefit that the subsidiaries will be able to focus on their core activity at the same time as the company will achieve leverage in its logistics function because the distribution system is managed in a more holistic manner. The results from this study illustrate how this can prove advantageous from an environmental perspective since a company will increase its bargaining power vis-à-vis, for instance, the carriers that operate the transport vehicles within the distribution system. This is because with an enhanced bargaining position a company can impose demands on carriers regarding such issues as the technology levels of the lorries that are used or education for drivers in eco-driving. Such demands can of course be posed in a decentralised distribution system as well, but with a centralised logistics function there exists a better opportunity to make demands that have an effect for the whole of the distribution system rather than some of its parts, which therefore makes it an important characteristic to consider.

In summary this study has identified three additional characteristics besides transport work and emergency deliveries that are of importance upon evaluating the environmental impact of a structural change, in this case a centralisation. The three characteristics that have been found to be of importance when considering a centralisation are:

- Centralised flow
- Modal change
- Bargaining power

These findings help us enhance the model presented in the previous section (see *Figure 36*) and *Figure 37* depicts a model that takes these characteristics into consideration.

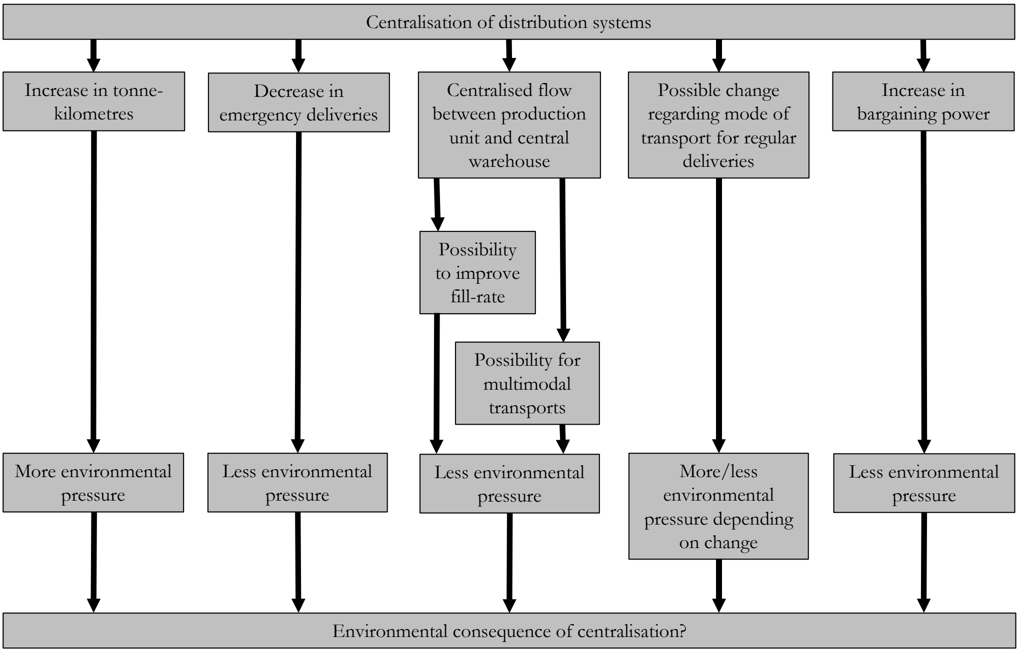

Figure 37: Important characteristics to consider upon evaluating the environmental effects of centralisation

This model does not aim to include all characteristics that can be relevant in the evaluation of a centralisation, but rather those that have been found significant in the investigation of ITT Flygt's centralisation. However, the model helps illustrate that there are many aspects that need to be considered when evaluating the environmental effects of centralisation and that, depending on the characteristics of the distribution system at hand, the results can vary quite extensively. The areas are also in many ways related to one another and the subsequent discussion will illustrate the relevance some of the characteristics in the model above can have for the environmental performance of a distribution system.

6.2 Discussion

In this section the results of this study will be discussed in a wider perspective and the aim is to illustrate how the outcome of a centralisation can differ depending on the characteristics of the distribution system at hand. The structural change of ITT Flygt will sometimes be used as a reference object in parts of this discussion.

6.2.1 The importance of emergency deliveries

Through a centralisation of the distribution system companies are expected to decrease the amount of emergency deliveries since it is possible to uphold a higher level of service towards the customers with a centralised warehouse (Abrahamsson, 1992). The analysis of ITT Flygt's centralisation supported this view and the company had in fact been able to reduce its need for emergency deliveries by 65 %. In this case however emergency deliveries accounted for a relatively small portion of total deliveries, as measured by weight, prior to the centralisation and as a result this decrease did not have such an extensive positive effect on the distribution system as a whole. This raises a question regarding what the effect would be for a company that has a larger portion of emergency deliveries to begin with. How large a part do emergency deliveries need to constitute in a decentralised distribution system and how much must emergency deliveries decrease in order for it to be advantageous from an environmental perspective to conduct a centralisation?

This question has been tested using different increases in total transport work as well as various decreases in emergency deliveries (see *Appendix E*). The results of these tests show that it is not only important to take into account the portion of emergency deliveries prior to a centralisation and how much this type of delivery decreases. The results also show that it is not only essential to consider what effect the structural change has on emergency deliveries but rather we also need to consider how the total amount of transport work within the distribution system is affected by the structural change. The more tonne-kilometres increase overall the larger the decrease in emergency deliveries needs to be if a centralisation is to prove beneficial from an environmental perspective, all other things being equal. For instance, if total tonne-kilometres increase by 25 % and emergency deliveries decrease by 25 % then a centralisation will prove advantageous when emergency deliveries account for approximately 25 % of total transport work prior to the structural change. If, however, tonne-kilometres increase by 50 % or 75 % then emergency deliveries need to constitute a larger part of total transport work than 25 % prior to the structural change in order for emissions to decrease as a consequence of centralisation.

6.2.2 Potential effects of a multimodal transport set-up

It is often advocated that one way to improve on the environmental performance of transport would be to shift a large part of those transfers that today are performed by road freight to multimodal transport set-ups that include rail freight. This form transport solution is especially believed to have a great potential for distances over 500 kilometres (Blinge, 1995). The case of ITT Flygt illustrates how the company has made attempts to transfer the centralised flow between Lindås and Metz to such a transport solution, but currently the European railway network does not suffice with regards to the company's demands on costs and service.

However, considering that this centralised flow constitute such a large portion of the total transport work in the current distribution system it is interesting to investigate what environmental effect such a change would have. According to Lenner (1993) a multimodal solution including 10 % of transport work by road will only cause 0.0072 kilograms of carbon dioxide emissions per tonne-kilometre of transport work[11]. This can be compared to 0.047-0.049 kilograms of carbon dioxide emissions per tonne-kilometre[12] that were used for the calculations regarding ITT Flygt's road transport in the centralised flow. In the current distribution system a total amount of 1,471,602 tonne-kilometres were generated by road transport in the centralised distribution system in 2003, which in turn caused carbon dioxide emissions of 68,379 kilograms. If this amount of transport work were to be transferred to a multimodal, such as the one described above, the same transport work would only generate 10,596 kilograms of carbon dioxide emissions. As illustrated by *Figure 38* below this would mean that the centralised distribution system would produce lower emissions to that of the decentralised distribution system.

