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Intermodal Transport in Less-than-Truckload Networks

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Abstract

In producing transport services several different transport modes are available. Through the last decades, road transport has increased rapidly. This development is recognised as unsustainable. A more sustainable alternative is intermodal transport. Less-than-truckload (LTL) networks, i.e. networks designed to transport consignments not filling a truck, are historically based on road transport. Intermodal transport is an alternative on some routes in the LTL networks. A transport mode choice is at hand on these routes.

The purpose of this thesis is to contribute to the understanding of how the mode choice between intermodal transport and road transport is made in LTL networks. Previous studies of the mode choice have identified factors that are important but also emphasise the complex nature of the mode choice. However, including the context in which the mode choice is made can provide a better understanding of the mode choice complexity.

Time pressure is high in LTL networks. Five aspects of time that are important in the mode choice in the studied LTL network are identified. These can be used to broadly measure the compliance of IRRT to consolidated cargo, a LTL service. Addressing the complexity of the mode choice, the decision-making that includes the mode choice is structured by applying theoretical perspectives of decision-making and company operations. A general and descriptive model is the result. This structure is a tool to explain how the decision-making that includes the mode choice is constituted.

In LTL networks forwarders often contract hauliers to perform the transport services. This entails the mode choice being distributed to the hauliers. Forwarders, the controlling actors of LTL networks, thus have limited influence over the mode choice. Applying the quasifirm organisational perspective to the organisation of LTL networks provides some explanatory concepts showing the strengths and weaknesses of this organisation structure when it concerns the mode choice. Consequently, the thesis shows some different aspects of the mode choice in LTL networks by both empirical investigation and theoretical application.

Keywords: intermodal transport, LTL networks, mode choice, decision-making

Preface

First, I want to thank my main supervisor, professor Mats Johansson, for guiding me through the process of writing this thesis. His support is truly appreciated. My assistant supervisor, associate professor Johan Woxenius, deserves gratitude for giving me this opportunity and providing expert knowledge about intermodal transport. Many thanks also to Vinnova, the Swedish road and rail administrations, for providing financial support.

Schenker provided the empirical base for the thesis, which I am very grateful for. A special thanks to Per Ericson and Robert Ljunggren for their time, patience, and door-opening to the Schenker organisation. Also, all people that have willingly been interviewed have my gratitude.

Finally, more general thanks to all the colleagues at the division of Logistics and Transportation for taking coffee breaks regularly and providing a place for discussion.

Göteborg, July 2006

Robert Sommar

List of appended papers

Paper I

Robert Sommar and Johan Woxenius (2006) Time perspectives on intermodal transport of consolidated cargo, submitted to Growth and Change: a journal of urban and regional policy.

Paper II

Robert Sommar (2006) Long-distance hauliers' transport mode choices, in the conference proceedings of the New Scholars' Conference on Sustainable Transportation, Bloomington, Indiana, USA, May 16-17.

Paper III

Robert Sommar (2006) Organisation of LTL networks – consequences for intermodal transport, presented at the Nectar Cluster Meeting in Göteborg, March 22-23.

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Introduction

Intermodal transport and less-than-truckload networks

In producing transport services several different transport modes are available. Traditionally, transport services are primarily based on a single transport mode or a combination of transport modes, e.g. wagonload is based on rail transport and express parcel services are based on air and road transport. In some transport services several modes are possible but road transport is currently by far the dominating transport mode for land transport. Road transport has increased significantly in past decades (see Figure 1) and this development is recognised as unsustainable due to the high external effects of road transport (European Commission, 2001). A shift to other modes is put forward as part of a solution. As road transport cannot be replaced by single mode rail or water transport, a combination of modes is required. Therefore, intermodal transport, which utilises the strengths of two modes, is promoted. This desired shift from road transport to intermodal transport makes the choice between transport modes an important issue. The use of intermodal transport is growing but still modest (Woxenius and Bärthel, 2006), which suggests that the choice can be problematic and is in favour of road transport.

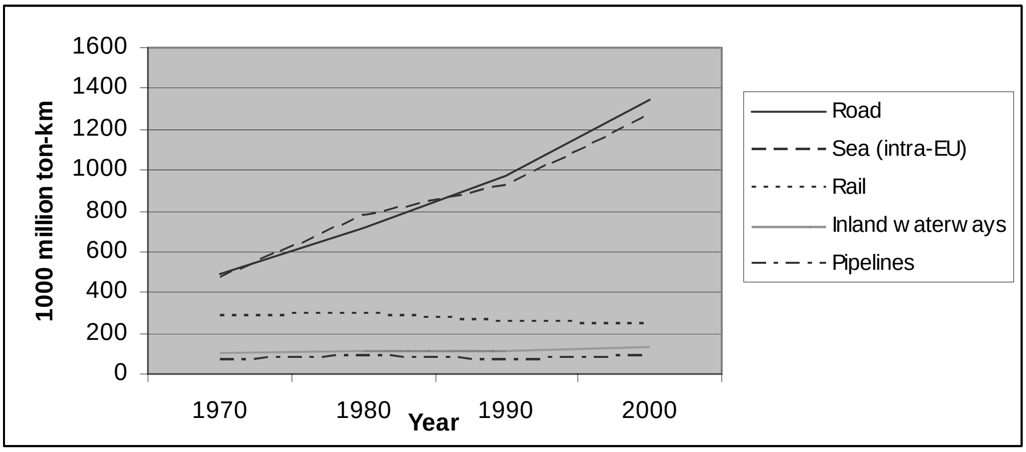

Figure 1 Goods transport in EU-15 (European Communities, 2003).

Transport services are generally suited for a particular kind of good and consignment size. Less-than-truckload (LTL) networks, i.e. networks designed to transport consignments not filling a truck, are historically based on road transport. However, intermodal road-rail transport (IRRT) is an alternative on some routes in LTL networks. A transport mode choice is at hand on these routes. Describing these two alternatives will provide a background to the problematic nature of the mode choice.

Using road transport fundamentally represents freedom in time and location. Basically, one can decide when and where to drive without the need to coordinate with other road users. To most destinations there are multiple routes to choose from. In road freight transport these characteristics enable the trucks to use a go-when-full policy, which requires limited planning. It also enables almost real-time re-planning of truck departure and arrival as well as route selection.

Rail transport is more restricted. The use of trains requires coordination with other rail transport users, i.e. only one train on a specific track section at the same time. For an efficient use of the tracks, the track access is divided into time-slots that are stipulated by the rail administration for a longer period of time, typically for six months. Consequently, train departures and arrivals are strictly defined and predetermined. When the tracks are highly utilized available time-slots become scarce, this results in the real-time re-planning of departures and arrivals as well as flexible route selection becoming more complicated. Using rail transport in a network that is basically built on the characteristics of road transport consequently requires more planning in advance as more restrictions are imposed.

Further, these two modes represent different scales. In Sweden, a truck's total weight is a maximum 60 tonnes and its total length 25.25 metres, while a train is allowed to weigh more than 2000 tonnes and be 750 metres. Consequently, a train can load about 30 times more goods. Thus, one of rail transport's strengths is its ability to transport large quantities. On the other side, filling a train requires a larger transport demand than road transport services are intended to fulfil, i.e. road transport service providers usually do not transport enough goods to fill a train. Using transport resource capacity represents good transport economy as the marginal cost of adding extra goods to a half full resource is relatively low. Consequently, the control of IRRT trains' capacity is held by an intermediary. Another strong point of rail transport is its energy efficiency. One negative side is that the railway tracks limit the rail transport's feasible spatial coverage. Combining the strengths of road and rail transport motivates the existence of IRRT. The road transport part of the IRRT is used for the transport of goods from the origin of the goods to the railway and from the railway to its final destination.

Deciding upon the road transport and IRRT alternatives implies different practical arrangements. For example, IRRT requires special adapted vehicles and load units implying that the choice of the IRRT mode first requires acquisition of special resources.

LTL transport services produced in networks

There are different, sometimes conflicting, priorities between customers of LTL transport services. Some customers want low cost while others require high service quality. The consolidation in LTL networks requires a trade-off between the cost and the service level. The LTL transport service is therefore a generalised service to suit a large population of individual customers. Using LTL service timetables, which specify arrival day depending on departure day to a certain destination, is a basic dimension of service quality; i.e., you know what transport time to expect.

In LTL networks, terminals are used for consolidating and transhipping consignments between vehicles. However, larger consignments can be more efficiently transported by the same vehicle without transhipping. Consequently, different policies exist for the routing of consignments through the network and allocation of resources depending on the consignment size. Consignments not routed via terminal primarily have deadlines for the collection and the distribution, which entails a deadline for the long-distance transport.

Additionally, consignments that are routed via terminals have deadlines for the sorting at consolidation terminals and the terminal-to-terminal transport. The many routes arriving to and departing from a consolidation terminal are often time sequenced to enable a relatively levelled workload at the consolidation terminals. The use of road transport enables this sequencing while using IRRT restricts the possible departure and arrival times on a specific route.

Consequently, which consignment routing policy, via terminal or not, that is applied determines the time requirements on the transport that is subject to a mode choice. However, consignments adhering to both routing policies can be transported by the same vehicle between two regions in the LTL network, as one basic objective of LTL networks is to optimally fill the employed transport resources. This co-utilisation of vehicles has implications for the mode choice as consignments with looser time requirements has to conform to those with tighter time requirements. Further, picking up consignments late from customers or delivering early is a service possible with road transport. When using IRRT this possibility is determined by the timetables set by the IRRT service provider, thus outside the control of the LTL network.

The mode choice is consequently connected to issues as planning restrictions and resource acquisition. These issues require more long-term planning than planning for the same or next day’s operations, especially as LTL networks are characterised as being structured and coordinated by their schedules, use of terminals, and division of tasks. Using IRRT requires adjusting to another service, thus complicating the network further. This makes the mode choice in LTL networks a fascinating issue to study.

IRRT is most common for full truckloads (FTL) or where a unit load already is used, e.g. maritime transport. Typical customers of IRRT are shipping lines, hauliers, forwarders, and logistics service providers. All the typical customers of IRRT are third-party logistics service providers, i.e. providing transport services and possibly other logistics services to shippers. Hauliers are providers of the basic transport service and logistics service providers make available, among other logistics services, consolidation services, in the role termed forwarders (Stefansson, 2004). Often, a forwarder contract hauliers to perform the actual transports with the result that both actor types are involved in LTL networks. The actors in LTL networks thus have different responsibilities, i.e. forwarders operate consolidation terminals and hauliers perform road haulage. These responsibilities influence the mode choice through issues as the above mentioned planning restrictions and resource acquisitions.

