# Logistics and Transport Management

# Master Thesis No 2002:34

# The Potential of West European Sea-based Intermodal Systems


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# Preface

During our studies at the School of Business and Commercial Law at Göteborg University, there has been an emphasis on exploring different logistic alternatives and solutions. Intermodal transportation is one of many. Europe today faces many problems with congestion, traffic jams, and increased environmental impact of transportation that needs urgent attention. One possible solution is intermodal transportation.

Our Professor, Arne Jensen, presented us with a thesis subject concerning these issues; through this research we saw an opportunity to contribute to the solution of these problems. The aim of the thesis was to remove as much heavy transport as possible from roads in Western Europe, through investigating the potential of conquering road transported freight by an intermodal transportation system where sea transportation is the fundamental mode of transport.

# Abstract

The purpose of this study is to analyse the present goods flows between Scandinavia and regions in Western Europe and to estimate the potential share of these flows that could be conquered by an intermodal transportation system where sea transportation is the fundamental mode of transport. The system is constructed from a scenario perspective, however with regard to present opportunities and limitations. Furthermore, this research is intended to function as a pre-study to a possible future EU project.

The result of this research is constituted by the potential amount of goods that can be conquered by the intermodal transportation system. The potential is presented in terms of tonnes, number of containers and vehicles.

We believe that the possibility of conquering this potential amount of goods is promising. The advantages of intermodal transportation, such as cost efficiency, environmental friendliness and the level of quality services are of such character and strategic importance that customers will be attracted of the intermodal transportation service.

Our final recommendation is to construct a pilot project of this sea-based intermodal transportation system and to realise it as soon as possible, for the sake of the economy in Europe, its population and the environment.

For further research, we believe that extending the research study to include the transport alternative of inland waterway transportation should be explored. An in-depth market research study should also be conducted before realising an intermodal transportation system of this nature.

## Acknowledgements

We would like to thank the people at the Department of Transport Statistics at Eurostat in Luxemburg for their hospitality and support throughout the research process. We would especially like to thank Ms. Oberhausen and Mr. Pasi, responsible for road and intermodal transport statistics.

We also want to thank all the helpful and kind people that have been involved in the interviews. It is your support and help that have realised the outcome and quality of this thesis. Especially, we want to thank those persons who have influenced and supported our work and helped us: Per Jessing and Christopher Pålsson at The Institute of Shipping Analysis and Hans Backman at Railcombi AB.

Finally we want to thank our tutor Arne Jensen, Professor at the School of Business and Commercial Law, Göteborg University, for his guidance and priceless assistance.

Göteborg, January 2003

Rickard Bergqvist    Pär Esping

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## ***LIST OF ABBREVIATIONS***

This list covers the abbreviations used in this document only. Abbreviations used in only one section and for the sake of convenience are not listed.

| | |
|---|---|
| CEN | The European Committee for Standardisation |
| CLM | Council of Logistics Management |
| Dwt | Dead weight tonnes |
| ECMT | European Conference of Ministers of Transport |
| EFTA | European Free Trade Association |
| EMU | European Monetary Union |
| EDC | Equal Distance Contour |
| EU | The European Union |
| EUR | The official abbreviation for the euro, which has been registered with the International Standards Organisation (ISO). |
| ESS | European Statistical System |
| FCL | Full Container Load |
| GDP | Gross Domestic Product |
| ISO | International Organisation for Standardisation |
| ITU | Intermodal Transport Unit (here comprising ISO containers) |
| LCL | Less than full Container Load |

| | |
|---|---|
| OECD | Organisation for Economic Cooperation and Development |
| SSS | Short Sea Shipping |
| TEN | Trans-European Networks |
| TEU | Twenty foot Equivalent Unit (measurement for container sizes) |

# 1 Introduction

## 1.1 Background

Economic development is a broad concept referring to the material aspects of community welfare. There are numerous facets of development: growth in income and wealth, equitable distribution of income and other indicators of the "quality of life" in a society. One consistent factor in any consideration of development is economic growth, which is the sustainable increase in community income and/or wealth.

Good transportation facilities support economic growth by lowering the transport costs to users of the transportation network. Direct user benefits are reductions in travel times and fuel consumption, increased reliability, and increased safety in the movement of people and goods. As users' transportation costs are reduced, resources are freed for other purposes.

Businesses benefit directly when goods can be shipped faster, or at lower cost. In addition, both businesses and individuals benefit when their travel times and costs are lowered. There are also indirect effects of the transportation system on economic growth. These secondary effects may include the expansion of existing businesses as reduced transport costs result in greater profitability and/or increased market share.

It is widely recognised that wise transportation investments and economic development are mutually reinforcing processes. Good transportation facilities support economic growth, which then leads to more movements of goods. Freight transport obviously makes a vital contribution to the economy and society, and is at the heart of globalisation. But its dramatic growth in the road sector is rapidly taking away the benefits, through impacts such as congestion, noise, pollution and infrastructure damage. Innovative policies and technologies can reduce these impacts by promoting the integrated transport chain for door-to-door services.

Traffic jams and congestion are common problems in today's society; the problem has grown the past decades, especially in Western Europe. This is due to fact that the amount of freight transport in Europe has increased remarkably, see *Figure 1-1*.

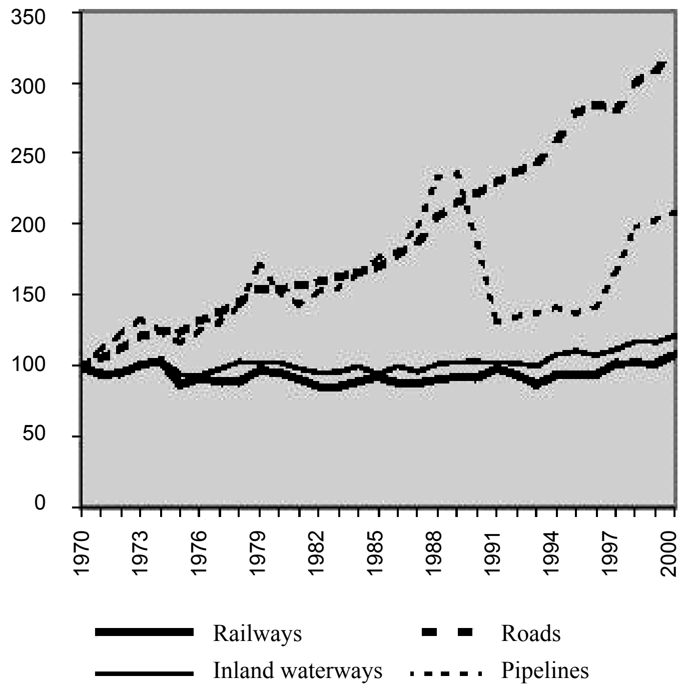


*Figure 1-1, Freight transport trends in tonne-kilometres for Western Europe between 1970-2000 (1970=100).1*

Road transportation has been the primary source of transportation and has gained great popularity. The last decades have provided Europe with a good economic growth; this has

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[1] European Conference of Ministers of Transport (ECMT), *Trends In The Transport Sector*, 2002

been enhanced by the creation and development of the European Union and the EMU[2]. Borders have been opened, realising simple movement of goods, capital, services and citizens. The growth in transported goods has exceeded the capacity; there have not been enough investments, resulting in congested roads, queues and traffic jams. The problem has already grown to such a degree that it threats both the environment and future economic growth.