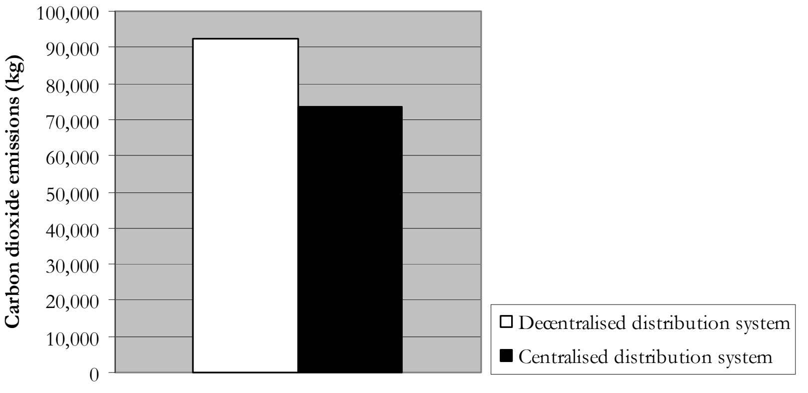

Figure 38: Fictive comparison of the two distribution systems illustrating the potential effect of a mulitmodal transport solution

Albeit that this is a speculative comparison it helps illustrate the potential that comes with a large centralised flow of products, a flow that is a direct result of a centralised distribution system. In this case the earlier increase in emissions by 42 % has been turned around to a decrease by 20 %. This then helps illustrate how a structural decision opens up a new opportunity to make decisions that improve on the environmental performance of a distribution system, an opportunity that does not exist in a decentralised distribution system since there generally does not exist a

[11] These calculations are based on the highest of those values that Lenner (1993) presents in his study.
[12] The deviation reflects whether low sulphur diesel or standard diesel is used.

transport flow of the same magnitude as that flow between the production unit and the central warehouse in a centralised distribution system.

6.2.3 The effects of a modal change concerning regular deliveries

In a centralised distribution system the aim is to find a solution that suits the whole of the distribution system, i.e. that solution which is best from a holistic perspective rather than from the perspective of the components that constitute the system (Abrahamsson and Aronsson, 1999). This was also the case for ITT Flygt in its centralisation and a consequence has been that today the company procures all of its transport services centrally instead of locally. Owing to this as well as the geographical location of the SDC in Metz ITT Flygt has experienced a modal shift for a large part of the transport work that is generated by transfers to Great Britain and Ireland. The analysis showed that in the decentralised distribution system more than 50 % of the transport work was performed by means of sea freight, whereas approximately 40 % was performed by road freight. When ITT Flygt changed to a centralised distribution system this also implied a change in how these two markets are supplied with products and today more than 80 % of the total transport work is generated by road transport. This change has had a relatively large negative impact on carbon dioxide emissions incurred by the company's distribution system, since these two countries account for roughly 30 % of the total transport work within the distribution system.

Hence, the conclusion that can be made is that even though it is important to consider how the distribution system is affected by a structural change from a holistic perspective, it is important to also take into account how regular deliveries are handled throughout the system both prior to and subsequent to the structural change.

6.2.4 Geographical location

It is not only important to consider the mere size of the flow, as measured by weight, but we also need to regard the geographical distance between the production unit and the central warehouse. An example may help to illustrate this. If we consider two centralised distribution systems that both generate a total amount of 3,000,000 tonne-kilometres and in both systems all transport work is handled by lorries with a cargo capacity of 26 tonnes and these are run on standard diesel. Further, all transportations are performed with an average fill-rate of 70 %. The only difference between the two systems is that in one of the systems the centralised flow accounts for 1,500,000 of the generated tonne-kilometres (distribution system 1), whereas the corresponding amount is 1,000,000 tonne-kilometres for the other system (distribution system 2). Hence, the difference is explained by alternative locations of the central warehouse.

Since both systems generate the same amount of transport work and the technology level of the lorries as well as the fill-rate are the same, transfers within the two systems consequently generate the same amount of carbon dioxide emissions. If we assume a ratio for carbon dioxide emissions per tonne-kilometre of 0.051, which according to NTM is a reasonable value for lorries with a cargo capacity of 26 tonnes and a fill-rate of 70 % that are run on standard diesel, then total emissions for both systems would amount to 153,000 kilograms of carbon dioxide.

Now imagine that we are able to improve on the fill-rate for the centralised flow whereby the fuel consumption for these transportations could be decreased by, for instance, 10 %. What would the consequence of this improvement be for the two distribution systems?

For distribution system 1 this decrease by 10 % would constitute a decrease in carbon dioxide emissions of 7,650 kilograms, whereas the corresponding figure for distribution system 2 would be 5,100 kilograms.

Table 12: Effects of fill-rate improvement for centralised flow depending on the geographical location of the central warehouse

	Distribution system 1	Distribution system 2
Total tonne-kilometres	3,000,000	3,000,000
Total carbon dioxide emissions	153,000	153,000
Tonne-kilometres generated by centralised flow	1,500,000	1,000,000
Carbon dioxide emissions generated by centralised flow	76,500	51,000
Carbon dioxide emissions generated by centralised flow after fill-rate improvement	68,850	45,900
Total carbon dioxide emissions after fill-rate improvement	145,350	147,900

As illustrated by *Table 12* the improvement in fill-rate for the centralised flow will have a more positive effect on that distribution system where the centralised flow constitutes the largest part of total transport work, all other things being equal. This shows us that the geographical location of a central warehouse has an effect on the environmental performance of a distribution system and that the optimal location depends on the size of the centralised flow as well as the geographical location of the customers.

6.3 Suggestions for future research

It can be argued that the research area of logistics and the environment is at its infant stages and consequently there are many areas that need to be explored further. As of yet companies have mainly viewed environmental issues in the light of cost minimisation rather than profit enhancement, but this can come to change in the future. On January 1st this year the European Union launched its trading scheme for greenhouse gas emissions and the idea is that companies in the future shall be able to trade their emission rights on a market that is regulated by the normal rules of supply and demand. Owing to this an opportunity has opened for companies to, in the future, profit from being environmentally friendly since they can then sell those rights that have not been used to another company. A consequence of this could be that pollution will in the future have a more concrete price than is the case today and maybe environmental issues will be considered a natural part of the logistics decision-making process alongside cost and service issues.

For this to become reality there are some areas that need further investigations in the future. For instance, this study has only focused on the environmental effects of one structural change. A natural continuation would therefore be to include more empirical assessments in order to be able to compare and contrast the results of various structural changes. If more cases are studied this could also help identify additional characteristics that are important to consider upon evaluating the environmental consequences of a structural change.

However, during my research process I have also found that if environmental issues are to be attributed the same level of importance as cost and service issues, then it will not be sufficient to only investigate further cases. There also exists a need to find a standard procedure for how calculations regarding the environmental impact of structural changes are to be carried out. Attempts in this area have been made, in Sweden as well as within the European Union. If it is not possible to come to an agreement as to how these types of calculations are to be carried out and this alone is a great obstacle for the research area to overcome. The reason why this is of importance is because it will become difficult to compare the results of various studies if there does not exist a common denominator between the studies. This has also been underlined by Blinge et al (2002) who in a pre-study concluded that even though we have come a long way regarding these types of issues, there still remains much to be done. If it is not possible to reach a consensus regarding how these calculations are to be made, then it seems unlikely that environmental issues will be considered a natural part of the logistics decision-making process alongside cost and service issues.