Theoretical problem discussion

Turning to literature on mode choice gives a list of criteria important in the mode choice (Murphy and Hall, 1995; Cullinane and Toy, 2000). In general, freight rate and service factors such as transport time and transport time reliability are most highly ranked. For different customer segments of IRRT factors have different rankings. Although factors are recognised to be context specific, the context in which the mode choice is made is generally not included in mode choice studies.

Further, listing a number of important criteria will not explain how the choice is made. How the mode choice is made needs clarification (Pisharodi, 1991;

SULOGTRA project, 2000). Criteria lists do not reveal at what stage or level the mode choice is determined. The mode choice can be made centrally or locally in the customer organisation or at one point of time for several years or from day to day. Studying the context in which the mode choice is made is therefore of interest and will provide better understanding of the role of the demand side of IRRT.

Many issues have been dealt with in literature on planning models (Crainic and Laporte, 1997). In Crainic and Laporte's (1997) review of planning models for freight transportation they outline a general model for freight transport networks that enables the co-existence of multiple transport modes. This model optimises for the lowest cost, as this is the most efficient use of the transportation infrastructure. The cost can have several components, such as monetary cost, delay cost, energy consumption, noise and pollution levels, and risk costs. This model assumes that all actors make the same choice when they have the same set of options. In the case of one organisation following some predefined decision rules this can be a correct assumption. When several actors are involved this assumption is less valid, which has implications for the ability of such network optimisation models to reflect the real behaviour of the network. Mode choice literature focuses at identifying and ranking criteria, while transportation network literature often seeks an optimal solution based on an econometric measure including several cost elements. Consequently, there is a gap between what is studied in mode choice literature and the treatment of the mode choice in optimisation models.

Purpose

Transport service providers are the main customers of intermodal transport, indicating that the mode choice is of importance to them. In LTL networks, comprised of forwarders and hauliers, several actors are involved. Consequently, there is both the network that has to be efficient and the mode choice to be made in a context of several actors. With the above background in mind the purpose of this thesis is:

> *To contribute to the understanding of how the mode choice between IRRT and road transport is made in LTL networks.*

Scope

In this thesis the focus is at the mode choice in relation to the actors in LTL networks; forwarders and hauliers. Also of central interest to mode choices are the activities and resources in both IRRT and LTL networks because a certain choice of mode implies the use of resources and the execution of these activities.

Thesis structure

This thesis consists of a compilation summary and three appended papers. The purpose of the compilation summary is to motivate the research and to take a holistic view of the papers. The three papers are appended in full and denoted by roman numerals, which are used when the papers are referred to in the compilation summary.

Following this short introduction to the thesis is a frame of reference. There are the central areas intermodal transport and LTL networks further presented, analysed, and discussed. Also, a more general theory associated to the mode choice is presented. Previous research and theories are used in order to formulate the specific research questions of the thesis. The next chapter, methodology, explains the research process and how the empirical data was obtained. A discussion on data analysis concludes the methodology chapter. The results of the research are presented in the next chapter. Chapter 5 discusses the results and the last chapter provides conclusions and some prospects for further research.

Frame of reference

In this section of the thesis important aspects of intermodal transport are presented to provide background knowledge to the alternatives in the IRRT and road transport mode choice. Therefore are transport distances and potential demand for IRRT are briefly presented but also IRRT technology and organisation are presented and explained in order to give a better understanding of what is involved in the choice of IRRT. For the purpose of understanding the context in which the mode choice is made LTL networks are further explained. Literature is reviewed to explain the theoretical context and background of the research, but also to motivate the specific research questions.

Intermodal transport

A definition of intermodal transport is "the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes" (UNECE, 2001). Depending on what modes of transport are used in intermodal transport, several subtypes of intermodal transport exist. In Europe there are five dominant market segments, or subtypes, of intermodal transport (Vreenken et al., 2005):

1. Shortsea feeder traffic
2. Hinterland traffic via inland waterways
3. Hinterland traffic by rail
4. Continental shortsea shipping
5. Continental intermodal rail traffic

In all of these types of intermodal transport road transport can be an integral part for the door-to-door transport. In three of these subtypes water transport is included, while the other two include rail transport. The fifth type is also termed road-rail transport, where by definition the rail mode constitutes the dominant part of the distance (UNECE, 2001). In this thesis the focus is on this last type of intermodal transport, here denoted intermodal road-rail transport (IRRT). IRRT comprise of the three main operations of road haulage, transhipment, and rail haulage (see Figure 2) (Bontekoning et al., 2004). That the goods are not handled themselves in changing modes of transport implies the use of loading units.

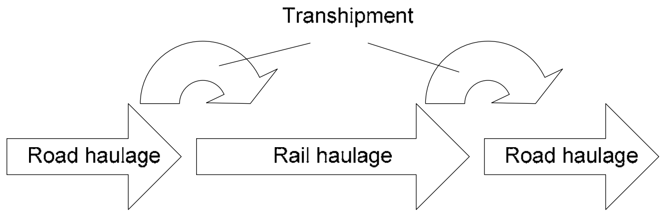

Figure 2 The three main operations of IRRT.

Distances and potential demand of IRRT

Intermodal transport, including the specific case of IRRT, is a potential mean to accomplish a sustainable transportation system (European Commission, 2001). Research has shown that over longer distances the external costs are lower for IRRT compared with road transport (Kreutzberger et al., 2003). The direct or private cost of IRRT can also be lower (Jensen, 1990; Cardebring et al., 1996). This lower cost is mainly possible through the larger scale of and the lower energy consumption by rail transport compared with road transport. Thus, intermodal road-rail transport can be both an environmentally better and a cost competitive alternative to road transport over longer distances. The traditional market for intermodal transport, from a cost perspective, is generally considered to be for transports longer than 600 km (Vreenken et al., 2005). However, studying statistics from the International Union of combined Road-Rail transport companies reveals that IRRT is used on considerably shorter distances (UIRR, 2005). There are many examples of intermodal transport services over shorter distances, some as short as 200–300 km.

Transport statistics can provide an estimate potential for IRRT. In Sweden during 2004, 90% of the transported goods by weight and 60% of the transport work of the domestic transports by road was for distances shorter than 300 km (SIKA, 2005). These statistics are for vehicles registered in Sweden but the share of cabotage was, at least in 2001, low (European Communities, 2003). The transport work for transports longer than 300 km was 13068 million tonnes-km. In comparison, domestic Swedish IRRT had a transport work of 2774 million tonnes-km during 2004 (SIKA, 2006). These figures show that IRRT already accounts for a sizable amount of transport work compared to road transport in Sweden, but that there is potential for growth. For 2000, rail had a share of 13,8% of the tonnes-km in the EU-15 countries while Sweden had a rail share of 38,2% (European Communities, 2003). While the transport performance of IRRT is less accessible for the EU countries than for Sweden, this indicates that IRRT accounts for a lesser amount compared to road transport in the other EU-15 countries. Thus, the potential for IRRT seems to be even greater in EU-15 than in Sweden.

Technology used in IRRT

In this part the most important features of the IRRT technology that is of concern to the mode choice in LTL networks will be presented. First, the transport resources, or loading units, used are affected. Within the European Union three main types of loading units are used in IRRT: semi-trailers, containers, and swap bodies (Woxenius and Bärthel, 2006). These different loading units have different advantages and pose different requirements on the different operations of IRRT (Bontekoning et al., 2004; Nelldal, 2005). Standardising the unit loads in intermodal transport is a mean towards more efficient intermodal transport (Bontekoning et al., 2004). One disadvantage faced in some countries is that rail haulage can limit the dimensions for loading units by a limited clearance at bridges and tunnels.

ISO containers are 20 or 40 feet long (approximately 6.1 metres and 12.2 metres, respectively), the outside width is 8 feet (2.44 metres), and the height is 8 to 9.5 feet. Even longer and higher containers exist today. The width is not optimally compatible with Europallet dimensions (0.8 x 1.2 metres). This is a disadvantage in some LTL networks since much of the goods are palletised. Containers are stackable and can be lifted from the top. These features make them ideal for maritime transport. In the road haulage operation containers require flat-bed lorries.

Swap bodies are generally designed for road transport with a width of 2.55 metres and comply with Europallet dimensions. Two types are most common: class C, with lengths of 7.15, 7.45, and 7.82 metres; and class A, with the most common lengths being 12.50 and 13.60 metres (Vreenken et al., 2005). They are, however, generally not stackable and cannot be lifted from the top. Often, swap bodies are equipped with support legs. Swap body lorries are correspondingly equipped with air suspension. This enables the lorry to leave and pick up the swap body without the support of special handling equipment. For transhipment to and from the train, however, special handling equipment is required.

Semi-trailers are also designed for road transport and are typically 13.6 metres long and 2.60 metres wide. They are equipped with wheels, which mean that they only require a semi-trailer tractor for road haulage. Like swap bodies, semi-trailers are not stackable and cannot be lifted from the top. Semi-trailers adapted for intermodal transport have a higher deadweight compared to semi-trailers only for road transport. For rail haulage the semi-trailer implies the use of pocket wagons, a more expensive wagon type than used for swap bodies and containers.

Second, road transport and IRRT represent different scales. In Sweden, a truck's total weight is a maximum 60 tonnes and its total length 25.25 metres. For other European countries the weight and length limits are 40 tonnes and 18.75 metres, respectively. A train is allowed to weigh more than 2000 tonnes and be up to 750 metres. Consequently, a train can load at least 30 times more goods, which has impact on the organisation of transport services. Further, the rail transport follows a timetable often established for a six-month period as the trains have certain time-slots on the tracks assigned by the rail administrations. Thus, the rail haulage is a rigidly scheduled transport service. Also of importance to the transport of goods is the risk of damage during rail transport due to vibrations, but generally this is the result of improper stowage of the goods in the load unit (Vreenken et al., 2005).

Transhipment between road vehicles and train wagons is generally done vertically by cranes or mobile equipment (Vreenken et al., 2005). Transhipment is executed in special terminals representing considerable investments. Containers are lifted from the top, and swap bodies and semi-trailers from the bottom with grapple arms or by fork lift trucks. Of note, loaded semi-trailers can weigh 35 tonnes, which requires adequate, often expensive, transhipment technology. There is a risk of damage to the loading units during transhipment. Horizontal transhipment technologies exist but have not been implemented in large scale.

Organisation of IRRT services

Filling a train requires a large transport demand. Using transport resource capacity represents good transport economy as the marginal cost of adding extra goods to a half full resource is relatively low. Road transport service providers usually do not transport enough goods to fill a train. Consequently, the control of an IRRT train's capacity is held by an intermediary. Transhipment and rail haulage is often produced by an intermodal operator and these two operations form the core of IRRT (Woxenius and Bärthel, 2006). Bureaucracy in the rail mode has been concluded to be an organisational aspect acting as a barrier to IRRT (Bithas and Nijkamp, 1997). This barrier is mainly obvious in international IRRT, where several railway organisations are required to cooperate. Thus, the core of IRRT can have undesirable organisational aspects.