In the global competitive market, cost efficiency is a key factor for survival and success; higher logistics costs caused by delays and time loss threatens companies' ability to compete both regionally, nationally and globally.

Borders have opened, administration decreased, free flow of goods, people, capital and services; these are all factors influencing the flow of goods in Europe, a influence Europe has been little prepared for. This problem possesses a serious threat to Europe's future economic well-being and must be taken seriously.

### 1.1.1 Congestion – A Time to Decide

From the European transport policy 2010, EU's perspective on the matter can be displayed. "Transport is crucial for our economic competitiveness and commercial, economic and cultural exchanges. This sector of the economy accounts for some 1000 billion, or over 10 % of the EU's gross domestic product, and employs 10 million people. Transport also helps to bring Europe's citizens closer together. However, the warning signs are clear. Congestion, resulting in environmental nuisance

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[2] European Monetary Union (EMU)

and accidents, is getting worse day by day, and penalising both users and the economy. If nothing is done, the cost of congestion will, on its own, account for 1% of the EU's gross domestic product in 2010 while, paradoxically, the outermost regions remain poorly connected to the central markets.

Europe must bring about a real change in the Common Transport Policy. The time has come to set new objectives for it: restoring the balance between modes of transport and developing intermodality, combating congestion and putting safety and the quality of services at the heart of our efforts, while maintaining the right to mobility."[3]

In many western countries today there are plans to internalise external costs trough different methods in order to assign more environmental responsibility to the transport service provider, examples of this are road-tolls and region based taxes. Germany plans to increase road fees in year 2003 in order to internalise the external costs further. Transportation by more than one mode, i.e., intermodal transport, has the advantage and ability to choose the best mode of transport for each distance and movement. This also concerns environmental impact. Since intermodal transport often requires large volumes of goods, the environmental impact per transported unit also decreases. Road transport has a number of negative impacts on the environment, not just from a pollution point of view but also in terms of land use, congestion, noise and accidents. In the next chapter we will describe the principle of sustainability and sustainable transportation.

[3] European Commission, White Paper, European transport policy 2010: time to decide, 2001

### 1.1.2 Sustainability and Sustainable Transportation

Substantial interest in sustainable transportation can be dated back to the early 1990s. While recognizing the three dimensions of the sustainable development, namely the economic, social and environmental, the focus of early research was on the economic and environmental dimensions. This is due to the fact that transport activity has three global environmental impacts of specific concern:

- Emissions of greenhouse gases (burning of fossil fuels results in carbon dioxide emissions),
- Emissions of compounds that thin the stratospheric ozone layer (such as, the use of fluorocarbons as coolants in vehicle air conditioning system), and
- Transport related production of Persistent Organic Pollutants and their effects on biological systems (dioxins and furans produced by automobile engines bio-accumulate through the food chain and pose the risk of causing adverse effects on human health).

The initiative of early studies in sustainable transportation came from the Organization for Economic Cooperation and Development (OECD), which in 1994 set in motion the so-called Environmentally Sustainable Transport project. Nine countries contributed to the project with case studies based on internationally recognised and accepted six criteria: noise, land use, emissions of carbon dioxide, emissions of nitrogen oxides, volatile organic compounds and particulate matter.[4] An important point in the history of sustainable transportation was the OECD Conference "*Towards Sustainable Transportation*"

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[4] Yevdokimov, Y., *Sustainable Transportation System: A System Dynamics Approach*, University of New Brunswick, 2001

1996 in Vancouver, Canada. During this conference some principles concerning sustainable transportation were formulated, the so-called Vancouver Principles for Sustainable Transport, these principles are:[5]

1. Access
2. Equity
3. Individual and community responsibility
4. Health and safety
5. Education and public participation
6. Integrated planning
7. Land and resource use
8. Pollution prevention and
9. Economic well-being.

From an economic standpoint, transportation is an important sector of an economy because it contributes substantially to the growth of gross domestic product (GDP). Since the growth of GDP over time reflects economic growth, transportation should be regarded as a substantial contributor to economic growth.[6] However, as population has increased, cities have grown, and globalisation and free trade have expanded the regional and international movement of people and goods. The result has been a dramatic expansion of transportation infrastructure and systems. The cars, trucks, buses, subways, trains, aeroplanes, ships and ferries used to move people and goods today have significant implications in terms of energy and material resource use, environmental pollution, noise and land use at local, regional and global level.

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[5] OECD Proceedings, *Towards Sustainable Transportation*, The Vancouver Conference, organised by the OECD, hosted by the Government of Canada, Vancouver, British Columbia, OECD, 1997

[6] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000

The concept of a sustainable transportation system can be illustrated as in *Figure 1-2*.[7]

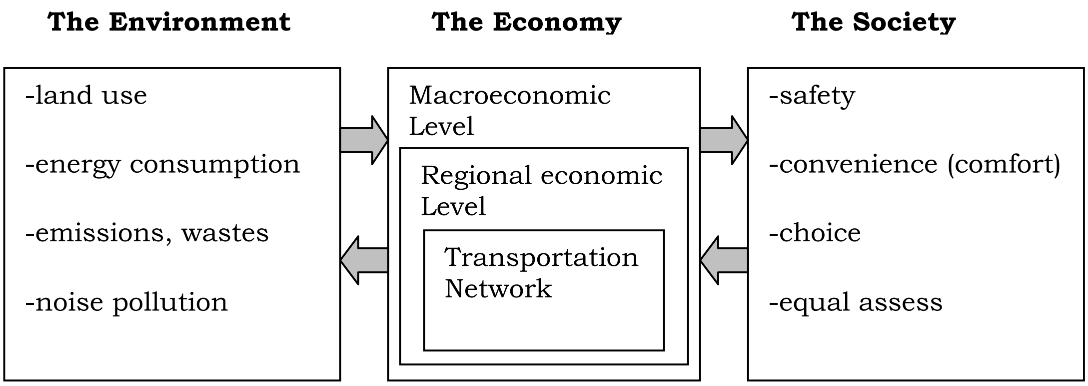


*Figure 1-2, Vertical and horizontal linkages of a sustainable transportation system*

In discussions about sustainable development and transportation the concept of intermodal transportation often arises. This is due to the possibility of using the most environmentally friendly mode for each movement in the transport chain. In the next chapter we will examine one of the prerequisites for the future concerning transportation, i.e., intermodal transportation.

### 1.1.3 Intermodal Freight Transport – A Prerequisite for Sustainability

Freight transport demand has been growing steadily at around 2% per annum over recent years, and this rate of growth is expected to continue. Road freight has increased dramatically, while the modal share of rail has decreased. This is exacerbating the problems of road transport, particularly congestion. The

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[7] Yevdokimov, Y., *Sustainable Transportation System: A System Dynamics Approach*, University of New Brunswick, 2001

demand for alternatives to road freight is getting stronger, especially as a result of policy on sustainable mobility. Intermodal freight transport would also contribute to the European strategy for security of energy supply, through a shift to less energy consuming transport modes. However, improving intermodal connections is critical, since road transport is likely to remain the first choice for the first and last leg of most freight journeys. After that, pricing policies may be needed to encourage more sustainable decisions on modal choice.