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Appendix A

List of respondents

ITT Flygt

Hans Axler	Director of purchasing
Gunnar Berggren	Senior purchaser
Ingrid Brauer	Sustainability manager
Carl-Johan Callenholm	Value Based Six Sigma, EMEA champion
Lennart Fagerström	Project leader
Olle Gunnarsson	Shipping manager
Lars-Olof Kronmar	Purchaser
Ivan Lindmark	Director of operations
Thomas Müller	ITT Flygt group analysist
Bengt Möller	Senior project leader
Anna-Lena Nordqvist	Coordinator
Jean-Marc Valdenaire	Site manager SDC Metz

Carriers

Pierre Grim	Transport manager, Wincanton
Kent Lindelöf	Area manager, DHL
Claes Älgne	Key Account manager, DHL

Appendix B
Cover letter to respondents at ITT Flygt (in Swedish)

Mitt namn är Christofer Kohn och jag är doktorand inom Logistik (www.eki.liu.se/logistik) vid Linköpings universitet. I min forskning kommer jag att använda mig av ITT Flygt som fallföretag och jag har efter samtal med Thomas Müller fått Ditt namn och det är därför Du återfinns på den lista med personer (se nedan) jag skulle vilja komma i kontakt samt intervjua inom en snar framtid. För att Du ska få en bättre uppfattning om vilken typ av frågor jag kan tänkas vilja diskutera vill jag med denna PM överskådligt förklara vad min forskning går ut på.

Jag tillhör en forskningsgrupp på Logistik som bedriver ett projekt vid namn *"Environmental Distribution Channel"* där syftet med forskningen är att skapa en bättre vetenskaplig grund för att kunna värdera miljökonsekvenser som en funktion av hur ett logistiksystem utformas, på samma sätt som konsekvenser för kostnader och tid idag kan utvärderas. Fokus i min egen forskning ligger på strukturella förändringar av distributionssystem och dess påverkan på kostnader, service och miljö. Det jag kommer att studera på ITT Flygt är den omstrukturering och centralisering av distributionssystemet som skedde i och med uppförandet av SDC i Metz.

En grundtanke i den forskning vi bedriver är att det finns en slags beslutshierarki som vi valt att dela in i tre nivåer, nämligen:

- Strukturella beslut, t.ex. centraliseringsbeslut, antal produktionsanläggningar och lager;
- Taktiska beslut, t.ex. val av servicenivå, tidsfönster för leveranser ut till kund;
- Operativa beslut, t.ex. val av transportmedel

Med hierarki menar vi att strukturella beslut skapar förutsättningar, men även sätter begränsningar för val som kan göras på de två efterföljande nivåerna, och det jag vill diskutera med Dig är vilka logistiska faktorer som är relevanta för var och en av de olika nivåerna och hur dessa nivåer är kopplade till varandra utifrån den förändring i distributionssystem som har skett hos Er på ITT Flygt.

Jag kommer att ta kontakt med Dig inom den närmsta veckan för att försöka boka in en intervjutid då vi kan diskutera dessa frågor ytterligare. Jag kommer även att förse Dig med ett frågeguide innan intervjutillfället, så att Du får möjlighet att sätta Dig in i vad jag söker för typ av information.

Tack på förhand!

Christofer Kohn

APPENDIX C
INTERVIEW GUIDE (IN SWEDISH)

Information om intervjupersonen:

- Namn?
- Befattning, ansvarsområde samt arbetsuppgifter såväl före som efter den strukturella förändringen?

Övergripande information om förändringen och dess uppkomst:

- Varför genomfördes den strukturella förändringen? Drivkrafter?
- Varifrån drevs förändringen/vilka drev den?
- Vad var avgörande för att valet hamnade på dagens valda system?
    - Ekonomiska faktorer
    - Logistiska faktorer (serviceelementen)
    - Miljö
    - Andra

- Varför placerades distributionscentret där det gjorde?
- Vilka mål ställdes upp för förändringen?
    - Ekonomiska mål?
    - Logistiska mål? (serviceelementen)
    - Miljömål?
    - Andra mål?

- Vilka steg ingick i förändringen?
- När togs dessa steg?
- Varför togs stegen i den ordningen?
- Hur lång tid tog det att genomföra hela förändringen?
- Har målen som ställdes upp uppnåtts?
    - Ekonomiskt?
    - Logistiskt? (serviceelementen)
    - Miljömässigt?
    - Övrigt?

Fysiskt flöde före förändringen:

- Vilken var distributionsstrategin före förändringen?
  - Ligga nära kunder?
  - Ha fullt sortiment i varje land?
  - Pull eller push?
- Antal produktionsenheter?
- Antal lagerpunkter, full- respektive delsortimentslager?
- Lagrens geografiska placering?
- Antalet mellanhänder (kanallängd), egna eller externa?
- Antal personer sysselsatta med fysisk distribution?

Administrativt flöde före förändringen:

- Hur mottogs en beställning?
- Hur förmedlas en beställning till produktionsenheten?
- Hur sköttes materialförsörjningen? Lokalt eller centralt?
- Hur fungerade systemets IT-system? Lokalt uppbyggda system eller centralt styrda system? Kompatibilitet mellan delsystem?
- Hur hanterades och förmedlades förändringar från kund?

Styrning av systemet före förändringen:

- Hur såg den organisatoriska strukturen för systemet ut innan förändringen? Budgetansvar? Personalansvar? Logistiskt ansvar? Ägande av produkter? Ägande av lagerbyggnader?
- Lokal eller central styrning?
- Skedde transportupphandling centralt eller lokalt? Vilka krav ställdes?
- Antal speditörer?
- Transportsätt till kund?
- Hur skedde transporter? Konsoliderade? Frekvens?
- Fanns det någon ruttplanering? Hur planerades/styrdes detta i så fall?
- Hade man några returtransporter? Hur planerades/styrdes detta i så fall?
- Hur stor andel av expressleveranser hade man?

Fysiskt flöde efter förändringen:

- Vilken är distributionsstrategin idag?
    - Ligga nära kunder?
    - Ha fullt sortiment i varje land?
    - Pull eller push?

- Antal produktionsenheter?
- Antal lagerpunkter, full- respektive delsortimentslager?
- Lagret/lagrens geografiska placering?
- Antalet mellanhänder (kanallängd), egna eller externa?
- Antal personer sysselsatta med fysisk distribution?

Administrativt flöde efter förändringen:

- Hur mottages en beställning idag?
- Hur förmedlas en beställning till produktionsenheten?
- Hur sköts materialförsörjningen idag? Lokalt eller centralt?
- Hur fungerar systemets IT-system idag? Lokalt uppbyggda system eller centralt styrda system? Kompatibilitet mellan delsystem?
- Hur hanteras och förmedlas förändringar från kund i dagens system?