There is often no strong chain management of domestic IRRT while in international IRRT ocean carriers have taken a leadership role (Bontekoning et al., 2004). The actors responsible for the different operations of IRRT are consequently not always fully coordinated and act somewhat independently. This affects strategic issues as standardisation and use of information technology as well as the possibility to gear the activities of IRRT to one another (Bontekoning et al., 2004).

Economy of scale in the road haulage operations of IRRT have been shown to be relevant in intermodal transport, especially by limiting the number of empty hauls of loading units (Morlok et al., 1995). This suggests that road haulage can be performed more efficiently with increased size of operations by limiting the empty hauls through coordination of a large number of collections and deliveries of load units. Single hauliers, as customers of the core of IRRT, may not reach a sufficient number of road haulage operations. Further, the use of IRRT is affected by the length of the rail haulage and the location of the consignor and consignee relative to the IRRT transhipment terminal (Nierat, 1997). A short rail haul or a long distance to the terminal limits the use of IRRT. However, empty hauls of loading units are not unavoidable as collection and distribution is usually performed during the afternoon and morning, respectively.

So, there are several types of intermodal transport of which IRRT is an important part. Intermodal transport is traditionally used for longer distances (above 600 km) but is also used over shorter distances. For users currently using road transport the most important difference of IRRT is the use of adapted load units and vehicles. The load units in Europe are of three types: semi-trailers, swap bodies, and containers. The use of rail implies that IRRT is a rigidly scheduled transport service and represents a larger scale than road transport. This larger scale and additional activity implies that more organisations are involved in performing IRRT compared to road transport. However, domestic IRRT have been observed to be in lack of overall chain management. Further, the road haulage part of IRRT is often performed by single hauliers but can benefit from economy of scale, which requires cooperation.

LTL networks

Important customers of the core IRRT service are forwarders and hauliers. A central transport service segment of forwarders is less-than-truckload (LTL), where they consolidate transport consignments from many shippers to make efficient use of vehicle loading capacity. They often contract hauliers to perform the actual transport. LTL services require coordination and administration. For smaller LTL consignments (typically 30 to 1000 kg) consolidation terminals are used for consolidation and sorting, thus the segment of smaller LTL consignments is termed consolidated cargo. Larger LTL consignments are termed part loads. When IRRT is used in LTL production the core of IRRT is an integrated part of a transport service where transport buyers usually do not specify road transport or IRRT. To use IRRT in LTL production these somewhat different transport services must correspond.

LTL networks transport consignments to and from many customers and can thus be defined as many-to-many networks. Typically these networks consists of pick-up (collection) and distribution, terminal operations, and line-haul between terminals (Daganzo, 1987; Hall, 1993). An important reason for using terminals in many-to-many networks is cost reduction (Daganzo, 1987). These terminals can have two different functions: end-of-line terminals and break-bulk terminals (Crainic, 2003). An end-of-line terminal is where trucks unload consignments picked up at consignors and load consignments for delivery to consignees. The catchment area of an end-of-line terminal is called its region and is often divided into several local territories (Hall, 1993). Break-bulk terminals are used for consolidating traffic from several end-of-line terminals, i.e. used as hubs in LTL networks. End-of-line terminals can be directly connected to each other or connected via break-bulk terminals or another end-of-line terminal. This connection is called a terminal-to-terminal service. In LTL networks break-bulk terminals are appropriate when the amount of goods between end-of-line terminals is not enough to justify direct connections. A network where several end-of-line terminals are connected to one break-bulk terminal is thus a kind of hub-and-spoke system. An illustration of these terms is presented in Figure 3.

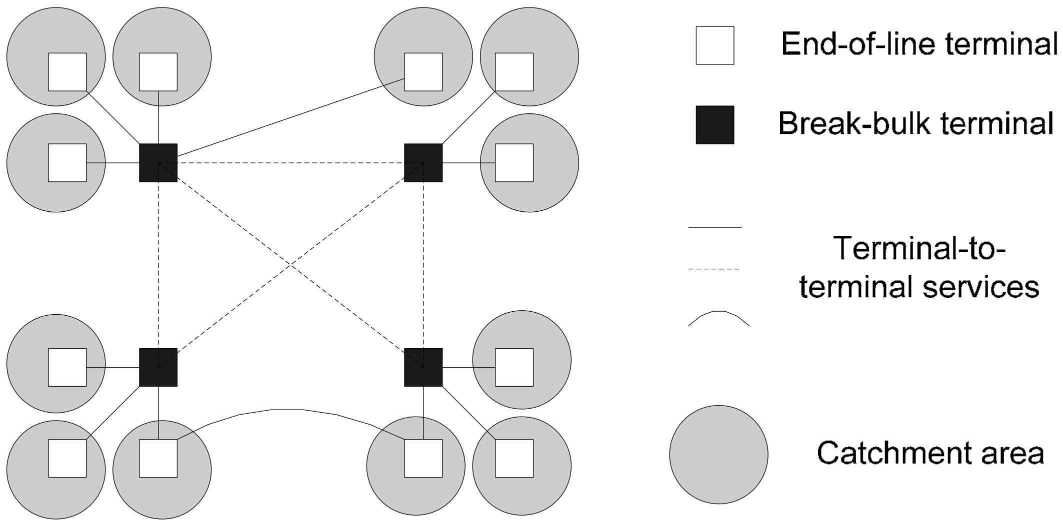

Figure 3 Example of a LTL network with terminals.

For the routes between terminals, earliest and latest departure times are specified to be able to offer customers a departure cut-off time and yet also ensure timely arrival at the destination terminal (Crainic, 2003). These departure and arrival times are often clustered within a limited time window, generally during the evening and morning. However, before the latest departure time trucks can leave on a go-when-full policy, implying that only part of the traffic follow the established departure times.

Consignments in LTL networks can be transported without handling them in terminals; for illustration see Figure 4 (Daganzo, 1987; Liu et al., 2003). In such a network the pick-up and distribution are local milk runs with several stops connected by a line-haul on the long-distance, which facilitates high volume capacity utilisation on the major part of the transport distance while avoiding visits at terminals. This is an appropriate network when lead-time requirements are tight or consignments are large, which is the reason for part loads to be handled this way. Thus, in LTL transport networks there are advantages for consignments to be handled in terminals as well as not to be handled in terminals, which can imply utilizing both alternatives simultaneously. Typically, routing via terminal is determined by the consignment size, i.e. consolidated cargo is routed via terminal and part loads are not.

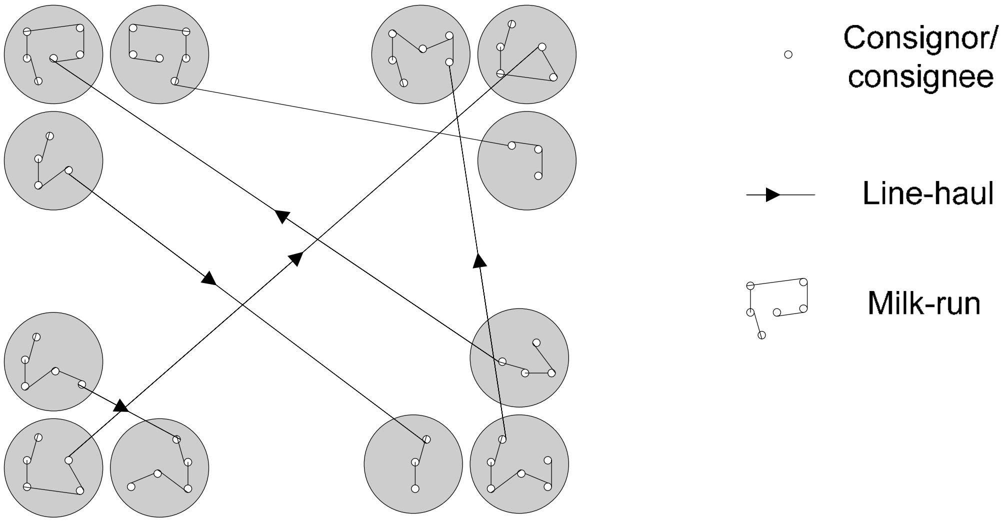

Figure 4 Example of a LTL network without terminals.

In the transport between regions in LTL networks, consolidated cargo and part loads are often co-produced to achieve high resource utilisation. This is made possible in that both services are mainly defined as overnight services; i.e. the delivery time is counted in days from the time the consignment is picked up.

As mentioned earlier, forwarders often contract hauliers to perform transport services. Figure 5 illustrates the relationship between consignor, consignee, forwarder, haulier, and intermodal operator. It highlights that using IRRT involves at least one more actor than when the haulier performs the whole transport in-house. Jeffs and Hills (1990) identified organisational aspects, among others, at the mode decision-making firm to affect the choice of transport mode. Examples of these organisational aspects are independence of the establishment, number of organisational levels, and sphere of operation. The organisational structure of the customer of IRRT could then support or impede the use of IRRT and impact on the mode choice.

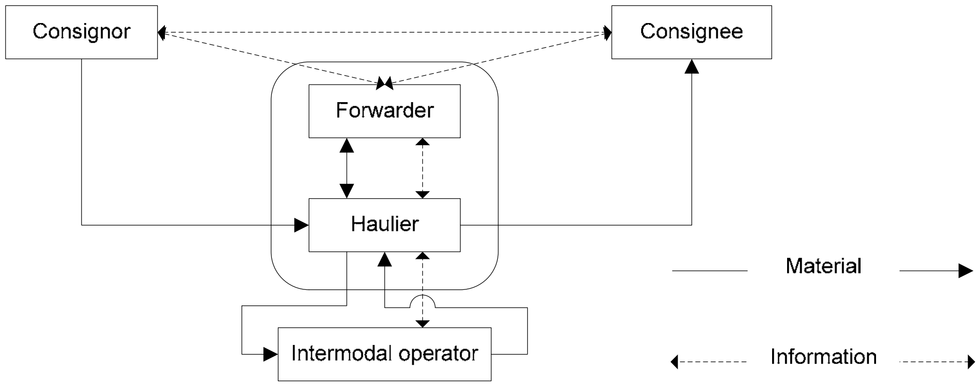

Figure 5 The relationships between actors in LTL network and IRRT.

Summing up, the role of IRRT in LTL networks is for long distance transport, i.e. the line haul or interregional transports. It is considered to be a low cost alternative and a strictly scheduled service. Further, IRRT has relatively high volume requirements, which makes the IRRT service general and not custom made. Consequently, adaptation is required by the customer of IRRT. In addition, the time available for LTL service is limited and several activities have to be coordinated in LTL networks, e.g. terminal, distribution, and long-distance. Each of the activities has its own performance and objectives that can cause conflicting objectives between activities.