Although intermodal transport still represents a small part of goods transport, between 2 and 4%, it is increasing rapidly, with an average growth rate of 10%. In a few important European corridors, intermodal transport has the potential to reach a market share of 30%.[8]

Another important aspect regarding intermodal transport is the strategic importance. If the congestion situation in Europe were to increase, the opportunities for using intermodal systems would instead be limited. Many countries also lack opportunities to use other transport modes than road due to lack of infrastructure or developed intermodal transportation systems. Import and export to and from Scandinavia regarding Western Europe is to a high extent conducted by road transportation. If the congestion situation were to become more severe in Europe, this would pose a serious threat towards Scandinavian companies' ability to compete in Europe, and the communication of trade would see more friction. More and more ocean based and Trans-Atlantic traffic is moved from the ports in Scandinavia to the huge ports in Western Europe. This situation leads to extensive logistic costs for Scandinavian companies that either

[8] European Commission, Freight Intermodality, 2001

import or export from countries where ocean or Trans-Atlantic freight is required. This is not only a threat for Scandinavia but clearly also to the European economy as a whole.

From this background it is obvious that an intermodal system between the Northern parts of Europe and the Western parts is desirable. Our thesis has the objective to investigate what the potential of such a system would be, regarding different levels of limitations. This step is necessary to see the possibilities and opportunities but also the threats when developing and realising such a system.

### 1.1.4 What is Intermodal Freight Transport?

The suitability of rail and sea transport for the substantial transport market for high valued goods is limited by, among other things, the extension of the railway network and the high costs of shunting wagons into private sidings. The high fixed terminal costs and the low variable haulage costs make railways and sea transportation particularly suitable for large-scale transport of heavy goods over long distances.

Road transport, on the other hand, offers accessibility with maintained economy for smaller shipments over short distances. Along with all the advantages of road transport, however, there are also disadvantages in terms of pollution, noise, traffic accidents as well as excessive use of energy and land, normally referred to as external effects[9]. For the road transport industry,

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[9] In a transportation perspective, the term external effects denotes effects caused by an activity, which cannot be priced in a normal business relationship. The term is commonly used for describing the effects caused by the different modes of transport, especially road transport that the society suffers from.

there are also risks of longer transport times, bad timing and limited growth possibilities due to increased road congestion.

Consequently, a combination of different modes of transport is a logical step for maintaining flexibility while decreasing the external effects. However, manual transhipment of part-loads and general cargo between modes of transport is costly, time-consuming and involves a high risk of damage to the cargo. One way to decrease these problems is to load the goods in strictly standardised Intermodal Transport Units (ITU:s), also referred to as unit loads, e.g., containers, semi-trailers or swap bodies.[10]

A normal container is simply a steel box with standardised measures, construction strength and fastening devices. A swap body is a detachable lorry superstructure equipped with support legs and a semi-trailer is a lorry trailer with rear wheel axles while the front part is to be hung onto a semi-trailer tractor.

By loading the cargo in ITU:s, vehicles and vessels can be used more efficiently through fast transhipment and the cargo can be protected from theft and damage. Shippers, shipping lines, railways, freight forwarders and haulers choose type of ITU considering type of cargo, destination and the organisation of the transport assignment. In order to obtain the highest advantage, the shipper should transport these load units unbroken for as large a part of the distance as possible.

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[10] Eurostat, Meeting of the Working Group on Intermodal Transport Statistics, Document: IM/2002/Room 2, Luxemburg, 11-12 November 2002

This method is called *the principle of unit loads*[11] and the transport arrangement is commonly referred to as intermodal transport.

## 1.2 Strategic Importance of the Project

Intermodal transportation and use of sea transport as part of an intermodal system is considered important to European cohesion because it:[12]

- Promotes European trade competitiveness
- Maintains vital transport links
- Decreases unit cost of transport
- Relieves congestion from land-based network
- Promote alternative transport alternatives
- Decreased environmental impact of transportation

The need for research in this field is substantial. Although much research is conducted about intermodal transportation, few of them result in concrete solutions and transportation systems. Our research is the beginning of a concrete research with the aim of realising a sustainable intermodal transportation system based on shortsea shipping.

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[11] The principle of unit loads is defined by Lumsden, K., Transportteknik (Transport Technology), Lund, Studentlitteratur, 1989 (freely translated):

"If possible, goods should be kept together in form of a transport unit adapted to all present vehicles and handling equipment. This transport unit should be formed as early as possible in the material flow, preferably at the consignor's, and be broken as late as possible, preferably at the consignee's."

[12] European Conference of Ministers of Transportation (ECMT), Shortsea Shipping in Europe, 2001

## 1.3 Purpose

The purpose of this study is to analyse the present goods flows between Scandinavia and regions in Western Europe, and to estimate the potential share of these flows that could be conquered by an intermodal transportation system where sea transportation is the fundamental mode of transport. The system is constructed from a scenario perspective, however with regard to present opportunities and limitations. Furthermore, this research will function as a pre-study to a possible future EU project.

## 1.4 Limitations

We will estimate the potential market for the intermodal transportation system when it is equally or more economical than road transportation. We will consider the goods flows between Scandinavia and the economically favourable markets in Western Europe. Goods flows in-between the West European countries would have a positive influence on the potential for the intermodal system. Since we have chosen not to consider these in-between goods flows it can function as an economical validation, i.e., the potential would increase when considering these flows.

Since the potential is seen from a scenario perspective the level of detail in limitations, especially technical ones, will be on a sparse level, although different potentials are obtained from different degrees of limitations.

The purpose of this research is to investigate the potential amount of goods to be reallocated from road transport to an intermodal system, therefore we will not measure the potential in monetary terms; only describe the benefits in terms of externalities.

Niche markets may involve considerable volumes. An example is waste logistics, whose requirements differ from many other segments. The same holds for the transport of empty container boxes. Our research will not consider these segments in particular since they often require specific solutions and often have very low profitability.

In order to increase the degree of validity we have chosen to investigate the methods in which statistics is retrieved and calculated. Our main source of statistics is the European Union's own statistical bureau, *Eurostat*. Since Eurostat is a governmental institute serving public interests, we assume that it has a high level of impartiality and objectiveness. Since this research project is a pre-study to a possible larger EU project, we believe that choosing EU as our main source of statistical data is the most sensible choice.

## 1.5 Research Questions and Information Needs

In this section we state the areas of research and the relevant questions concerning our scope of study, our given purpose and our limitations. The research questions are stated in the same order as we intend to work with the project. For each research question, a need for information will be generated. Below we specify our main research questions and their information needs:

- **Economical breakpoint: At what point is the intermodal transportation choice more economically preferable than ordinary road transportation?**

This economical breakpoint will be calculated for different types of combined transport e.g., sea/road, sea/rail/road etc. In order to calculate this breakpoint, cost data will be collected and applied to modes of transport. Also, a theoretical model will be constructed to guide the calculations needed.

- **Quality dimensions: What are the quality aspects of goods transported through an intermodal system?**

  More specific this means to find the limit for throughput time for an intermodal system, etc. The quality aspects and characteristics must also be related to the different types of goods. This question is answered through qualitative interviews and literature studies.

- **Potential market: What is the potential geographical market for transferring goods from road transport to an intermodal system?**

  The limit for throughput time combined with the economical breakpoint will result in a geographical mapping of potential markets. By answering the two first questions a geographical mapping is possible through the combination of the results obtained by the two first research questions.

- **Goods flow: What are the sizes of the goods flows between Scandinavian and the potential market?**

  This research question is interesting in order to find the potential amount of goods that are of interest for the intermodal system. This question will foremost be answered through statistical study of already existing investigations, statistics and reports.