Styrning av systemet efter förändringen:

- Hur ser den organisatoriska strukturen för systemet ut idag? Budgetansvar? Personalansvar? Logistiskt ansvar? Ägande av produkter? Ägande av lagerbyggnader?
- Lokal eller central styrning?
- Sker transportupphandling centralt eller lokalt? Vilka krav ställs?
- Antal speditörer?
- Transportsätt till kund?
- Hur sker transporter? Konsoliderade? Frekvens?
- Finns det någon ruttplanering idag?
- Har man några returtransporter idag?
- Hur stor andel av expressleveranser har man idag?

Resultat av förändringen:

- Hur har kostnader förändrats, med avseende på följande:
  - Fasta distributionskostnader
    - Anläggningskostnader
    - Personalkostnader
    - Administrationskostnader

  - Rörliga distributionskostnader
    - Kapitalbindningskostnader
    - Kostnader för inkuranta varor
    - Transportkostnader
    - Kvalitetskostnader

  - Övriga kostnader
    - Inlärningskostnader
    - In- och utfasningskostnader

- Hur har servicen förändrats med avseende på följande:
  - Ledtid
  - Leveranspålitlighet
  - Leveranssäkerhet
  - Information
  - Kundanpassning
  - Flexibilitet
  - Lagertillgänglighet

Kvantifiering av emissioner:

- Transportslag (detta är en given parameter eftersom det enbart är vägtransporter som studeras)
- Beskrivning av transportaktivitet
- Typ av fordon
- Typ av motor och kvalitet/typ av bränsle
- Bränsleförbrukning
- Avstånd för frakt
- Andel av frakt som sker i stadstrafik
- Fyllnadsgrad

Frågor om ITT Flygt, marknaden och ITT Flygts produktsortiment:

- Hur ser ägarförhållandet ut mellan ITT och Flygt AB?
- Hur är Flygt organiserat och var i organisationen finns logistiken?
- Har logistiken fått en förändrad betydelse till följd av den strukturella förändringen?
- Hur såg marknaden ut för pumpar när Flygt bestämde sig för att genomföra förändringen? Hur stor del andel hade företaget på respektive marknad?
- Hur ser marknaden ut idag? Har Flygt kunnat öka sina marknadsandelar tack vare förändringen?
- Vilka är företagets största konkurrenter idag?
- Vad ställer kunderna för krav på Flygt, t.ex. med avseende på ledtid? Hur står sig Flygt i förhållande till sina konkurrenter på dessa områden?
- Hur ser företagets produktsortiment ut? (knutet till beskrivning av det fysiska flödet)
- Har man kunnat utveckla produktsortimentet tack vare förändringen? (knutet till det fysiska flödet samt frågan om in- och utfasning)

APPENDIX D

DESCRIPTION OF CALCULATION PROCEDURE FOR QUANTITATIVE ANALYSIS

1.1 Introduction

The description of the calculation procedure that is presented in this appendix is divided into two parts. In the first part I present those main assumptions that were necessary to make during the research process in order to follow through the calculations. The second part of the description illustrates how the actual calculations have been carried out and throughout this description a sample country has been used in order to exemplify how the calculation procedure.

1.2 Assumptions prior to the calculations

The goal of the quantitative analysis has been to compare the physical structure of the two distribution systems and analyse the effect that centralisation has on tonne-kilometres as well as carbon dioxide emissions. Through discussions with ITT Flygt it was concluded that eight sales companies/countries that were to be used in this comparison included the following:

- Flygt Austria (FA)
- Flygt Belgium (FB)
- Flygt Germany (FD)
- Flygt France (FF)
- Flygt Great Britain (FGB)
- Flygt Italy (FI)
- Flygt Ireland (FIRL)
- Flygt the Netherlands (FNL)

The reason why these countries were chosen is that they all had fully owned subsidiaries prior to the structural change and that they had all been connected to SDC Metz by 2003.

In the decentralised distribution system ITT Flygt shipped the products from the production unit in Lindås to the sales companies in each of the country, which in turn supplied the final customers. In today's distribution system the sales companies have been short-circuited and the final customers receive deliveries from the central distribution centre in Metz, which receives daily deliveries from the production unit in Lindås. *Figure 1* shows a generic illustration of the transport situation in the two distribution systems.

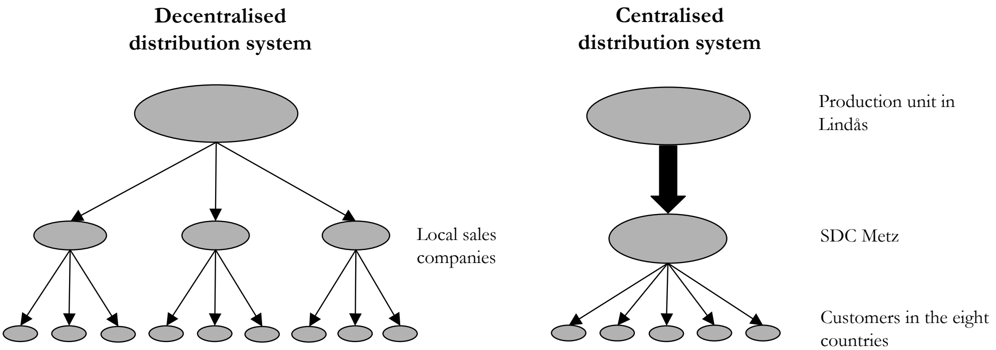

Figure 1: Generic illustration of ITT Flygt's structural change

After discussions with ITT Flygt I soon realised that it would be impossible to study the whole chain of transportations, originating at the production unit in Lindås and ending at customer in any of the eight countries. The reason for this was that it would be too time-consuming to investigate the actual location to where every product has been delivered. Instead an assumption was made stating that the sales company in each of the eight countries would serve as the final destination for all of the deliveries in the two systems. The logic behind this assumption is that in reality customers are, in geographical terms, likely to be spread out evenly in relation to the sales companies. Through discussions with ITT Flygt the conclusion was made that this assumption serves as a good representation of reality, meaning that in some cases the actual distance to the customer would be greater than the assumed distance, but that this would be compensated by the fact that the situation would be the opposite in other cases.

In the decentralised distribution system there was also a vast amount of carriers operating ITT Flygt's distribution system and consequently the products could be shipped many different routes depending on the carriers' transport network. This situation would more or less be impossible to recreate today and therefore I needed to make a second assumption. This assumption stated that data obtained from DHL on its transport network were to be used to recreate and depict the decentralised distribution system. DHL was chosen since it is that carrier which handles all of ITT Flygt's transfers from the production unit in Lindås to the European market in the current distribution system. This assumption has the downside that the actual transport distances for each carrier were not to be obtained and thereby the recreation of the decentralised distribution system might not give a fair representation of how transport in reality were carried out. However, since my aim is to investigate the structural change itself rather than the individual route planning of a carrier it would be fair to argue that the transport network of DHL serves as a good representation of how transport are actually carried out. This is because carriers, DHL as well as others, seek to offer the highest level of service to the lowest possible cost and therefore it is reasonable to believe that they also try and transport products from point A to point B by using as short of a route as possible.

For the centralised distribution system the situation was not as complicated. Here I used data provided to me by DHL and Wincanton to construct the transport linkages that illustrate how the products are shipped throughout the distribution system.