The mode choice

There is a vast body of literature on mode choice factors but in Bontekoning et al.'s (2004) literature review on intermodal transport it is concluded that these are specific to a certain data set, research population, and geographical area. There are some common factors though; some factors generally considered are presented in Table 1.

Table 1 Typical mode choice factors considered.

Study	(McGinnis, 1990)	(Cullinane and Toy, 2000)		(Jeffs and Hills, 1990)
Factors	Freight rates	Cost/price/rate	Flexibility Infrastructure availability	Customer requirements
	Reliability	Speed	Capability	Product characteristics
	Transit time	Transit time reliability	Inventory	Company structure/organisation
	Loss, damage, claims processing, and tracing	Characteristics of the goods	Loss/damage	Government
	Shipper market considerations	Service (unspecified)	Sales per year	Available transport facilities
	Carrier considerations	Frequency	Controllability/tracability	Decision maker
		Distance	Previous experience	

McGinnis (1990) reviewed mode choice and carrier selection literature from the 1970's and 1980's by categorising factors from the literature into six main factors. Studying the choice between road and rail in the paper, printing, and publishing industry in the UK Jeffs and Hills (1990) identified some different factors than usually identified. Cullinane and Toy (2000) applied content analysis to literature on freight route and mode choice decisions from which they constructed 15 factors. The factors identified are seldom defined or explained in detail. Interestingly, McGinnis identified factors that can mainly be attributable to the transport service. Cullinane and Toy identified some different aspects as also influential, e.g. inventory and previous experience. Jeffs and Hills, a specific study, conversely, identified factors as company structure/organisation and decision maker. This exemplifies the complexity of the mode choice and that factors involved in the mode choice represent a broad variety of issues.

Despite this variety of factors, a few of them are consistently highly ranked. McGinnis' (1990) main conclusion was that U.S. shippers value service higher than freight rates, but that the rates were an important factor. In some segments, though, freight rates were more important than all service factors. Further, priorities between service factors varied between the different studies reviewed. In a follow up literature review by Murphy and Hall (1995) also including literature from the 1990's, it was noticed that the importance of freight rates has increased but that reliability was always top-ranked. They also recognised that rankings were different between studies on motor carrier selection and other transport selection studies. Cullinane and Toy (2000) found that cost/price/rate, speed, transit time reliability, characteristics of the goods, and service (unspecified) were consistently top ranked factors. In studying the impact of shipper perception of individual transport service factors on overall mode perception, Evers et al. (1996) identified the factors of timeliness and availability as most important. The order of importance was also relatively similar across modes. Taking a Nordic shipper perspective on transport choices between the Nordic countries and continental Europe, Ludvigsen (1999) concludes that there is no differentiation between quality requirements for intermodal and single-modal transit, but that the relative importance of factors differ between the countries. Generally, intermodal transport was rated lower than single-modal transport.

Another aspect that has been identified as affecting the mode choice is attitude towards different modes. Interestingly, non-users of intermodal transport have been found to be more negative than the actual users (Bontekoning et al., 2004) suggesting that attitude and actual experience do not always correlate. Shinghal and Fowkes (2002) correspondingly identified that different sectors had different attitudes towards intermodal transport in the Delhi – Bombay transport corridor in India.

In a study of Dutch road transport companies, congestion resulted in less reliable service and higher costs (Van Schijndel and Dinwoodie, 2000). However, 45% felt unable to switch to intermodal transport and most chose to leave earlier to avoid congestion. Improving service and cost for intermodal transport is perhaps not enough since dependence on other companies was perceived as problematic.

Freight rates of IRRT and service factors are also expected to be relevant in the mode choice in LTL networks as an important objective of LTL networks usually is to provide high service quality at a competitive price (Abshire and Premeaux, 1991; Lambert et al., 1993; Crainic, 2003). LTL networks are scheduled to enable the provision of a time definite transport service, putting high service demands on each operation.

Generally, freight rate and different service related factors, typically transport time and transport time reliability, seem to be the most important in the mode choice. However, no common set of factors have been concluded to be prevalent in determining the mode choice. There even seems to be no mode choice in some situations (Jeffs and Hills, 1990).

Intermodal transport is compared to road transport in LTL networks as road transport is the base for operations. Theoretically, this implies that acceptable time and cost performance by intermodal transport compared to road transport would result in an increased usage of intermodal transport in LTL networks. There are, however, several time aspects identified as important in the mode choice, the most important being transport time and transport time reliability. Several of these aspects are also highly ranked by customers of LTL services (Abshire and Premeaux, 1991; Lambert et al., 1993). Consequently, there is interest in whether or not the same time aspects that are important in the evaluation of LTL services are important in the mode choice in LTL networks. However, several mode choice studies indicate that improving the important factors in the mode choice is not enough for an increased use of IRRT, which means that there are more dimensions to mode choice.

Mode choice decision-making

There exist different perspectives of mode choice decision-making in literature. A convenient and simplified perspective is the use of break-even distance as a rule of thumb for when IRRT is a viable alternative from a cost perspective. This distance could be calculated or based on experience. A handbook in intermodal transport mentions a break-even distance of 600 km (Vreenken et al., 2005). In another perspective, a textbook states the generalised cost model as the way mode choice decision-making is done (Powell, 2001). In this model different cost items, e.g. freight rate, inventory holding costs, and risk costs, are calculated, summed in a generalised cost metric and the least cost alternative is chosen. According to Jeffs and Hills (1990) transport decision-making is more complex, which makes models that rely on a common metric, typically generalised cost, inadequate. The generalised cost model is, of course, a simplified approach to how the mode choice is made; there is more to the mode choice than comparing freight rates and translating time and other aspects into monetary terms as making a specific mode choice in LTL networks has implications for required resources and drivers. Further, shippers may have requirements not compatible with IRRT, cargo may not be suitable for IRRT, or the decision maker may have a lack of knowledge about IRRT (Jeffs and Hills, 1990). Trying to understand the mode choice from cost and time factors or a simple rule of thumb is consequently not adequate because the interaction of other aspects not directly related to cost and time are not captured in these perspectives.

Pisharodi (1991) recognises that literature on the mode choice emphasises the identification of factors instead of explaining or analysing the decision process. The SULOGTRA project (2000) also recognised a research need of mode choice decision-making. Transport buyers have been ascribed a multi-step decision-making process when choosing what transport service to buy, where they first determine the desired quality of transit, identifying the viable suppliers, and finally negotiating rates (Ludvigsen, 1999). This is a rather straightforward, rational model. However, the model is inadequate for hauliers facing a mode choice as they use their own resources when producing transport services; the model treats the choices as separate and ignores the possibility that earlier decisions influence the choice at hand.

Interestingly, Jeffs and Hills (1990) found that the mode choice is a repetitive process requiring strong stimulus for a change to occur. Moreover, the behavioural stability of product logistics managers in Austria, when making transport choices, was determined by the shipments suitability for a certain transport mode (Maier et al., 2002). This shipment decision was done by someone other than the dispatcher and the existence of performance controls from the existing supplier, such as delivery guarantees, which prevents a change of transport supplier and transport mode. These studies show that a mode choice is not done actively at every point a particular transport service is used. However, these studies were focused at transport buyers with a mode choice and not transport service providers. If these findings are transferable a similar mode choice stability is also expected of transport service providers.

Basic decision-making theory can contribute an additional perspective to listing factors in the understanding of the mode choice. A choice is typically part of a process including a problem definition, different alternatives, evaluations of the alternatives, implementation, and follow up; see Figure 6 (Greenberg and Baron, 2000). This process is defined as decision-making. Using the decision-making perspective can help to better understand the mode choice by explaining the different steps before and after the actual choice.

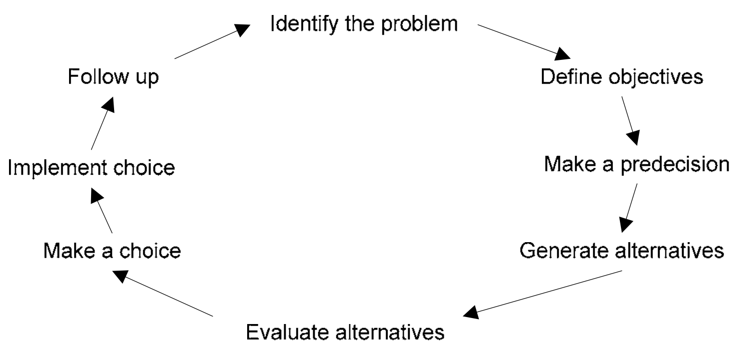

Figure 6 Decision making (Greenberg and Baron, 2000).

In an attempt to study transport mode decision-making, Tsamboulas and Kapros (2000) provide a model that can test various factors' impacts on the choice of transport mode and identify three different so called decision patterns. These decision patterns show that possible customers of IRRT have different attitudes towards IRRT, which result in different usage. However, the decision patterns are only constituted of the important factors while the process perspective of the decision-making is left less articulated. Further, in trying to generalise mode choice decision-making into mathematical models, as in the general model in Crainic and Laporte (1997), the individual perspective is lost. Capturing individual differences in mode choices is difficult in mathematical models. Consequently, mode choice literature will be enriched by putting mode choice in its decision-making context. Agent-based simulation has been suggested as an appropriate tool (Ramstedt and Woxenius, 2006).

The dominant technology of an organisation can be viewed to determine suitable organisation structure (Scott, 2003). Technology here is a broad concept referring to the work performed by an organisation and can be described by the three dimensions of complexity, uncertainty, and interdependence (ibid.). In LTL networks many terminals are connected with each other, which results in a number of internal stakeholders, i.e. terminal operators and transport operators. This causes some complexity and interdependence. The LTL service lends rather easily to a division of tasks through the use of terminals. The division of tasks between actors result in a structure that broadly defines the decision-making responsibilities of each actor. Decision making in LTL networks are consequently distributed among several actors.

LTL networks, with their associated problems, have to a great extent been studied with an operational research approach. Typical issues in transportation networks are facility location, design of the physical network, resource acquisition, definition of broad services and tariff policies, route choice, type of service to operate, general operating rules for each terminal, work allocation among terminals, repositioning of resources, and different scheduling issues (Crainic and Laporte, 1997). The operations research methods, models and tools can enhance and assist the analysis of planning and decision-making processes. Thus, the objective of this approach is not to provide a final and definitive solution to the problems and issues in transportation networks. Transportation network operation and the mode choice are often treated separately in research. In a LTL network, however, most of these issues are faced simultaneously in addition to mode choice.

Forwarders and hauliers face a mode choice. In LTL networks, however, the main decision issue is not the mode choice but rather how to provide a competitive transport service. Different subordinated decision issues have varying time horizons, e.g. facility locations have a long-term effect while which road to drive has a short-term effect. Thus, there is decision-making with different time horizons. Traditionally decision-making is divided into strategic, tactical, and operational decision levels with time horizon as the distinguishing factor (Crainic and Laporte, 1997).