- **Limitations: What are the technical limitations and reasonable assumptions of the intermodal system.**

  In order to make an intermodal system that is reasonable from a scenario perspective it is important to consider the technical limitations of today and the possible future innovations. This is a difficult balance since future innovations most probably will result in a higher potential for the intermodal system on the other hand, by using limitation from today the system will most probably gain higher rate of validation.

- **Potential: What is the potential, related to assumptions and the degree of limitations.**

  This question concerns the potential of the system related to assumptions and limitations constructed and identified. By considering different limitations, different potentials will be obtained. This, in order to give readers the opportunity to decide for themselves the amount of limitations that are interesting and valid from his or her point of view.

# 2 Research Design and Methodology

*In this chapter we will describe the methodology used in this research.*

## 2.1 Research Design

In order to fulfil the aim of the report, the following point of view has been used:

System analysis, this point of view is based upon already existing elements in a present system or nature, this with the purpose of describing, explaining and understanding the system. Analysing with the system point of view has the aim of investigating each component's relation to each other and to the whole. In the analysis, studying the whole in relation to the actual system is essential. Constructing a system means to develop a new system, a system that hopefully can be constructed in reality.[13]

The following method was used to fulfil the aim of the report:

The theoretical background has been obtained through literature studies and theories. These theories have been analysed and conclusions have been made with the purpose of supporting the construction of the model. As metioned, our point of view has been system analysis.[14]

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[13] Abnor, I. Bjerke, B., *Företagsekonomisk Metodlära*, Sweden, Lund, Studentlitteratur, 1994

[14] Bruzelius, H., *Integrerad Organisationslära*, Sweden, Lund, Studentlitteratur, 2000

For the empirical study we have done open interviews and mapping. The selection among persons and informants for interviews was based upon their involvement in statistical retrieval and methods or excellence in the subject. This with the purpose of constructing a model that corresponds to reality. Theory analysis and empirical study is conducted in parallel, since none of them can be described without the other (also called abduction).

### 2.1.1 The Method of Abduction

To illustrate which elements that are included in our research, we have constructed a schematic model; see *Figure 2-1, Course of action.*

The creation of this schematic model will not only work as an illustrator, but it will also guide our empirical and theoretical studies. This problem solving process is called the abduction method, working with both theory and empirical data, letting one guide the other. To further explain our approach, both theories and empirical experiences are used to map and plan the construction of the model (intermodal system). It can be explained as a continuous examination of theories in relation to the empirical experiences, and the other way around. During this process the empirical research area is continuously developed in relation to the theoretical framework, which is refined and adjusted simultaneously. The empirical data is consequently used to lead the search of theory and produce new ideas. Therefore, the theory analysis and empirical study are conducted in parallel, since neither of them can be understood without the other. An empirical study is necessary to identify the nature of the problem and the theory study is necessary for solving and describing the problem.[15] The relation between the theoretical and empirical study and the disposition of the thesis is showed in *Figure 2-1*.

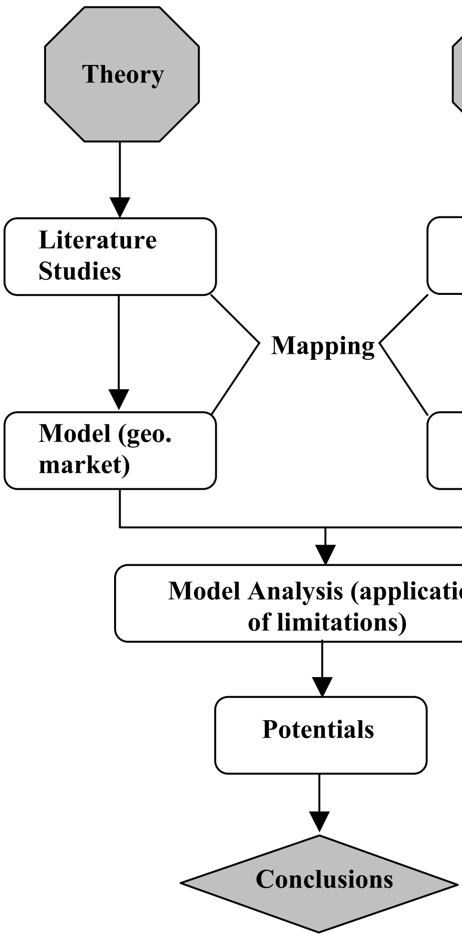


*Figure 2-1, Course of action*

The mapping section in *Figure 2-1* is an essential part of the course of actions. In this research, mapping is important for understanding the complexity of the subject. The theory study is based upon existing theory mostly concerning the subject for this study and elements of intermodality. The study ends up

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15 Alvesson, M., Sköldberg, K., *Tolkning & Reflektion, Vetenskapsfilosofi & Kvalitativ metod*, Sweden, Studentlitteratur, Lund, 1994

with an analysis and conclusions upon the output from the model and the different potentials.

Validation and reliability of the model and statistical data are based upon interviews with people that are involved in obtaining the statistical data, or/and have excellent knowledge in the subject. The interviews conducted are of an open character, which means that we do not have any specific questionnaire when interviewing different people, although we have prepared questions. A disadvantage of this interview method is that we cannot compare answers. This method is preferable when discussion is the goal of the interview. This method allows the respondents to freely express their different opinions and views without being controlled by the nature of the questions. A continuous validation has been done during the whole stage of the report, through interviews, comparisons, etc.

### 2.1.2 The Nature of Data and Information

In this section, the framework of data, information and knowledge is presented. The conceptual model of the information value chain, as shown in the *Figure 2-2*, includes *data* as the raw material, *information* as the structured and communicable semi-manufactured product of data processing and *knowledge* as the finished product where information has been transformed into a meaningful form by use of analysis, interpretation based upon earlier experience as well as modelling. [16]

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[16] Polewa, R., Lumsden, K., Sjöstedt, L. *Information as a Value Adder for Transport User*, Pergamon, Oxford, 1997

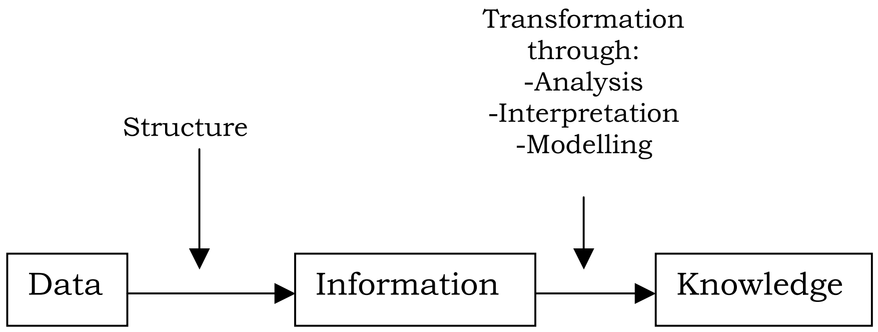


*Figure 2-2, The information value chain. (source: Polewa et al. 1997).*

In basic and mature research fields, there is normally a well-trodden path made up of textbooks and articles in scientific journals to follow for a comparatively fast advance to the research conductor. But, in a young and multi-disciplinary research field such as intermodal transport, there is normally no single set of literature to consult for approaching the research problem.

We have consulted a wide variety of secondary sources such as textbooks, research and investigation reports, articles in academic and business journals, speeches at and proceedings of conferences, statistical publications, annual reports, pamphlets, etc. Also primary sources such as structured and open-ended interviews, surveys, direct observations and data supplied by actors have been used in the research.