After a model illustrating the transport linkages and their distances had been constructed I needed to add transport volumes, i.e. products and their weight, in order to come to a conclusion regarding how many tonne-kilometres each of the distribution systems generate. For this purpose ITT Flygt presented shipment data on the amount of goods that were being shipped from Lindås to Metz, as well as from Metz to any of the eight countries in 2003. The figures that I have used in my calculations do not encompass the whole of 2003 and the time-period that has been used cannot be conveyed due to confidentiality reasons. For the same reason the amount of goods that have been shipped, i.e. the weight, has also been indexed so as to ensure that no important data for ITT Flygt is revealed in the calculations. However, analyses have been carried out so as to ensure that the chosen time-period functions a fair representation of the transport situation in the distribution system.

1.3 Illustration of calculations

This part of the appendix describes the actual calculation procedure that serves as the basis for the quantitative analysis. The calculations have been done in two steps, where the first has focused on tonne-kilometres and the second has focused on transforming these tonne-kilometres to carbon dioxide emissions. When conducting calculations as these there exist numerous databases that could serve as input-data in order to estimate the environmental impact of transport. In this study data from The Network for Transport and Environment (NTM) have been used. The reason for this is that these data are the closest Swedish industry has come to a consensus decision regarding what values to use when conducting this type of environmental calculations (Blinge et al, 2002).

The description of the calculation procedure is divided into four parts:

- Calculations of tonne-kilometres as a consequence of regular deliveries
- Calculations of tonne-kilometres as a consequence of emergency deliveries
- Calculations of carbon dioxide emissions as a consequence of regular deliveries
- Calculations of carbon dioxide emissions as a consequence of emergency deliveries

Throughout the description Belgium will serve as a sample country in order to better illustrate the assumptions that have been made throughout the analysis process.

1.4 Calculations of tonne-kilometres as a consequence of regular deliveries

The calculations for regular deliveries comprise of three parts, all of which are described below (also see *Figure 2*):

1) Transportations from SDC Metz to Belgium (centralised distribution system)
2) Transportations from Lindås to SDC Metz (centralised distribution system)
3) Transportations from Lindås to Belgium (decentralised distribution system)

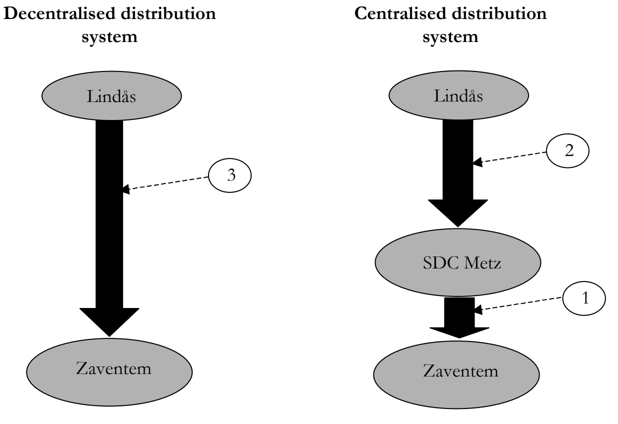

Figure 2: The three parts that constitute the calculations

1.4.1 Transportations from SDC Metz to Belgium

During the chosen time-period 4,600 kilograms of goods were shipped from SDC Metz to customers throughout Belgium. The international carrier Wincanton handled the transportation of these goods, which were shipped in various ways through the carrier's transport network depending on its weight. All goods were picked up at SDC Metz and transported to a hub 89 kilometres away. From thereon all packages up to 30 kilograms were transported in one transport chain in order to get to Zaventem, whereas all other packages were transported using another transport chain (also see *Table 1*).

Table 1: Length of haul depending on weight of package

Packages up to 30 kilograms	Distance (km)	Packages of 30 kilograms or more	Distance (km)
Linkage 1	89	Linkage 1	89
Linkage 2	341	Linkage 2	229
Linkage 3	23	Linkage 3	112
Total lenght of haul	453	Total lenght of haul	430

The 4,600 kilograms of goods that were shipped were done so in either of these two chains of transport linkages, thus causing a total amount of 1,977 tonne-kilometres (see *Table 2*) for all regular transport between SDC Metz and Belgium.

Table 2: Tonne-kilometres generated by transportations between SDC Metz and Belgium

	Packages up to 30 kilograms	Packages of 30 kilograms or more
Weight (kg)	830	3,770
Distance (km)	453	430
Tonne-kilometres	376	1,621

1.4.2 Transportations from Lindås to SDC Metz

In the centralised distribution system ITT Flygt today has a centralised flow of goods between the production unit in Lindås and the central warehouse in Metz. This flow serves as a replenishment flow for those goods that have been ordered from SDC Metz by Flygt Belgium. Consequently, those transfers that were carried were in fact replenishment for goods that has most likely been shipped from SDC Metz during an earlier time. Therefore the same amount of goods, i.e. 4,600 kilograms, has been used to calculate the amount of tonne-kilometres that has been generated by these transfers.

In this case the transport work has been carried out by DHL and the transport chain comprises of three transport linkages, where linkage one and three are road transport and linkage two is a ship transport. The total distance between Lindås and Metz was 1,329 kilometres and the total amount of tonne-kilometres that was generated by having 4,600 kilograms transported this distance was 6,113 (see *Table 3*).

Table 3: Tonne-kilometres generated by Flygt Belgium products in centralised transport flow between Lindås and Metz

	Weight (kg)	Distance (km)	Tonne-kilometres
Linkage 1	4,600	266	1,224
Linkage 2	4,600	300	1,380
Linkage 3	4,600	763	3,510
Total		1,329	6,113

1.4.3 Transportations from Lindås to Belgium

These calculations are built on the assumption that DHL would have carried out all shipments in the decentralised distribution system in the same manner as direct transport of non-standard products are handled today.

In this instance the transport chains consists of four linkages, where three linkages are road transport and one linkage is ship transport. The total transport distance amounts to 1,258 kilometres, whereas tonne-kilometres amount to 5,787 (see *Table 4*).

Table 4: Tonne-kilometres in the decentralised distribution system

	Weight (kg)	Distance (km)	Tonne-kilometres
Linkage 1	4,600	250	1,150
Linkage 2	4,600	98	451
Linkage 3	4,600	300	1,380
Linkage 4	4,600	610	2,806
Total		1,258	5,787

1.5 Calculations of tonne-kilometres as a consequence of emergency deliveries

The calculations for emergency deliveries comprise of two parts:

- Emergency deliveries from Lindås to Belgium in the centralised distribution system
- Emergency deliveries from Lindås to Belgium in the decentralised distribution system

In both sets of calculations the goods have been transported in the same way. First they have been transported by lorry from Lindås to Copenhagen airport and here a distance of 270 kilometres has been used. From Copenhagen the goods have then been transported by use of airfreight to the airport closest to the sales company, which in the case of Belgium is located 755 kilometres away[13]. The road transport between the airport and the end destination have been

[13] Distances regarding airfreight have been provided by Luftfartsverket, the Swedish Aviation Authority.

excluded in these calculations since all airports are quite close to the location of the sales company in each country, which would mean that this distance is of a smaller dignity.

According to data from ITT Flygt, Belgium received 4 kilograms of emergency deliveries from Lindås for the studied time-period, whereas the corresponding figure in the decentralised distribution system was 55 kilograms. Given this data, the centralised distribution system in the case of Belgium generated a total amount of 4 tonne-kilometres of transport work, whereas the decentralised distribution system generated 57 tonne-kilometres (see *Table 5*).