In summation, decision making is a process involving more than a choice. This perspective of the mode choice is in need of further development. Mode choices have been observed to be stable, thus suggesting that the mode choice is part of a repetitive process. In LTL networks several actors are involved with their individual decision-making.

Research questions

LTL networks are based on road transport characteristics and performance. Using IRRT is an alternative to road transport. Thereby there is a choice, either explicit or implicit, in LTL networks between road transport and IRRT.

IRRT services are rigidly scheduled. LTL networks are scheduled as well, thus limiting the basic freedom that road transport provides. Time aspects are important in both services and have been concluded to be highly ranked selection criteria in the mode choice. However, time can be expressed as several aspects, but time is also a quantifiable measure that can express the correspondence between IRRT and LTL services. The first research question is formulated as:

RQ1 *What time aspects of IRRT are of importance for the mode choice in LTL networks?*

However, the choice between IRRT and road transport in LTL networks is part of a more comprehensive decision-making process taking place at different actors and at different decision levels. Many issues are involved in producing LTL services. These services are produced in networks with many terminals and several subsequent activities. This constitutes a decision-making context in which a mode choice is made. Each issue in the LTL network involves choices with its decision-making. However, these issues are not expected to be treated as isolated but as part of an operation with the goal of providing competitive LTL transport services. Theoretically the decision-making perspective of the mode choice is in need of development. To better understand the mode choice in LTL networks research question number two is:

RQ2 *How is the decision making that includes the mode choice constituted in LTL networks?*

Several actors are involved in LTL networks for one or another reason, e.g. specialisation. These actors then hold different responsibilities as a result of the division of tasks. One can be responsible for the line-haul while another holds the overall responsibility for the network performance. The line-haul is the activity subject to the mode choice, but the line-haul is not independent in the network. The third research question addresses this issue:

RQ3 *How is the relationship between forwarder and hauliers in LTL networks affecting the mode choice?*

Each of the research questions correspond to the paper with the same number.

Methodology

This chapter starts with outlining the research process and moves on to describing that the research was performed as case studies. A description of how the data collection and analysis was done is given to provide a basis for judging the trustworthiness of the research.

Research process

As the purpose of this thesis is explorative, and the research questions are quite general, a qualitative approach is appropriate (Bryman, 2004). The aim with this qualitative approach in this thesis is not to generate theories but to apply and combine existing theories to the research area together with empirical inquiry to generate better understanding.

The starting point for this thesis work was to create applicable research results that are practically relevant. Gaining access to reality is a real challenge for management researchers (Gummesson, 2000). For the purpose of gaining and maintaining access the collaborative research approach was deemed appropriate. Collaborative research is defined as "an emergent and systematic inquiry process, embedded in a true partnership between researchers and members of a living system for the purpose of generating actionable scientific knowledge" (Adler et al., 2004). This is indeed an ambitious approach that has not been established within the realm of this thesis work. The explorative nature of the research led to a focus at understanding rather than generating actionable scientific knowledge. However, the emergent and systematic inquiry process and the true partnership of collaborative research have been present features of the research.

A partnership, inspired by collaborative research, has been conducted with Schenker AB, one of the largest forwarders that provide LTL transport services in Sweden. First, this partnership gave access to managers and business data of crucial importance to the thesis. Second, research issues relevant to IRRT in the LTL network were discussed and analysed jointly. This partnership implied a focus on one forwarder with their LTL network. Thus, the result of the research is specific to this company and their context.

Case study

Yin (2003) states that "the case study is the method of choice when the phenomenon under study is not readily distinguishable from its context". As argued in the previous chapters, the mode choice needs to be investigated in the context where it is made. A case has been defined as a phenomenon of some sort occurring in a bounded context and being the unit of analysis (Miles and Huberman, 1994). Reasons to use case studies are to create understanding and provide a holistic view (Gummesson, 2000).

Mode choices between road transport and IRRT in LTL networks is the wide phenomenon studied that constitutes the base from which to form cases to study. To cover the aspects in the research questions, the different papers have different empirical focus within the LTL network, as Figure 7 illustrates. Paper I includes all of the hauliers within the studied LTL network currently using IRRT but also terminal-to-terminal services where IRRT is a possible solution that is currently not used. When studying a haulier‘s mode choice decision-making in paper II, this particular haulier’s decision-making is the case. Two hauliers are studied, one that uses IRRT and one that is considering to start using IRRT. In paper III the case is Schenker’s Swedish LTL network, including the subcontracted hauliers, with a primary focus at the relationship and interaction between the forwarder and hauliers.

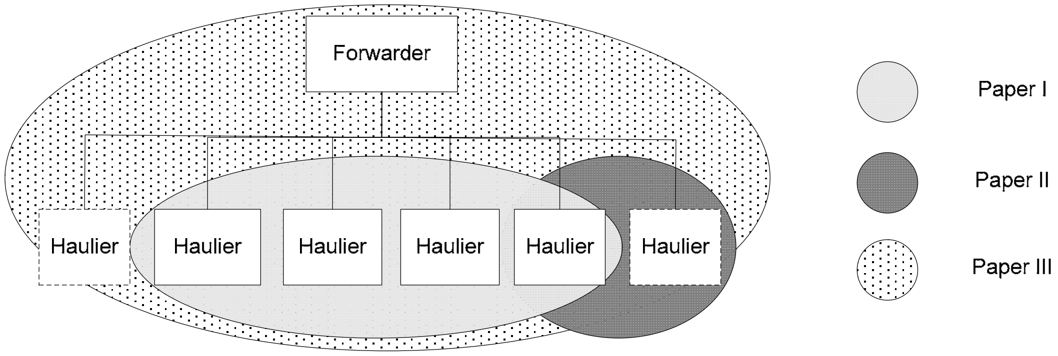

Figure 7 Empirical focus from an organisational perspective of the LTL network in the appended papers.

That only one forwarder with their contracted hauliers is studied has some pros and cons. It gives the possibility for deeper knowledge as the phenomenon can be studied from several perspectives within the same context. This gave the opportunity to connect and apply theories from disciplines as decision-making, inter-organisational relationships with earlier research of the mode choice phenomenon. Thereby this thesis can be seen as a case study of one LTL network, including several smaller case studies. However, this thesis consequently only represents one view and the results should be viewed as introductory.

Data collection

Contextual knowledge and data was obtained by trade journals, archival records, documentation, earlier research, and interviews within Schenker, their contracted hauliers, and at other organisations. All interviews conducted followed predefined open-ended questions and were transcribed shortly after the interviews. Most of the interviews were also conducted together with a colleague. In these interviews one researcher primarily took notes while the other led the interview. One problem faced was the ambiguousness of the studied phenomena, i.e. although a general case can be distinguished many exceptions exist. This was managed by exploring some of the exceptions and interviewing several people.

In paper I, data was provided by the intermodal operator for the usage of IRRT by the forwarder with its contracted hauliers. This data was based on the hauliers’ purchases of IRRT services over a two year period. Information included transport route, type and of number load unit transported, price paid, loading status and weight, and what haulier had purchased the service. Further, the paper also uses the official timetable of the intermodal operator as well as the forwarder’s internal departure and arrival times at consolidation terminals. The intermodal operator’s timetable states latest hand-over time at departure and earliest pick-up time on arrival to and from the intermodal transhipment terminal. The amount of data was extensive and managed in spreadsheets.

Quality and correct interpretation of the data was discussed with experts at the intermodal operator as well as the forwarder.

In paper II, interviews were initially done jointly by the author and an internal consultant from the forwarder with the executive officer at each haulier. These interviews were focusing at the individual haulier's contextual decision-making and based on a literature review which made them semi-structured. Next, the hauliers' goods flows where mapped with sheets where departure and arrival times from and to each region, addresses for collection and distribution for larger consignments, type of goods transported, idle time, and driver changes were recorded. This mapping was done for each vehicle, together with an experienced transport planner. These transport planners were also interviewed about their operational decision-making. A meeting was held with the executive officer at each haulier concluding and discussing the data obtained.

Paper III is based on interviews and public statements from a selection of large hauliers contracted by the forwarder. The selection of large hauliers was based on the number of region-to-region relations each haulier is responsible for and included the top 14 hauliers. The interviews were mainly semi-structured and done with executive officers and transport planners at a few hauliers, and with managers and experts at the forwarder. This approach was deemed adequate as the aim with the paper is to apply a theoretical concept to the forwarder-haulier organisation that provides LTL services.

Data analysis

Miles and Huberman (1994) define qualitative data analysis as consisting of three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification. In this research effort, data have been reduced continuously as the focus of the research grew clearer. Mainly, previously published categorisations have been used to determine what data to display. Examples of such categorisations are decision issues common in transport networks, main activities of IRRT and time aspects of transport services. Benbasat et al. (1987) emphasise the need to establish a clear chain of evidence. Data and analysis is therefore sought to be presented in a consistent, logical, and comprehensive way in order to make the reasoning explicit. Further, the collected data have continuously been analysed and presented to company contacts as well as supervisors and research colleagues.

More specifically, in paper I some IRRT routes were left out from the analysis because they had been used infrequently in the LTL network. Thereby two clearly contrasting groups of IRRT routes where identified: regularly used routes and routes not used. To analyse whether or not these two groups differed in the time aspects studied, appropriate statistical tests were conducted and interpreted with the help of a research colleague. Data on the time aspects is grouped and presented in tables and further explained in the text. Interpretation of what the data means is done on the basis of contextual knowledge. Early analysis results were presented to and discussed with a working group within the forwarder.

In paper II literature studies guided how to structure the description of the hauliers' decision-making. Focus was given to decision issues considered to impact the mode choice most, each decision issue was tried to be described with the general steps of decision-making. The contextual perspective of the decision issues is given by treating it as part of the haulier's transformation process. By this theoretical lens relevant data is presented and analysed. Further, goods flow mapping was used to distinguish goods with time requirements not suitable for IRRT and to display the actual mode choice implemented by the hauliers. As the vehicle route schedules are determined at a tactical level and subject to operative changes and adjustment the mapping compelled a choice of what to map; the planned routes or the actual vehicle routes carried out. The planned routes were mapped because that reflects what is made at the tactical level.

Paper III first establishes the applicability of a concept from organisation theory on the studied LTL network by describing the organisational structure in the parameters of the theory. Second, this theory is used in the analysis of the organisational structure's impact on the mode choice and the LTL network's relation towards the different activities of IRRT.

Results

Results are here presented by answering the research questions.