## 2.2 Research Model

*Figure 2-3* is a basic illustration of our research and the layout. In order to let the reader of the report decide for himself, we have obtained two potentials, ranked by the degree of limitations. Potential 1 will therefore have a larger amount of goods than potential 2. The following description of our approach is illustrated in *Figure 2-3.*

- ***Geographical market:*** By calculating the economical breakpoints between the intermodal transportation system and road transportation, we obtain a potential geographical market. This market is based upon the model decried earlier.
- ***Throughput time, transit time of transportation:*** In order to examine the potential markets for different goods it is important to investigate the lead-time of the intermodal system.
- ***Economical breakpoint:*** With a logical cost-model, an economical breakpoint between modes can be calculated. Generalised costs for each mode are identified and equal landed cost contours are calculated.
- ***Statistical data:*** By quantitative investigation of statistical data, the amount of goods flow within the potential geographical market can be obtained.
- ***Potential market:*** By using the statistical data obtained through the previous step we can get the potential market in terms of tonnes. This will be the first potential, more or less free from limitations, especially technical ones.
- ***Limitations:*** The five areas described below will determine the limitations of the system.
- ***Barriers to intermodal transportation systems:*** This section will deal with the common and existing barriers towards intermodal transportation systems. Attitudes, and scenario thinking is a part of this section, which deals with attitudes and prejudices towards the different modes of transport and intermodal transportation.
- ***Technical limitations:*** This section will concern technical limitations for vessels used in sea

transportation, road and train transportation. Infrastructure limitations shall also be investigated to investigate capacity limits, loading time etc.

- *Load unit:* In order to determine some limitations and potentials concerning load units we have to examine the most commonly used unit loads but also investigate if there are opportunities to use more effective and better types of unit loads. Looking at pilot projects within this field will foremost do this.
- *Vessels:* This section will describe the different limitations concerning sea transportation and the vessels carrying the goods.
- *Infrastructure:* In this section we will examine the infrastructure needed in an intermodal network and the threats and opportunities concerning infrastructure.
- *Interfaces:* This section will answer the question of how the different modes of transport can be combined and the friction between them, i.e., the interfaces.
- ***Quality aspects of transportation services:*** In order to determine the types of goods that the intermodal system can handle it is important to examine the quality aspects of different goods and the degree of fulfilment the intermodal system can offer regarding these aspects.
- ***Theoretical background:*** The two sections below will be the foundation of the theoretical background, which will give a general understanding to the subject.
- *Sea transportation:* This section will examine and explain the trends in the sea transportation sector and give brief introduction about technical innovations and general prerequisites for infrastructure. This section will also investigate the external costs of sea transportation.
- *Intermodality:* Description about the development within the field of intermodality, the concepts behind etc.

- ***Capacity constrains in intermodal networks:*** This section will concern general prerequisites of an intermodal system from a capacity point of view, e.g., bottlenecks.
- ***Geographical market 2 & Potential market 2:*** If we add the limitations to the potential market 1, we will decrease the geographical market and the amount of potential goods transferred from road transportation to the intermodal system but we will increase the degree of reasonability, i.e., increase the reliability of the potential of the intermodal transportation system.

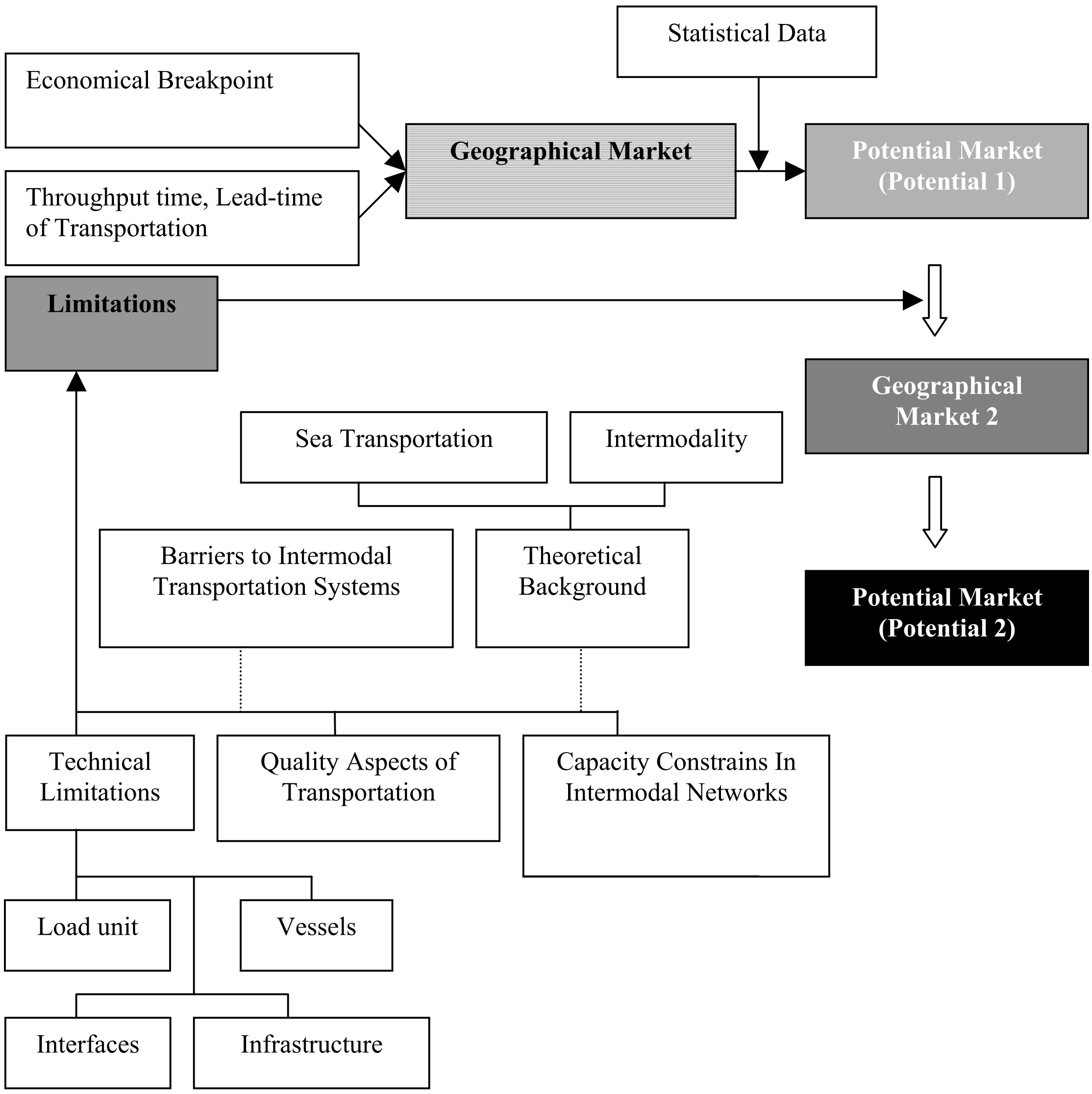


*Figure 2-3, Research Model (process map)*

The research model has a strong connection to the model in *Figure 2-1*, but gives more detailed information about which areas that will be investigated and the relationship between them.

*Figure 2-1* gives information in a chronological order, i.e., it describes the course of action during the research work.