Table 5: Tonne-kilometres generated by emergency deliveries in the two distribution systems

	Decentralised distribution system			Centralised distribution system		
	Weight (kg)	**Distance (km)**	**Tonne-kilometres**	**Weight (kg)**	**Distance (km)**	**Tonne-kilometres**
Linkage 1	55	270	15	4	270	1
Linkage 2	55	755	42	4	755	3
Total		1,025	57		1,025	4

1.6 Calculations of carbon dioxide emissions as a consequence of regular deliveries

The emission calculations for regular deliveries consist of the same three parts as the calculations regarding tonne-kilometres for regular deliveries. These were:

- Transportations from SDC Metz to Belgium (centralised distribution system)
- Transportations from Lindås to SDC Metz (centralised distribution system)
- Transportations from Lindås to Belgium (decentralised distribution system)

When I translated the transport work into carbon dioxide emissions I used input-data from NTM for the three modes of transport that are employed in ITT Flygt's distribution system for regular deliveries and this is described next, starting with road transport.

Assumptions regarding road transport

- *Type of lorry*

NTM presents the following classification of lorries that make up for a large proportion of all road transport within Sweden (see *Table 6*).

Table 6: Vehicle classes according to NTM

	Total weight (tonnes)	Cargo capacity (tonnes)	Approximate length (metres)
Parcel delivery vehicle, distribution services	3.5	1.4	5.5
Light lorry, distribution services	3.5-14	1.5-8.5	9
Medium lorry, regional transport	14-24	8.5-14	10
Heavy lorry with trailer, long-distance transport	40	26	18
Heavy lorry with trailer, long-distance transport	60	40	24

After discussions with both DHL and Wincanton it was concluded that the most commonly used lorry for transfers that involved ITT Flygt products was a heavy lorry with a trailer with a cargo capacity of 26 tonnes. Various parts of the transport linkages were handled by smaller lorries, but given that the aim is to analyse the structural change this type of lorry has been used for all road transport.

- *Technology level of engine*

There exists various types of classes for engines, where the most commonly used today in Europe are Euro 2, Euro 3, and also just recently Euro 4. For the chosen type of lorry a Euro 3 engine is the most commonly installed engine for DHL as well as Wincanton and therefore this engine has been used in all calculations.

- *Type of fuel*

There are two types of fuel to chose from when making this type of calculations: standard diesel (MK3) and low sulphur diesel (MK1). The emission factor for standard diesel is 2.7 kilograms of carbon dioxide per litre of consumed fuel. The corresponding number for low sulphur diesel is 2.6 kilograms (Scania, 2000). The former type of fuel has been used for all transport outside of Sweden, whereas low sulphur diesel has been used within Sweden. Again, this choice has been made after discussions with the two carriers that operate those ITT Flygt transfers that are of relevance for this study.

- *Fill-rate*

According to NTM lorries used for more local distribution can be expected to have a fill-rate of 50 %, whereas lorries used for long-haul distribution generally can be expected to have a fill-rate of 70 %. The degree of information obtained from the two carriers varies regarding this issue and therefore a constant fill-rate of 70 % has been used in all calculations except for one transport flow and that is the flow between Lindås and Metz in the centralised distribution system. The fill-rate for these transfers is not dependent on the fill-rate that the carrier can manage to uphold in its transport network, but rather on ITT Flygt's ability to better plan this particular flow that DHL operates with lorries that only transport ITT Flygt products. Instead fill-rate data from ITT Flygt have been used for this flow.

- *Fuel consumption*

The fuel consumption of a single transport is dependent on such things as type of vehicle, fill-rate, weather conditions, tyre pressure, driving style (see *Table 7*).

Table 7: Fuel consumption lorry with trailer with a cargo capacity of 26 tonnes

Total weight (tonnes)	Cargo capacity (tonnes)	Fuel consumption without load (l/100 km)	Fuel consumption with load (l/100 km)
40	26	22-27	32-38

These figures are relevant for Swedish conditions, but since the purpose of this study has been to evaluate the effect of the structural change itself these figures have been used for all calculations that concern road transport. From these figures it has been possible to calculate a fuel consumption depending on the fill-rate (see *Table 8*).

Table 8: Fuel consumption depending on fill-rate

Fill-rate	Low fuel consumption (l/100 km)	High fuel consumption (l/100 km)
70%	29.0	34.7
79% (centralised flow)	29.9	35.7

What the figures above indicate is that the fuel consumption does not increase in the same degree as the fill-rate. For instance, when the fill-rate is increased from 70 % to 79 %, which is an increase of almost 13 %, this will only increase the fuel consumption by about 3 %.

Both Wincanton and DHL claim that their fuel consumption is best represented by the figures presented for high fuel consumption and consequently these figures have been used throughout the calculations.

- *Carbon dioxide emissions per tonne-kilometre*

Finally, the amount of carbon dioxide emissions per tonne-kilometre for road transport needed to be calculated and the following equation from NTM has been used:

Carbon dioxide emissions per tonne-kilometre = (FC*EF)/(CCw*CCUw)

where

FC = Fuel Consumption (l/km)
EF = Emission Factor
CCw = Cargo Capacity by weight, i.e. maximum capacity (tonnes)
CCUw = Cargo Capacity Utilisation by weight, i.e. fill-rate (%)

Given this equation the values presented in *Table 9* below were obtained.

Table 9: Carbon dioxide emissions per tonne-kilometre

Type of fuel	Fill-rate	Carbon dioxide emissions per tonne kilometre (kg)
Standard diesel	70%	0.051
Low sulphur diesel	70%	0.050
Standard diesel	79%	0.047
Low sulphur diesel	79%	0.045

Assumptions regarding ship and rail transport
The carriers' have not been able to supply data regarding type vessel that has been used for ship transport or what type of engine that has been used for rail transport.

For ship transport a *"Roll on-Roll off"* vessel with a medium level of carbon dioxide emissions has been used for the calculations. Also, consideration has only been taken to those emissions that are incurred by actually operating the vessel and according to NTM this value should be 0.0245 kilograms of carbon dioxide emission per tonne-kilometre

For rail transport, which mainly concern transfers in the Eurotunnel, a wagonload train has been used throughout the calculations. Here a medium LCI value has been used, which according to NTM is 0.003 grams per tonne-kilometre, or 0.000003 kilograms per tonne-kilometre.

After these values had been compiled the calculations for the regular deliveries within the two types of distribution systems could be carried out and this is described below.

1.6.1 Transportations from SDC Metz to Belgium

In order to calculate the carbon dioxide emissions that occurred from transfers between SDC Metz and Zaventem the values obtained through calculations regarding tonne-kilometres were used as input. As discussed above the same type of lorry has been used for all calculations, so there is no difference in type of lorry for those tonne-kilometres that were generated by packages up to 30 kilograms and those that weighed 30 kilograms or more. The standard fill-rate of 70 % has been used and since all transfers between Metz and Zaventem are performed outside of Sweden standard diesel has been used as type of fuel for all transport linkages. Consequently, those 1,997 tonne-kilometres that were generated from goods being transported between Metz and Zaventem resulted in carbon dioxide emissions of 102 kilograms (see *Table 10*).