Time aspects of intermodal road-rail transport in LTL networks

RQ1 *What time aspects of IRRT are of importance for the mode choice in LTL networks?*

Transport time, timing, frequency, punctuality, and order time were identified from literature as tentatively important time aspects of IRRT usage in LTL networks. The order time is defined as the required time before departure that a transport has to be ordered to guarantee capacity, a certain price, or service level. This time aspect could not be attributed to a single IRRT route in the studied case as the other time aspects were because of time restraints on data collection. Generally, however, at the order time of the IRRT service, relevant volume information is not available to the haulier, which results in that the haulier must act on an assessment of the amount of goods if the consolidated cargo should go by IRRT.

The IRRT routes were divided into two groups: those regularly used by the hauliers in the studied LTL network (defined as hauliers transporting five or more TEU per week), and those IRRT routes not used. For each time aspect measured, these two groups of IRRT routes were compared and found to be significantly different by statistical tests.

Transport time is here defined as the scheduled duration of a transport. Figure 8 presents the transport time of both the IRRT services, including road haulage from and to the consolidation terminals, and the consolidated cargo terminal-to-terminal transport. The hauliers contracted by the forwarder were found to use intermodal transport primarily over longer distances, which is in line with the common view of the competitive strength of intermodal transport.

Distance is usually linearly related to transport time when vehicles move at maximum speed. In IRRT the transhipment activity adds time but no distance, which is a disadvantage. If the IRRT service would be offered at this minimum transport time the IRRT routes in Figure 8 would be on a line with positive inclination crossing the y-axle above zero. However, this is not the case and evidently the IRRT service is in some cases scheduled to take longer than the distance requires. Consequently, IRRT has a large disadvantage on these routes compared to road transport. The fact that the average transport time for the regularly used IRRT routes is shorter and that the average distance is longer than for the IRRT routes not used shows that the relation between distance and transport time, i.e. average speed, differs considerably between the two groups. Transport time of the IRRT service compared to road transport is therefore an important time aspect in the mode choice.

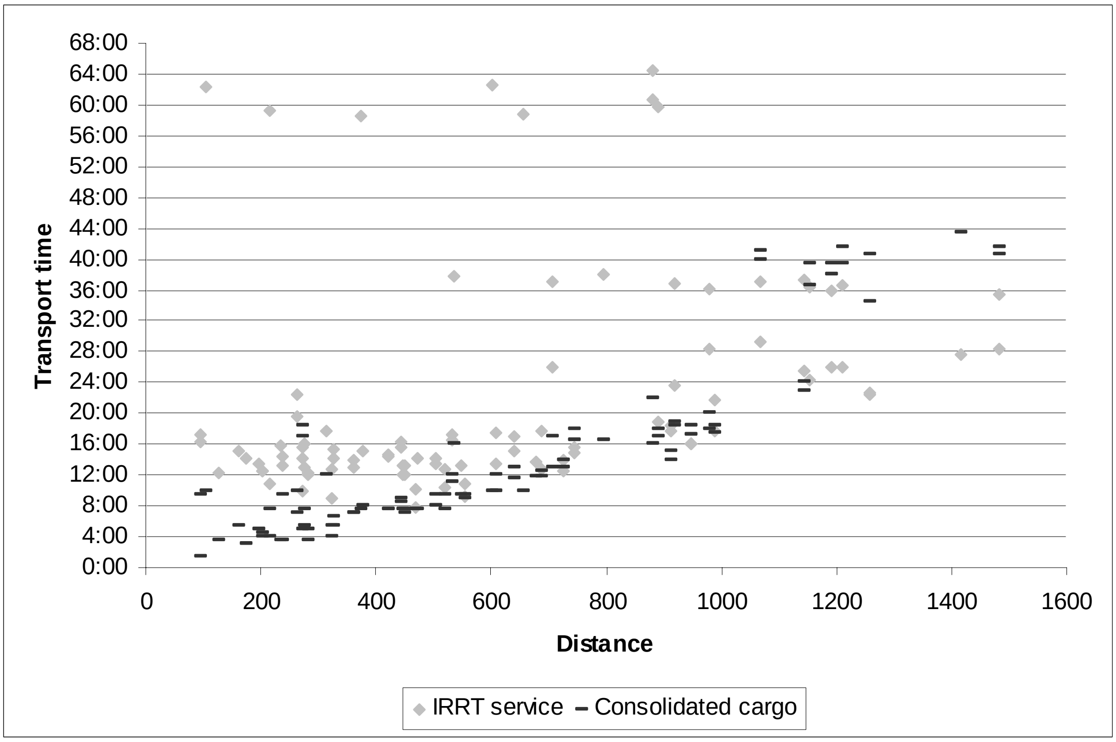

Figure 8 Transport time of IRRT and terminal-to-terminal consolidated cargo.

Regarding timing, correspondence of departure and arrival times, between the demands from consolidated cargo and the IRRT service is significantly higher for the IRRT routes regularly used by the forwarder's hauliers. On all relations but two where the transport time of the IRRT service corresponds with the transport time available for consolidated cargo, the timing of departure and arrival also corresponds. This fact suggests that the intermodal operator has timed their departure and arrival correctly to the demand of the forwarder on these routes or, the opposite, that the forwarder has adjusted its departure and arrival times to enable IRRT on these routes. However, only on 17 of the 98 relations does the IRRT fulfil the departure and arrival timing demands from consolidated cargo. This fact shows the limited possibility to use the available IRRT service for consolidated cargo.

Regularly used IRRT routes had, on average, more departures per week than the IRRT routes not used by the hauliers in the LTL network. The difference is statistically significant. Thereby is frequency, defined as the number of departures during a certain time period, of the IRRT service an important time aspect for frequent use of IRRT in this LTL network.

For the punctuality of IRRT, routes that are frequently used by the forwarder's hauliers show better performance than the IRRT routes not used. However, a punctuality of 75% is low even for rail transports. Even though the data is for only one month these statistics show that punctuality needs further attention.

Table 2 Time aspects measured in the LTL network.

	Unit of measure	IRRT routes regularly used	IRRT routes not used	Statistically significant difference at $p < 0.05$
Transport time of the IRRT service	Hours and Minutes	20:15	23:13	Yes
Timing (both departure and arrival)	Number of routes	15 of 37	2 of 61	Yes
Frequency of the IRRT service	Weekly departures	5,49 departures/week	4,44 departures/week	Yes
Punctuality of the IRRT service	Share of late arrivals compared to total arrivals	25% late	42% late	Yes

Table 2 presents measures of the four time aspects transport time, timing, frequency, and punctuality. In conclusion, transport time, timing, frequency, and punctuality were measurable and are significantly different for IRRT routes where the forwarder's hauliers used IRRT regularly and where they did not use it.

Mode choice decision-making in LTL networks

RQ2 How is the decision making that includes the mode choice constituted in LTL networks?

Paper II identified that the studied hauliers transport goods that are suitable for intermodal transport from a cost and time requirement perspective but that are currently transported by road transport. Thus, the mode choice is not all determined by customer requirements; hauliers' decision making affects their share of IRRT. Hence, hauliers, in the role of a mode decision making firm, can play an influential role in making use of the expected large potential for intermodal transport.

The mode choice decision making firm perspective of the mode choice is taken by describing and analysing the mode choice as part of strategic, tactical, and operational decision making with an input-transformation-output perspective of the haulier. Describing the decision making in which the mode choice is embedded provides the basis for a contextual understanding of the mode choice. By dividing a haulier's decision making into levels, it is highlighted that decisions at higher levels set the preconditions to decide to use intermodal transport at lower levels. Treating the mode choice as part of a haulier's input-transformation-output process illustrates that the transport mode is a mean to an end for the haulier; i.e. the end is to produce requested transport services.

This perspective, as illustrated in Figure 9, aims at describing the mode choice in its decision-making context. With this model of the context of the mode choice the paper explores how the mode choice is treated at two hauliers. The mode choice is largely determined at the strategic level when resources are acquired because then the adaptation to IRRT is decided upon.

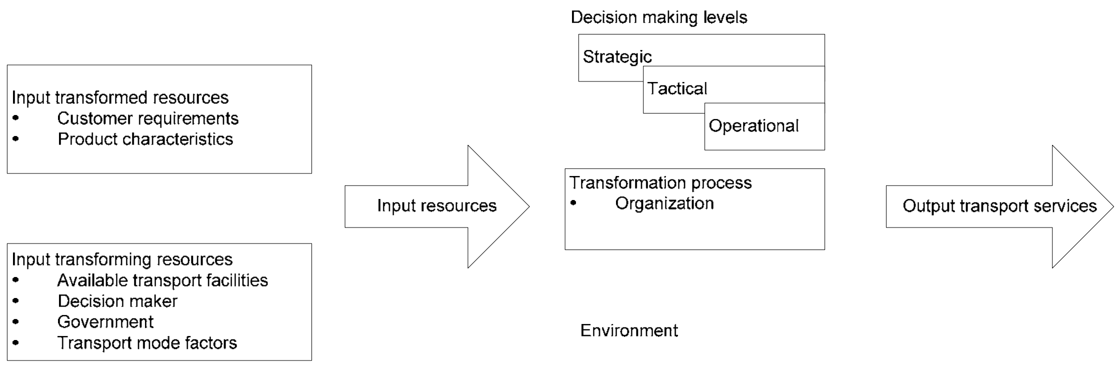

Figure 9 A model of mode choice decision-making.

Input transformed resources impact the mode choice to a large extent at the strategic and tactical levels and to a limited extent at the operational level. The input transforming resources must match the transformed resources in the transformation process in order to produce requested transport services, i.e. available transport facilities and intermodal transport services must match product characteristics and customer requirements. This match of input resources is established at the strategic and tactical levels through resource acquisition and vehicle route (motive power) scheduling while transport services are executed at the operational level with the use of acquired resources and based on the established vehicle schedules.

Describing the central issues relating to the mode choice at the studied hauliers in more detail, with the help of the steps in the decision-making (see Figure 6), provides better understanding of how the choice is made. Two of these issues are presented in Table 3. Resource acquisitions are about fulfilling a transport capacity requirement, either in the form of replacing an existing worn out resource or increasing the capacity with additional resources. The transport demand considered in the acquisition decision is often general, but can be specific to a specific contract with a transport buyer. The resources can have different features. Most importantly, road and IRRT vehicles differ and several additional features exist. Flexible resources are highly desirable; that is, flexible in the sense of fulfilling customer transport requests, not flexible in the mode choice. A repetitive behaviour in regard to the mode choice is shown in the resources acquired. The managing directors are responsible for investment judgements and suggest to the board what resources to acquire.

Table 3 Decision-making steps for two important decision issues relating to the mode choice at the studied hauliers.