## 2.3 Outline of the Report

The text is written for readers experienced in the transportation field, meaning that terms and technical matters are not explained on the "beginner's level". The reader that finds himself unfamiliar with terms and abbreviations in the text is recommended to first consult the introduction section where some terms are described, then the terminology and abbreviation sections and finally the reference list for basic reading. Literature advice on certain subjects is given in footnotes throughout the report.

# 3 Theoretical Framework

*This chapter will give a broad theoretical framework to the concept of intermodal transportation and its components, relevant to the subject and our research.*

## 3.1 External Effects and Impacts of Transportation

Transport is one of the largest sources of environmental pollution. The large number of significant environmental impacts associated with transport range from local to global, and across a large range of issues including air quality, energy use, waste production and health. Many of these impacts are increasing. Others are beginning to decrease but these impacts may start to increase again in the longer term unless action is taken to reduce transport growth. Transport policy-making has begun to respond to the issues of sustainability but is increasingly being required to do more.

The connection between living standards and the need for transportation is clear. As the scenario is today, transportation stands for an enormous amount of the environmental effects. Simultaneously, many other countries are getting more and more industrialised both in Europe and the rest of the world, leading to an increased need for transport services. Policies, technical innovations, laws and rules etc. are essential for a sustainable development in the future in order to leave an environment suitable for living many generations to come. The EU is in many cases a role model since environmental issues have been continuously discussed within the union, and much research has been done within this topic.

External effects are increasingly important in design of transportation systems. In addition to existing regulations, authorities have revealed intentions for charging the full external costs for each mode of transport. Still, proper costing is a delicate task and petitions about the costs are frequently issued. Nevertheless, higher taxes and even prevention and the prohibition of polluting, noisy and dangerous vehicles are foreseeable. Although, this might be seen as a catalyst for new cleaner and safer operations, e.g., increased use of intermodal transport, system designers must conform to existing and preferably also to proposed future regulations when designing new technology. Even demand for the recycling of materials and working conditions for drivers are included in this problem area.[17]

When considering environmental issues from a management point of view, many companies today are certificated with the so-called ISO 14001 certificate.

ISO 14001 is an international standard for environmental management. This standard applies to all companies and organisations irrespective of their size or activities. Certification is strictly voluntary and is designed for structured and efficient environmental work. One requirement states that the company must work to enhance its environmental performance. However, direct requirements are lacking regarding environmental impact, including transport-related emissions. This lack of direct environmental focus is a threat to the environment and future competitiveness of companies, especially within the transport sector.

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[17] Woxenius J., *Development of Small-Scale Intermodal Freight Transportation In a Systems Context*, Chalmers University of Technology, 1998

Today, environmental friendliness has become an important factor in the competition for end customers; environmental certification might not be enough. Environmental certification of products will certainly include how the products are transported thus adding a new dimension to an issue up until now seen as a matter of obeying governmental regulations. In the future, environmental friendliness will not only be seen on the cost side of the balance sheet and the transport industry is expected to not only live up to the minimum level set in the regulations.

For intermodal transport that is often marketed with environmental arguments, a consistent environment concern is of utmost importance. Technical resources must be developed and manufactured, maintaining the “green” reputation of the transportation system. Environmental indicators by the different modes can be found in *Appendix 1 - Environmental Indicators* and the main environmental impacts of transportation in *Table 3-1*.

| Environmental impacts | Contribution from the transport sector |
|---|---|
| Climate change | $CO_2$, $N_2O$ (+$NO_x$, water vapour, $SO_2$, soot from aviation) |
| Ozone depletion | Ozone depleting substances |
| Acidification | $SO_x$, $NO_X$ |
| Eutrophication | $NO_X$, $NH_3$ |
| Ground level ozone | $NO_X$, VOC |
| Air pollution in urban areas causing health impacts like increased breathing resistance, cancer, acute fatalities | $NO_2$, PM, PAH, benzene, etc. |
| Noise | Noise levels, $L_{Aeq}$, $L_{Amax}$ |
| Impacts on the landscape | Land take, fragmentation, barriers, accessibility to parkland and natural areas |
| Risks and waste | Pollution of soil and water |

*Table 3-1, Summary of main environmental impacts linked to the transport system*[18]

### 3.1.1 Sea Transportation

Shortsea shipping can be considered as an environmentally friendly mode of transport, in particular, because of its comparatively low external costs and high-energy efficiency. Making more use of shortsea shipping could decrease the total external cost for transportation in the community, especially through promoting the intermodal solution. However, the environmental performance of shortsea shipping can still be

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[18] European Environment Agency, *Are we moving in the right direction? Indicators on transport environment integration in the EU*, Brussels, Belgium, 1999, European Communities

improved. Nitrogen oxide ($NO_x$) emissions from shortsea shipping are actually lower by tonne-kilometre than those from other modes, but these could be further decreased. However, sulphur dioxide ($SO_2$) emissions from shipping are too high and should be reduced as much as possible, this area has had great technological development in recent years. More ecologically sound transport solutions would further improve the sustainability of shortsea shipping and they could also increase the use of the mode, as customers are becoming increasingly conscious of the environment. Shipping, in addition to its environmental advantages, is also considered as a comparatively safe mode of transport. However, this statement can easily be debated; transportation of different commodity types requires different safety measures and has different levels of risks to the environment.

A sea vessel produces large amounts of carbon substances but maritime transport has a much higher energy-efficiency than other modes of transport. Consequently, shipping produces less $CO_2$ than other modes of transport per tonne or passenger carried.[19]

Also, in relation to carbon monoxide (CO), hydrocarbon (HC) and particulate emissions, a tonne or passenger carried one kilometre by shipping affects the environment less than that carried by any other mode of transport.

On the other hand, nitrogen oxide ($NO_x$) emissions from shipping raise some concerns. There is undoubtedly room for improvement of the $NO_x$ performance of shipping. Nevertheless, shipping appears also in this respect to be relatively

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[19] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1992

environmentally friendly. The $NO_x$ emissions from shortsea shipping are lower per tonne-kilometre than those from rail transport and considerably lower than those from road transport.

Of the total NOx emission in the Community, 51% derive from road vehicles and 12% from other transport. The good environmental performance of shipping is unfortunately hampered by sulphur dioxide emissions ($SO_2$), which are significantly higher than in other modes. However, of the total $SO_2$ emissions in the Community, road emissions constitute 3% and other transport modes together 2%.[20]

The external advantages of shortsea shipping can be summarised as follows:[21]

- Compared with road transport, shortsea shipping is most cost effective; sea lanes (so called marine motorways) do not have to be constructed like roads, motorways, canals or railways. Congestion is unknown in this field.
- Shortsea shipping is friendlier to the environment in terms of pollution and noise.
- It is efficient in terms of energy consumption per ton/miles carried.
- Shortsea shipping could contribute (as it does already in difficult accessible areas) to the development of the port community and port area.

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[20]Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, *The Development of Shortsea Shipping in Europe: A Dynamic Alternative in a Sustainable Transport Chain*, Brussels, 1999

[21] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1992

- Shipping and inland water transports have a good safety record.
- Europe has a considerable coastline (some 35,000 km), realising easy access to almost all of Europe.

### 3.1.2 Road Transportation

The environmental impacts of road vehicles in use can be divided into three main areas: Air Quality, Climate Change and Noise Pollution

#### 3.1.2.1 Air Quality

People are increasingly concerned about the impact that air pollution has on health, and on the urban and rural environment. Increasing scientific evidence concerning air quality further enhances this concern.