Table 10: Carbon dioxide emissions arising from transfers between Metz and Zaventem in the centralised distribution system

	Packages up to 30 kilograms	Packages of 30 kilograms or more	Total
Tonne-kilometres	376	1,621	
Carbon dioxide emissions per tonne kilometre (kg)	0.051	0.051	
Total amount of carbon dioxide emissions (kg)	19	83	102

1.6.2 Transportations from Lindås to SDC Metz

For the centralised transport flow between Lindås and Metz in the centralised distribution system there were two transport linkages that were identified, that between Lindås and Trelleborg as well as that between Travemünde and Metz. Again all calculations have been made with the assumption that all transfers are carried out with a lorry that has a cargo capacity of 26 tonnes and a Euro 3 engine. However, since the first linkage, i.e. that between Lindå and Trelleborg, is in Sweden low sulphur diesel is the type of fuel that has been used for those 1,224 tonne-kilometres that were generated through transporting the 4,600 kilograms for a distance of 266 kilometres. For the remaining 763 kilometres, i.e. the distance from Travemünde to Metz, the emission calculations have been carried out with use of standard diesel instead. This is illustrated in *Table 11*.

Table 11: Carbon dioxide emissions arising from transportations between Lindås and Metz in the centralised distribution system

	Linkage 1	Linkage 2	Linkage 3	Total
Tonne-kilometres	1,224	1,380	3,510	6,113
Carbon dioxide emissions per tonne kilometre (kg)	0.045	0.0245	0.047	
Total amount of carbon dioxide emissions (kg)	55	34	165	254

1.6.3 Transportations from Lindås to Belgium

As already illustrated earlier the transport linkage that aims at illustrating how the transport work was carried out in the decentralised distribution system consists of four linkages. For those two linkages that are within the boundaries of Sweden, i.e. that between Lindås and Helsingborg, and that between Helsingborg and Trelleborg, low sulphur diesel has been used, whereas standard diesel has been applied to the calculations for the final linkage between Travemünde and Zaventem. The results of these calculations for Belgium are presented below (*Table 12*).

Table 12: Carbon dioxide emissions arising from transportations between Lindås and Zaventem in the decentralised distribution system

	Linkage 1	Linkage 2	Linkage 3	Linkage 4	Total
Tonne-kilometres	1,150	451	1,380	2,806	5,787
Carbon dioxide emissions per tonne kilometre (kg)	0.050	0.050	0.0245	0.051	
Total amount of carbon dioxide emissions (kg)	58	23	34	143	257

1.7 Calculations of carbon dioxide emissions as a consequence of emergency deliveries

The emissions calculations for emergency deliveries comprise of those two parts that were presented in *section 1.2*, namely:

- Emergency deliveries from Lindås to Belgium in the centralised distribution system
- Emergency deliveries from Lindås to Belgium in the decentralised distribution system

As described earlier emergency deliveries consist of two transport linkages, one that is carried out by means of lorry and one where airfreight is used. For the road transport between Lindås and Copenhagen the same logic as that of regular deliveries has been used, i.e. that the lorry has a cargo capacity of 26 tonnes and an average fill-rate of 70 %. Further, low sulphur diesel is used, since the transport originates in Sweden, and consequently a value of 0.050 kilograms of carbon dioxide emissions per tonne-kilometre has been used to calculate the environmental impact for those 63 and 4 tonne-kilometres that were generated by the decentralised and centralised distribution system respectively.

In order to calculate the environmental impact for the second transport linkage, i.e. that which is performed by means of airfreight, a value indicating the amount of carbon dioxide per tonne-kilometre needed to be determined. According to DHL the most commonly used airplanes for transport from Copenhagen is Airbus 300, Airbus 320, and Boeing 757. An Airbus 300 has served as the standard type of plane for all calculations and by use of data from NTM it has been possible to estimate carbon dioxide emissions per tonne-kilometre.

This value has been computed in a different manner than for road transport. For airplanes a substantial amount of carbon dioxide emissions are incurred by take-off and this amount varies according to the fill-rate of the plane. *Table 13* illustrates values according to NTM for an Airbus 300 depending on the fill-rate.

Table 13: Emission values for Airbus 300 depending on fill-rate

Aircraft	Max freight load (kg)	Freight factor (%)	Max distance (km)	Carbon dioxide emissions (constant)	Carbon dioxide emissions (variable)
A300-B4 Freighter	45,000	50	7,557	3,140	21
A300-B4 Freighter	45,000	75	5,605	3,948	22
A300-B4 Freighter	45,000	100	3,850	5,181	22

These values alone do not indicate how much carbon dioxide that is emitted per tonne-kilometre. For this purpose the equation presented in *section 1.3* was once again used, i.e.:

Carbon dioxide emissions per tonne-kilometre = (FC*EF)/(CCw*CCUw)

However, in order to use this equation the fuel consumption needs to be known. By dividing both the constant and variable amount of carbon dioxide emissions with the amount of carbon dioxide that is being emitted per consumed litre of fuel (low sulphur diesel) it was possible to obtain an average fuel consumption (see *Table 14*).

Table 14: Constant and variable fuel consumption given that low sulphur diesel is used and fill-rate is 75 %

	Constant	Variable
Carbon dioxide emissions (kg)	5,605	3,948
Fuel consumption (l)	2,156	1,518

However, with both a constant and a variable factor the average fuel consumption, as measured by litres per travelled kilometre, becomes dependent on the distance travelled. For instance, given the values above the average fuel consumption for a distance of 1,000 kilometres would be 9.90 litres per kilometre whereas the fuel consumption would be 9.14 litres per kilometre for a distance of 2,000 kilometres. In the case of Belgium the fuel consumption was estimated to be

10.39 litres per kilometre, given a fill-rate of 75 %. After this it was possible to compute the amount of carbon dioxide emissions per tonne-kilometres that is incurred by air transport and in the case of Belgium this value amounted to 0.8 kilograms per tonne-kilometre.

An average fill-rate of 75 % has been used for all air transport and in the case of Belgium the total amount of carbon dioxide emissions incurred by the decentralised distribution system amounted to 34 kilograms, whereas the analogous figure for the centralised distribution system was 2 kilograms (see *Table 15*).

Table 15: Carbon dioxide emissions generated by emergency deliveries in the two distribution systems

	Decentralised			Centralised		
	Linkage 1	Linkage 2	Total	Linkage 1	Linkage 2	Total
Tonne-kilometres	15	42	57	1	3	4
Carbon dioxide emissions per tonne-kilometre (kg)	0.050	0.800		0.050	0.800	
Total amount of carbon dioxide emissions (kg)	1	33	34	0	2	2

1.8 Summary of the results

When all of the calculations had been made the following results for Belgium could be obtained (see *Table 16*).