Decision-making step	Resource acquisition	Vehicle route scheduling
Problem	Fulfil a transport capacity requirement that is often based on a general transport demand but can be specific to a specific contract.	To make sure all goods are transported according to customer requirements, that the vehicle is used efficiently, and to enable steady schedules for the drivers.
Alternatives	Vehicle combination can be lorry with truck body with an attached trailer (24 metres) or semi-trailer with tractor (18.75 metres). Extra features considered are tail lift, removable sides, fridge or freeze capacity, swap body on the truck, horizontal bars for double stacking, dangerous goods classification, and IRRT adaptation.	Road transport requires a setup of long-distance drivers during the night, either as point change or round-trip with stay over. For distribution and collection an extra driver is required, termed pilot driver. IRRT implies no night driving but collection and distribution during the day, i.e. only pilot driver. Adaptation to the IRRT service is required. Departure between 17:40 and 21:00 with arrival between 03:30 and 06:15 for the different services available for the studied hauliers.
Evaluation	Flexible resources are highly desirable, which is flexible in the sense of fulfilling customer transport requests, not flexible in the mode choice. Balance features in the whole fleet of vehicles.	Timing requirements are often outside the IRRT service offered. Tries to utilise load capacity maximally.
Choice	A repetitive behaviour in regard of the mode choice is shown in the resources acquired. The managing directors are responsible for investment judgements and suggest to the board what resources to acquire.	One haulier dispatches 4 semi-trailers with IRRT daily and 14 lorries by road transport from each region. The other haulier dispatches about 12 lorries by road transport daily from each region.
Follow up	Vehicle lifetime costs	Practical execution of routes

Vehicle route scheduling has the objective to make sure all goods are transported according to customer requirements, and that the vehicle is used efficiently and to enable steady schedules for the drivers. Regular recurring consignments and anticipated daily consignments usually reserve capacity on a specific route. Both hauliers studied transport a considerable amount of FTL. One basic wish is to fill the loading capacity in both directions, but, unfortunately, the transport demand is unbalanced. One implication is that, for the direction having the most goods demand, transport requests are either turned down or vehicles return not fully loaded. In the opposite direction the hauliers have more time requirements suggesting that the competition is tougher and they accept more easily time requirements outside the realm of the IRRT service. The demands of the forwarders' customers are generally expressed in timing requirements and special requirements on the vehicle, besides the type and volume of goods to be transported. Only one customer has requested intermodal transport. IRRT has one to two daily departures and the same transport time as road transport, eight to ten hours, on one intercity route and up to three hours longer on the other intercity routes. The IRRT services have, for example, longer transport time, lower punctuality, and lower frequency compared to road transport, which disqualifies intermodal transport in many cases.

Timing requirements, as late departures and early arrivals, prevent a large share of the transported goods to go with IRRT. However, consignments preventing the use of IRRT are scheduled at most vehicles, implying that a re-planning of the vehicle routes could enable an increased use of IRRT. Such re-planning is rarely done, implying that IRRT is used to a lesser extent than possible. Another practice inhibiting rescheduling for the use of IRRT is the setup of long-distance drivers. Most common is the practice that drivers meet somewhere along the long-distance drive to change vehicles, which results in that they come home after every shift, called point change. A result for the mode choice is that both vehicles must go by road transport when one of the vehicles could be scheduled for IRRT.

At the operational level, resource allocation was found to affect the mode choice at the haulier currently using IRRT. They first filled their road transport vehicles and then the semi-trailers used for IRRT because the road vehicles are scheduled with point changes, making them harder to cancel than the IRRT service.

Road transport is the preferred alternative over intermodal transport by the studied hauliers. One reason is that a time flexible transformation process is desired and intermodal transport is not time flexible. Another reason is that customers have timing requirements not suitable for IRRT. This preference for road transport is manifested in the resource acquisition but is based on demands faced in the vehicle route scheduling. Further, many actors have an impact on the mode choice; e.g. customers (both the forwarder and transport buyers) by their timing requirements, hauliers by making the actual mode choice, government by providing suitable road and rail infrastructure, and the intermodal operator by their transport service times and frequency.

Effects of the forwarder-haulier relationship on the mode choice

RQ3 *How is the relationship between forwarder and hauliers in LTL networks affecting the mode choice?*

The studied LTL network was found to have an organisation structure that fit the description of what has been termed a quasifirm. Luke et al. (1989) characterizes inter-organisational relationships by the tightness of coupling and the degree of a shared inter-organisational purpose. They define the quasifirm as "a loosely coupled, enduring set of inter-organizational relationships that are designed to achieve purposes of substantial importance to the viability of participating members". Thus, main characteristics of the quasifirm are the loose coupling between separate organisations and the high degree of shared purposes between these member organisations. Eccles (1981) provides a more applied and detailed description of the quasifirm based on the construction industry. He defines the quasifirm as an organisation form "based on a set of stable relationships between a general contractor and special trade subcontractors" (Eccles, 1981).

Orton and Weick (1990) have reviewed literature on loose coupling. They conceptualized the concept in causes, types, direct effects, compensations, and organisational outcomes of loose coupling. The most frequent direct effects of loose coupling are modularity, requisite variety, and behavioural discretion. Modularity implies a low degree of interdependence between two entities; requisite variety is when a system's entities serve as a medium that can register inputs with accuracy; and behavioural discretion is the capacity for autonomous action. Typical outcomes adherent to loose coupling are persistence, buffering, adaptability, satisfaction, and effectiveness. These direct effects and outcomes illustrate benefits of loose coupling and thus give reasons why a loosely coupled system is preferred and maintained.

Paper III shows that the forwarder-haulier organisation of Schenker can be viewed as a quasifirm because the forwarder and hauliers are separate entities but have shared strategic purposes and long, enduring relationships based on specific region-to-region transports for which a certain haulier is the primary subcontractor. The quasifirm organisation has beneficial characteristics for the forwarder in terms of avoiding the practical execution of the transports, cost control, incentives for efficient performance, and stable subcontractor relationships. Beneficial characteristics for the hauliers are that they maintain their autonomy and that marketing is mainly performed by the forwarder.

Consequences for intermodal transport of the quasifirm organisation were also identified and analysed. The modularity that each haulier represents and the hauliers behavioural discretion, which is an important effect of the loose coupling in the quasifirm, limits the LTL network's strength in all three activities of intermodal transport in that the use of intermodal transport is uncoordinated between the hauliers. For example, demands on the rail haulage and transhipment by the hauliers are individually communicated to the intermodal operator and each haulier performs IRRT road haulage on their own. Thus, the quasifirm is a relatively uncoordinated customer of intermodal transport.

An example can illustrate the effects of the organisational structure on the regional road haulage operations of IRRT. If the transports between the 12 regions in Figure 4 are all contracted to different hauliers this would imply that 11 hauliers depart from each region. Each haulier has their behavioural discretion over the mode choice and is responsible for their deliveries and collections in that region. That means that each haulier performs their road haulage when using IRRT and the economy of scale of coordinating road haulage operations in a region is unutilised.

Further, persistence to the road transport mode due to the greater adaptability it provides is anticipated to impede an increased use of intermodal transport if left unattended. Considering these outcomes of the loose coupling result in lack of a unified effort towards intermodal transport, emphasises the need of management strategies directed both at the provision of the external service (rail haulage and transhipment) and the road haulage operations performed within the quasifirm. Thus, the organisation of the LTL network, in this case a forwarder with contracted hauliers, has important consequences for the efficiency and development of intermodal transport.

Discussion

This chapter discusses how and to what extent this thesis has contributed to the understanding of how the choice between IRRT and road transport is made in LTL networks. The discussion is structured around each paper.

Paper I

Paper I identifies five important time related aspects. These can be used to broadly measure the compliance of IRRT to a scheduled LTL service as consolidated cargo, and the paper shows that IRRT needs improvement in terms of better performance in the time aspects in order to better compete with road transport. This study of time aspects cannot solely explain why IRRT is used or not used on an individual route because IRRT routes with fairly good performance are not used and IRRT routes with lower performance are used. Other factors such as cost, damages, customer requirements, and mode preferences also influence the mode choice.

Further, the causal links between performance in the time aspects and the usage frequency is not self-evident. For example, that regularly used IRRT routes have better punctuality does not necessarily mean that hauliers disregard IRRT because of low punctuality on the other routes. An alternative explanation could be that the intermodal service provider has focused on achieving high punctuality on these routes. Turning to frequency it can be noted that using an infrequent IRRT service regularly requires a high concentration of the goods to the specific day of departure. This means that an infrequent service impedes regular use.

These hauliers transport FTL, part loads, and consolidated cargo. Which of these goods types that went with the used IRRT service is unknown based on the statistics. This means that the departure and arrival times from and to consolidation terminals cannot be expected to have had a decisive impact on the mode choice, as FTL and part loads are not routed via the consolidation terminals. Transport time correspondence between the consolidation network and the intermodal network are therefore not a prerequisite to use IRRT. This means that the time requirements consolidated cargo puts on the IRRT service are not instrumental to whether or not the hauliers will employ intermodal transport. The study of time aspects is therefore not completely attributable to the use of IRRT in the production of consolidated cargo but rather to the use of IRRT in the network where LTL as well as FTL transport services are produced. However, fulfilling the time requirements of consolidated cargo will make the IRRT service more competitive as consolidated cargo is based on road transport.

The methodology to compare IRRT with consolidated cargo in these time aspects can be applied to other forwarders and geographical areas. It can be used as a benchmark tool for intermodal operators in order to analyse the performance of their services compared to what road transport can achieve. However, forwarders might be reluctant to share their internally established departure and arrival times, which means that a comparison can be difficult for the intermodal operator to make. Conversely, forwarders can themselves use the methodology as a tool to analyse the compliance between LTL services and IRRT as well as their IRRT usage.

Further, there is a practical issue with using the established departure and arrival times from and to the consolidation terminals because of the possibility to employ the go-when-full policy when using road transport. This implies that trucks can leave earlier and also arrive earlier than the established times, which implies a reliability problem with the measurement compared to the actual behaviour in the LTL network. However, theoretically the comparison is correct and a possible starting point to assist IRRT service improvements.

Paper II

Paper II structures the decision-making by applying several theoretical perspectives. The hauliers' transport operations perspectives were illustrated by applying the general transformation process model from operations management. Typical mode choice factors were placed in this model. Further, the different time horizons of decision issues are captured by applying decision-making levels. This structure is a tool to explain how the decision-making is constituted, which includes the mode choice. By nature the combined model is general and descriptive. How it is best used in further empirical studies is less explicated. The model is not explanatory to why a haulier makes a certain mode choice but it broadly outlines a structure that can support further investigation into the mode choice decision-making in transport firms.