Air pollution also has other effects on our environment; forests, lakes, crops, wildlife and buildings can all suffer significant damage from high levels of airborne pollutants. Oxides of nitrogen ($NO_x$), for instance, can be transported over hundreds or even thousands of kilometres before being deposited as acid rain, which can acidify soil and, because of its ability to fertilise the soil, can cause changes in species composition and biodiversity. $NO_x$ also reacts with volatile organic compounds (VOCs) in the atmosphere in the presence of sunlight to form ground level ozone, a significant component of summertime smog. Ozone is also a long-range pollutant, which can cause direct effects on sensitive vegetation. It has been associated with reduced yields in crops and forestry, as well as with changes in species composition and biodiversity in natural and semi-natural ecosystems.[22]

Air pollution does not just affect us when we are out in the open. Pollution levels indoors can sometimes be higher than outdoors, although the main sources of indoor air pollution often arise outside, especially when windows are open. Furthermore, recent research suggests that road users could be exposed to up to three times as much air pollution when inside a vehicle compared to when walking, or even cycling by the side of the road. This is due to exhaust emissions concentrating in the middle of the road, which vehicles then travel through.[23]

Road transport is one of the major sources of air pollution, especially in urban areas. The other sources being industrial and domestic emissions. But the national road transport emissions do not give a complete picture of the situation. Air pollution is predominantly a local phenomenon, although often with major international implications (for instance, in the well-known case of sulphur dioxide and acid rain). Accordingly, the extent to which road transport is a significant source of specific pollutants at any place and time varies depending on the level of traffic and proximity of other sources of that pollutant, as well as the prevailing meteorological conditions.

But the level of local emissions of air pollutants from road transport is not always indicative of the level of pollution in the atmosphere. Transboundary emissions can be a major source of

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[22] Department of the Environment, Transport and the Regions, The Environmental Impacts of Road Vehicles in Use; Air Quality, Climate Change and Noise Pollution, Published 13 August 1999

[23] Department of Health, Quantification of the Effects of Air Pollution on Health in the United Kingdom, Committee on the Medical Affects of Air Pollutants, UK, January 1998.

pollution levels, depending on prevailing meteorological conditions. In the case of $PM_{10}$, as well as emissions from combustion sources such as road traffic, secondary sources of particulates arising from atmospheric chemical reactions and long range sources, can be equally important in determining pollution levels. The European Unions' member states take many actions to tackle these transboundary sources of pollution.[24]

Exhaust emissions are the predominant source of air pollutants from road transport. The main driving force of measures to cut down on pollution from vehicles has been directed towards improving the exhaust emission performance of new vehicles, since the scope for improvements to existing vehicles is limited by their original design capabilities. However, since the economical lifetime of road vehicles is between 20-25 years, there will be many environmentally unfriendly vehicles on the roads for many years to come.

#### 3.1.2.2 Climate Change

Climate change is one of the greatest environmental threats facing the world today. There is now a broad consensus amongst the world's foremost climate scientists on the Intergovernmental Panel on Climate Change that human activities are having a discernible effect on the climate. Certain gases, naturally present in the atmosphere, keep the Earth at a temperature suitable for life by trapping outgoing terrestrial radiation from the Earth's surface. Levels of some of these so called greenhouse gases are increasing as a result of human activity and this, scientists

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[24] European Environment Agency, *Are we moving in the right direction? Indicators on transport environment integration in the EU*, Brussels, Belgium, 1999, European Communities

believe, is leading to a gradual increase in the temperature of the atmosphere.[25]

The main human activity believed to be responsible for climate change is the burning of fossil fuels and their derivatives (coal, oil, gas, petrol and diesel) to provide heat and power for our homes, industry and transportation. Transportation, and especially road transportation, constitutes a large share of the climate changes due to burning of fossil fuels. This releases carbon dioxide, the most important greenhouse gas, adding to the natural levels of this gas in the atmosphere and increasing the average global temperature. Other significant greenhouse gases include methane and nitrous oxide ($N_2O$).[26]

#### 3.1.2.3 Noise

Noise from road transport has, to date, been seen as an issue of less concern than climate change or air pollution. But noise is a major environmental issue, which affects a large proportion of the population. Whilst the effects of ambient noise are rarely life threatening, it can have a considerable detrimental effect on people's quality of life, and may well lead to sleep disturbance and may impact on cognitive development in children.

Noise emissions from different vehicle types also vary considerably. Large buses and lorries produce more noise than most other types of vehicles, partly due to their large size, but

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[25] Department of the Environment, Transport and the Regions, The Environmental Impacts of Road Vehicles in Use; Air Quality, Climate Change and Noise Pollution, Published 13 August 1999

[26] European Commission, *EU OCH MILJÖN*, Brussels, Belgaum, Europeiska gemenskaperna, 1998

also because diesel engines are generally noisier than petrol engines.[27]

The reductions in noise levels brought by vehicle standards will continue, as new vehicles enter the fleet. This will be particularly beneficial in urban areas where the main source of noise from vehicles is the mechanical operation of the vehicle rather than contact between road surface and tyres. However, substantial reductions in emissions from source have been eroded by traffic growth, and if traffic continues to grow in line with forecasts, it is likely that there will be an intensification of the noise problem.[28]

### 3.1.3 Rail Transportation

Increased environmental awareness combined with the energy shortages of the 1970s has made countries increasingly more aware of the need to conserve natural resources. The railroads today are in a favourable position, especially when compared to motor carriers, because they are efficient energy consumers. For instance, a train locomotive uses less fuel than a tractor-trailer when pulling the same amount of weight. Another important factor is that the nature of the energy used often is electricity. The environmental impact is highly dependent upon how the electricity is produced.

Studies made indicate that railroads are more energy efficient than motor carriers, even when measured in terms of

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[27] European Environment Agency, *Are we moving in the right direction? Indicators on transport environment integration in the EU*, Brussels, Belgium, 1999, European Communities

[28] Department of the Environment, Transport and the Regions, The Environmental Impacts of Road Vehicles in Use; Air Quality, Climate Change and Noise Pollution, Published 13 August 1999

consumption per tonne-km. In addition to being more energy-efficient, railroads cause less damage to the environment than trucks do. Railroads are therefore able to move large amounts of freight with less energy and less harm to the environment, compared to road vehicles.[29]

In terms of energy efficiency and the weight of goods which can be moved one kilometre by one litre of fuel, the figure for road haulage is 50 tonnes, for rail haulage, 97 tonnes and for inland waterways, 127 tonnes.[30]

Other factors affecting the environment are noise and land use. Noise can be especially annoying and disturbing when railroads are travelling near or through densely populated areas. The land use of rail exists but is not significant compared to road transportation. The EU is committed to enhance the railway's competitive edge. The Commission's White Book for 2001 argues in favour of innovative and sustainable freight and logistics solutions that will be able to handle the expected increase in European traffic. Although the outcome is difficult to foresee, there is a patent desire to develop environmentally friendly solutions and real will to revitalise the railway sector. The EU is developing combined traffic in the so-called Marco-Polo programme, which will cover all segments of the freight market and actions of three types:[31]

- Start-up aid for environmental sustainable freight services;

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[29] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000

[30] European Commission, White Paper, European transport policy 2010: time to decide, 2001

[31] Eurostat, Meeting of the Working Group on Intermodal Transportation Statistics, Document: IM/2002/Room 2, Luxemburg, 11-12 November 2002

- Catalyst action steered by the Commission;
- Knowledge sharing and a strategy for spreading good ideas.