Table 16: Summary of calculations for Belgium

	Decentralised distribution system			Centralised distribution system		
	Regular deliveries	Emergency deliveries	Total	Regular deliveries	Emergency deliveries	Total
Tonne-kilometres	5,787	57	5,844	8,110	4	8,114
Carbon dioxide emissions	257	34	291	356	2	358

Appendix E
Test for conclusions

Test 1:

Increase in tonne kilometres = 25 %; Decrease in emergency deliveries = 25 %

Total tonne-kilometres	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000
Emergency deliveries (%)	0%	0%	5%	4%	10%	8%	15%	11%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	93,750	200,000	187,500	300,000	281,250
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	75,000	160,000	150,000	240,000	225,000
Tonne-kilometres caused by regular deliveries	2,000,000	2,500,000	1,900,000	2,406,250	1,800,000	2,312,500	1,700,000	2,218,750
Carbon dioxide emissions caused by regular deliveries	100,000	125,000	95,000	120,313	90,000	115,625	85,000	110,938
Total carbon dioxide emissions	100,000	125,000	175,000	195,313	250,000	265,625	325,000	335,938
Increase/decrease in carbon dioxide emissions		25,000		20,313		15,625		10,938

Increase in tonne kilometres = 25 %; Decrease in emergency deliveries = 50 %

Total tonne-kilometres	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000
Emergency deliveries (%)	0%	0%	5%	3%	10%	5%	15%	8%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	62,500	200,000	125,000	300,000	187,500
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	50,000	160,000	100,000	240,000	150,000
Tonne-kilometres caused by regular deliveries	2,000,000	2,500,000	1,900,000	2,437,500	1,800,000	2,375,000	1,700,000	2,312,500
Carbon dioxide emissions caused by regular deliveries	100,000	125,000	95,000	121,875	90,000	118,750	85,000	115,625
Total carbon dioxide emissions	100,000	125,000	175,000	171,875	250,000	218,750	325,000	265,625
Increase/decrease in carbon dioxide emissions		25,000		-3,125		-31,250		-59,375

Increase in tonne kilometres = 25 %; Decrease in emergency deliveries = 75 %

Total tonne-kilometres	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000	2,000,000	2,500,000
Emergency deliveries (%)	0%	0%	5%	1%	10%	3%	15%	4%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	31,250	200,000	62,500	300,000	93,750
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	25,000	160,000	50,000	240,000	75,000
Tonne-kilometres caused by regular deliveries	2,000,000	2,500,000	1,900,000	2,468,750	1,800,000	2,437,500	1,700,000	2,406,250
Carbon dioxide emissions caused by regular deliveries	100,000	125,000	95,000	123,438	90,000	121,875	85,000	120,313
Total carbon dioxide emissions	100,000	125,000	175,000	148,438	250,000	171,875	325,000	195,313
Increase/decrease in carbon dioxide emissions		25,000		-26,563		-78,125		-129,688

Test 2:

Increase in tonne kilometres = 50 %; Decrease in emergency deliveries = 25 %

Total tonne-kilometres	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000
Emergency deliveries (%)	0%	0%	5%	4%	10%	8%	15%	11%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	112,500	200,000	225,000	300,000	337,500
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	90,000	160,000	180,000	240,000	270,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,000,000	1,900,000	2,887,500	1,800,000	2,775,000	1,700,000	2,662,500
Carbon dioxide emissions caused by regular deliveries	100,000	150,000	95,000	144,375	90,000	138,750	85,000	133,125
Total carbon dioxide emissions	100,000	150,000	175,000	234,375	250,000	318,750	325,000	403,125
Increase/decrease in carbon dioxide emissions		50,000		59,375		68,750		78,125

Increase in tonne kilometres = 50 %; Decrease in emergency deliveries = 50 %

Total tonne-kilometres	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000
Emergency deliveries (%)	0%	0%	5%	3%	10%	5%	15%	8%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	75,000	200,000	150,000	300,000	225,000
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	60,000	160,000	120,000	240,000	180,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,000,000	1,900,000	2,925,000	1,800,000	2,850,000	1,700,000	2,775,000
Carbon dioxide emissions caused by regular deliveries	100,000	150,000	95,000	146,250	90,000	142,500	85,000	138,750
Total carbon dioxide emissions	100,000	150,000	175,000	206,250	250,000	262,500	325,000	318,750
Increase/decrease in carbon dioxide emissions		50,000		31,250		12,500		-6,250

Increase in tonne kilometres = 50 %; Decrease in emergency deliveries = 75 %

Total tonne-kilometres	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000	2,000,000	3,000,000
Emergency deliveries (%)	0%	0%	5%	1%	10%	3%	15%	4%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	37,500	200,000	75,000	300,000	112,500
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	30,000	160,000	60,000	240,000	90,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,000,000	1,900,000	2,962,500	1,800,000	2,925,000	1,700,000	2,887,500
Carbon dioxide emissions caused by regular deliveries	100,000	150,000	95,000	148,125	90,000	146,250	85,000	144,375
Total carbon dioxide emissions	100,000	150,000	175,000	178,125	250,000	206,250	325,000	234,375
Increase/decrease in carbon dioxide emissions		50,000		3,125		-43,750		-90,625

Test 3:

Increase in tonne kilometres = 75 %; Decrease in emergency deliveries = 25 %

Total tonne-kilometres	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000
Emergency deliveries (%)	0%	0%	5%	4%	10%	8%	15%	11%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	131,250	200,000	262,500	300,000	393,750
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	105,000	160,000	210,000	240,000	315,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,500,000	1,900,000	3,368,750	1,800,000	3,237,500	1,700,000	3,106,250
Carbon dioxide emissions caused by regular deliveries	100,000	175,000	95,000	168,438	90,000	161,875	85,000	155,313
Total carbon dioxide emissions	100,000	175,000	175,000	273,438	250,000	371,875	325,000	470,313
Increase/decrease in carbon dioxide emissions		75,000		98,438		121,875		145,313

Increase in tonne kilometres = 75 %; Decrease in emergency deliveries = 50 %

Total tonne-kilometres	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000
Emergency deliveries (%)	0%	0%	5%	3%	10%	5%	15%	8%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	87,500	200,000	175,000	300,000	262,500
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	70,000	160,000	140,000	240,000	210,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,500,000	1,900,000	3,412,500	1,800,000	3,325,000	1,700,000	3,237,500
Carbon dioxide emissions caused by regular deliveries	100,000	175,000	95,000	170,625	90,000	166,250	85,000	161,875
Total carbon dioxide emissions	100,000	175,000	175,000	240,625	250,000	306,250	325,000	371,875
Increase/decrease in carbon dioxide emissions		75,000		65,625		56,250		46,875

Increase in tonne kilometres = 75 %; Decrease in emergency deliveries = 75 %

Total tonne-kilometres	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000	2,000,000	3,500,000
Emergency deliveries (%)	0%	0%	5%	1%	10%	3%	15%	4%
Tonne-kilometres caused by emergency deliveries	0	0	100,000	43,750	200,000	87,500	300,000	131,250
Carbon dioxide emissions caused by emergency deliveries	0	0	80,000	35,000	160,000	70,000	240,000	105,000
Tonne-kilometres caused by regular deliveries	2,000,000	3,500,000	1,900,000	3,456,250	1,800,000	3,412,500	1,700,000	3,368,750
Carbon dioxide emissions caused by regular deliveries	100,000	175,000	95,000	172,813	90,000	170,625	85,000	168,438
Total carbon dioxide emissions	100,000	175,000	175,000	207,813	250,000	240,625	325,000	273,438
Increase/decrease in carbon dioxide emissions		75,000		32,813		-9,375		-51,563

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