At the studied hauliers, resource acquisition, vehicle route scheduling, and operational resource allocation were decision issues that affected the mode choice. However, this study only included two hauliers. Studying more hauliers will give a more general empirical base to establish how hauliers' decision-making is constituted. Studying other types of mode choice decision-making firms, e.g. shipping lines and shippers, can probably include other or more decision issues. For example, here only the haulier perspective is taken of the mode choice decision-making. The full spectrum of the LTL network is therefore not studied. The forwarder's decision-making could consequently also have been studied with the aim of describing more decision issues with relation to the mode choice in the LTL network.

In describing the decision-making at the hauliers it is shown that time aspects are important in the vehicle route scheduling. For example, suitable goods are planned on a vehicle route to accomplish efficient round trips. If one consignment has timing demands outside the intermodal service, the whole round trip must be by road transport. Further, the forwarder has an influence on timing demands by setting departure and arrival times to and from the consolidation terminals, but also when transport services are sold to customers in making promises of late collection and/or early delivery. Moreover, once a vehicle route is established it is seldom re-planned, suggesting that the mode choice is stable for several years.

Paper III

Paper III shows the applicability of a concept from organisation theory, the quasifirm, on the studied LTL network. The impact on the mode choice by the organisational structure with several actors in the LTL network could be analysed through this theory. That the hauliers are contracted to perform all the transports between two regions means that the forwarder gives the hauliers a lot of behavioural discretion over how to perform these transports, i.e. the mode choice is also subcontracted. The hauliers are also quite independent from the other hauliers contracted by the forwarder. The result is decentralised mode choices. This perspective explicated that the mode choice is a basic part of the haulier responsibility and their behavioural discretion, which implies that the direct effects and outcomes of the quasifirm are basically working against centrally coordinated mode choices. Centrally coordinated mode choices could imply a stronger position in improving the IRRT services.

Effective strategies for increased usage of IRRT in the studied LTL network should therefore be adjusted to work with the quasifirm's direct effects and outcomes, such as the behavioural discretion and the adaptability, to preserve the advantages of the quasifirm. The promotion of IRRT in this LTL network consequently requires careful management. In LTL networks with other organisation forms, effective strategies for increased usage of IRRT are therefore anticipated to require adjustment to the principles prevalent in those other LTL networks. In conclusion, both paper II and paper III develop descriptive models that try to structure the understanding of the mode choice in LTL networks.

Planning restrictions imposed when using IRRT point to the need of better planning tools and processes. These tools and processes should incorporate both the mode choice and the network perspective to be effective. In vehicle route scheduling the mode choice is affected by the departure and arrival times at consolidation terminals. In establishing these times the effect on the mode choice could be highlighted. The time requirements of the customers to the forwarder were shown to affect the mode choices towards road transport. Implementing the awareness of the affect on the mode choice in the sales process is therefore another strategy that can have affect on IRRT usage.

In the studied LTL network mode choices are taken by the individual hauliers; thus, the mode choice is not made centrally by the forwarder, and hauliers' mode choices are, in the long-term, manifested in what type of resources that are acquired. When making resource acquisitions the studied hauliers mainly replace old vehicles and most often acquire a vehicle for the same transport mode. However, new road vehicles are often equipped with more features than the ones they replace but other features are favoured over IRRT adaptation. This choice determines the mode choices for that haulier for several years to come. This fact suggests that the benefits of IRRT should be made clear when resources are acquired in order to favour the choice of the IRRT mode. Tools to support the choice of IRRT during the resource acquisition could be cost calculation and goods flow analysis, tools which highlights the benefits of and potential to use IRRT for the individual haulier.

IRRT is in need of product development in order to better compete with road transport and therefore also better suited to the LTL segment. Collaboration between IRRT customers and intermodal operators is one strategy to start development. One forwarder with its LTL network cannot usually fill an IRRT service on its own. Further, a resistance has been observed from forwarders to build up shared IRRT services. Intermodal operators are consequently required to build new services without close cooperation with a single forwarder. However, a general IRRT service targeting the LTL segment would attract forwarders with their contracted hauliers. Transport time of similar duration as road transport, timed departure and arrival, high frequency and high punctuality are some of the LTL requirements on IRRT. These requirements are not specific to a certain forwarder, except perhaps timing, which enhances the potential for an IRRT service targeting LTL requirements to be successful even without one key customer.

Conclusions

This chapter first concludes the results of the thesis and then outlines some prospects for future research. The thesis focuses at mode choices in LTL networks. An explorative approach was taken as the purpose was to contribute to a better understanding of the phenomenon. Time aspects of transport services were identified as important to study and also the decision-making context of the mode choice, as well as the impact on the mode choice of the involvement of several actors in LTL networks.

Transport time, timing, frequency, and punctuality were found to be significantly different for IRRT routes where the forwarder's contracted hauliers used IRRT regularly and where they did not use it. The causation between performance in the time aspects and the usage frequency is not self-evident; i.e., if good performance is prior to frequent usage or good performance comes from frequent usage. Order time is another time aspect found to be important because the amount of LTL is unknown at the IRRT order time.

In the studied LTL network the forwarder's contracted hauliers were found to use intermodal transport primarily over longer distances. Further, where the transport time of IRRT matched the demands from consolidated cargo the IRRT service had also correctly timed departure and arrival on 15 of 17 routes. However, transport time was too long on most IRRT routes, low punctuality and frequency pointing to the limited possibility of using the available IRRT service for consolidated cargo.

Methodologically the thesis has shown that IRRT can be compared with consolidated cargo in important time aspects. With IRRT usage statistics, different categories of IRRT routes can be distinguished. Combining the study of time aspects and the usage statistics can show in what time aspects differences exist between usage categories. However, as it was unknown whether or not the goods in the IRRT usage statistics are routed via the consolidation terminals, the departure and arrival times from and to consolidation terminals cannot be expected to have had a decisive impact on the mode choice in the studied LTL network. The comparison is still considered to be valid as a measure of IRRT performance as the demands from consolidated cargo can be fulfilled with road transport, which is the norm that IRRT can be compared to. Thereby the comparison is more one of comparing road transport with IRRT rather than only comparing consolidated cargo time requirements with IRRT time performance.

A theoretical perspective is developed that aims at describing the mode choice in its decision-making context. This structure is a tool to explain how decision-making is constituted that includes the mode choice and broadly outlines a structure that can support further investigation into the mode choice decision-making in transport firms. At the studied hauliers, resource acquisition, vehicle route scheduling, and operational resource allocation were decision issues that affected the mode choice, and road transport was the preferred alternative over IRRT in most situations.

In resource acquisitions flexible resources are highly desirable, that is flexible in the sense of fulfilling customer transport requests, not flexible in the mode choice. A repetitive behaviour in regard of the mode choice is shown in the resources acquired, which favour road transport resources, as road transport is the prevalent mode choice because it provides the highest flexibility. IRRT adaptation of acquired resources is consequently not chosen with the implication that IRRT is not possible for those resources during the depreciation time, usually up to eight years.

In studying the vehicle route scheduling the thesis shows that both the studied hauliers transport goods that are suitable for intermodal transport from a cost and time requirement perspective, but which are currently transported by road transport. Consignments preventing the use of IRRT are namely scheduled for most vehicles. Thereby, if one consignment has timing demands outside the intermodal service, the whole round trip must be by road transport. Consequently, a re-planning of the vehicle routes could enable an increased use of IRRT. Such re-planning is rarely done, implying that IRRT is used to a lesser extent than possible.

Operational resource allocation affects the mode choice in that the haulier first filled their road transport vehicles and then the semi-trailers used for IRRT because the road vehicles are scheduled with point changes of drivers making the route hard to cancel, as two vehicles are affected while the IRRT service only requires a phone call to cancel.

The studied LTL network was found to have an organisation structure that fits the description of what has been termed a quasifirm. Main characteristics of the quasifirm are the loose coupling between separate organisations and the high degree of shared purposes between these member organisations. Direct effects of loose coupling are modularity, requisite variety, and behavioural discretion. Typical outcomes adherent to loose coupling are persistence, buffering, adaptability, satisfaction, and effectiveness. Some of these direct effects and outcomes were found to be useful in the further analysis of the position of the mode choice in the organisational structure and the subsequent effect on the development and efficiency of IRRT in the LTL network. For example, observed phenomena as haulier independence and separateness from the forwarder represent behavioural discretion and provide adaptability for the forwarder, which makes the organisational structure mutually beneficial.

The individual hauliers are also quite independent from the other hauliers and the mode choices are decentralised. The modularity that each haulier represents and the haulier's behavioural discretion limits the LTL network's strength in the three main operations of intermodal transport in that the use of intermodal transport is uncoordinated between the hauliers. For example, each haulier performs their road haulage when using IRRT and the economy of scale of coordinating IRRT road haulage operations within the LTL network in each region is unutilised.

Effective strategies for increased usage of IRRT in the studied LTL network should therefore be adjusted to work with the direct effects and outcomes of the quasifirm, such as behavioural discretion and adaptability, to preserve the quasifirm's advantages. Implementing the awareness of the effect on the mode choice in the sales process is therefore another strategy that can have effect on IRRT usage. Tools to support the choice of IRRT during the resource acquisition could be a cost calculation tool and goods flow analysis, tools which highlights the benefits of and potential to use IRRT for the individual haulier.

Many actors were found to have an impact on the mode choice; e.g. customers (both the forwarder and transport buyers) by their timing requirements, hauliers by making the actual mode choice, government by providing suitable road and rail infrastructures, and the intermodal operator by their transport service times and frequency.

Further research

In this final section of the thesis a few areas of interest to further explore are outlined. These areas are considered to be theoretically and practically relevant in the context of LTL and IRRT.

First, concerning the time aspect perspective, a longitudinal study of IRRT timetables is of interest in order to identify trends and development regarding the identified time aspects and network coverage. This can be compared to the use of these IRRT services in LTL networks over the same period. It would then be possible to identify how the trends of the IRRT service have influenced the IRRT usage by this important customer segment of IRRT. Another approach could be to determine if there is a difference between different customers of IRRT regarding the importance of time aspects.

Second, focusing on the individual haulier's decision-making, the studied hauliers rarely made re-planning of existing vehicle routes while a potential for IRRT existed. Consequently, there is a need of investigation into how to work with vehicle route re-planning. One way is to find existing or develop appropriate support tools. Considering that the hauliers studied here are affected to a large extent by their customers' time requirements in their mode choices the exploration of how to implement consideration of the mode choice in the sales process could contribute to a shift towards IRRT.

Third, having in mind that several actors are involved in LTL networks, there is a lack of coordination between hauliers but also a lack of collaboration and communication between the forwarder and hauliers concerning the mode choice and its long-term preconditions. Therefore, it would be of interest to study how mode choices and their preconditions can be coordinated within LTL networks. Further, a comparative study of a LTL network with more centralised mode choices can provide a contrasting perspective of mode choices in LTL networks. This implies the study of other LTL networks, both domestic and continental, to analyse how their organisational structure and mode choice position with the structure impacts the use of IRRT.

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