The aim is to see rail and sea freight surpass the expected increase in road transportation. The railway's major challenge lies in providing reliable international transport, both as a service provider and as an environmentally friendly solution.[32]

## 3.2 Theoretical Background

### 3.2.1 Transportation Systems as Networks

Freight transportation systems are characterised by the successive movement of goods between supply and demand points, in transportation theory usually denoted as *nodes.* Activities such as consolidation, sorting, storing and transhipment between vehicles as well as between transportation modes are performed at nodes. For each transport commission, each node can be defined as a source, a sink or a transhipment node and the goods flow is always stemmed at nodes. *Links* represent transport and movement activities connecting the nodes.[33]

A *transport network* can be modelled by connecting all sources and sinks with a number of links through transhipment nodes. This structure represents the physical flow of goods and resources. By restricting the view to the demand for a single transport commission without considering the actual path, a transport relation can be defined by connecting the source and

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[32] Vision, Vocation, Value (sustainable development 2001), Green Cargo, 2001

[33] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

the sink directly. Figure 3-1 shows a transport network and an example of a corresponding transport relation.

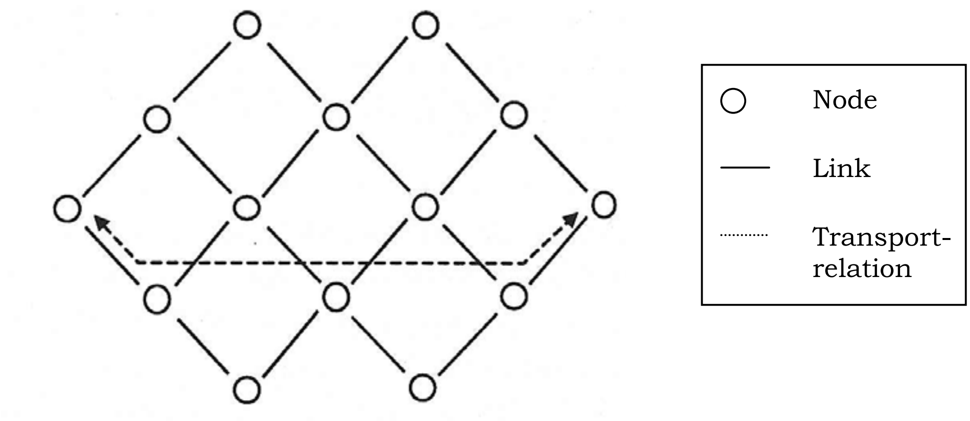


*Figure 3-1, A transport network and a transport relation.*

Links and nodes are strictly abstract terms used for modelling. In the real system, links are characterised by vehicles and vessels using infrastructure. For the physical unit corresponding to nodes, the word terminal is used although the node-specific terms *airport, port* and inland terminal are more commonly used.

### 3.2.2 Trends and Developments

The environment in which transport has to operate in has changed significantly and will change further and continuously change the service requirements of transport.

Various developments lead to the transport of smaller transhipment sizes with a higher frequency, resulting in more sophisticated transport requirements:[34]

[34] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

- Shorter life-spans of products and shorter delivery times results in a change of logistical concepts, e.g., resulting in central distribution and value added logistics
- The internationalisation of production processes i.e., global sourcing leads to an increase of international containerised transport, resulting in an increase of logistic co-ordination requirements, e.g., electronic parts production and assembly
- The trend of "internationalisation" shifts part of production capacity to other trade blocks results in significant changes of transport volumes and structures, e.g., passenger car transport to Europe.

There are also a number of market developments resulting in changing logistical solutions:

- The increasing power of shippers and consignees, due to economic concentration and consolidation
- The internationalisation of the marketplace
- The increasing international competition not only results in lower prices but also in higher customer service levels.

Through the availability of fast communication methods it has become technically possible to fully organise, co-ordinate, and control the logistic process in order to provide transparency for the whole material flow.

As a result of higher attention to logistics within companies, it is interesting to note that there are some changes in the logistic thinking in companies. Higher requirements on logistic services are a reality, logistic and transport costs have been highlighted and this trend can only expand as transport costs are recognised as a significant element of the total product. Within this business environment intermodal sea-based transport has to find its market niche.

### 3.2.3 Intermodality

Intermodal transport in basic terms is about utilising more than one mode of transport in the transport chain, e.g., combining truck, rail and sea transport in one chain from the point of origin to the point of delivery. Intermodal transport can be defined as:

"*The combination of various modes to form a transportation movement*"[35]

There is no generally accepted definition of the terms Intermodal or Combined Transport. There is however a general agreement in all definitions that intermodal transport constitutes a transport process in which the following conditions must be fulfilled:

- Two or more different transport modes (lorry, train, barge, ship, plane) are deployed,
- The goods remain in one and the same transport load unit for the entire journey.

This corresponds well with the definition used within the European Union. According to European Transport Ministers Conference ECMT, which was held in 1993, multimodal transport is defined as "the transport of goods by at least two different transport modes". A subset of this is *intermodal transport,* which ECMT defined as "the transport of goods in one and the same load unit by various transport modes, whereby a change in the load unit does not entail a transfer of the

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[35] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000, p 489

transported goods themselves. The load unit can be either a vehicle or an intermodal transport unit."[36], e.g., a twenty foot container (TEU).

When doing research about intermodal transport we believe it is important to understand that intermodal transport is part of a supply-demand chain, the transport company supplies the demand by offering transportation resources e.g., trucks to enable movement of goods. The quality requirements are set by shippers and by transport companies and in some cases the forwarders working on behalf of shippers. These requirements often differ, e.g., the shipper may focus on maximum safety and reliability but may be less demanding as regards transport speed while the transport company might add additional requirements of its own above the requirements set by the shipper, such as high transport speed in order for its equipment to be available for the next shipment as soon as possible. In order to reach success it is essential to satisfy all sets of requirements.

### 3.2.4 Shortsea Shipping Needs to Become Part of Intermodal Thinking

In spite of the current lack of sufficiently reliable and detailed Europe wide statistics on shortsea shipping, available data indicates that shortsea shipping grew considerably between 1990 and 1997 (by 23% in tonne-kilometres). Road transport, however, increased even more during the same period (by 26% in tonne-kilometres). Growth in the carriage of containers by shortsea shipping has been particularly strong. Though this growth may be due mainly to growth in shortsea feeder traffic,

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[36] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000, p.6

the situation looks promising also for more new and existing cargo being carried by sea.[37]

Shortsea shipping should be fully integrated into door-to-door transport services. The further development of freight intermodality should have beneficial effects on the mode. However, integration of this type is only possible when the individual modes, such as shipping, are constantly developing to meet the service requirements of the customers.

Shortsea shipping should become part of comprehensive intermodal approaches, create networks to attract cargo volumes and actively look for cooperation with other modes and other parties in the supply chain.[38]

The considerable difference between the average distances of a tonne carried by shortsea shipping (1385 km) and by road (100 km) leads to the conclusion that the markets for shortsea shipping and road are partly separate (*Table 3-2)*. About 90% of the tonnes are carried over short distances, mainly in domestic transport. Nevertheless, shortsea shipping can still be competitive within a considerable market segment. That segment would increase proportionally if transport users could, through logistic solutions, be attracted to using shortsea shipping for shorter distances.

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[37] Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, *The Development of Shortsea Shipping in Europe: A Dynamic Alternative in a Sustainable Transport Chain*, Brussels, 1999

[38] Ibid.

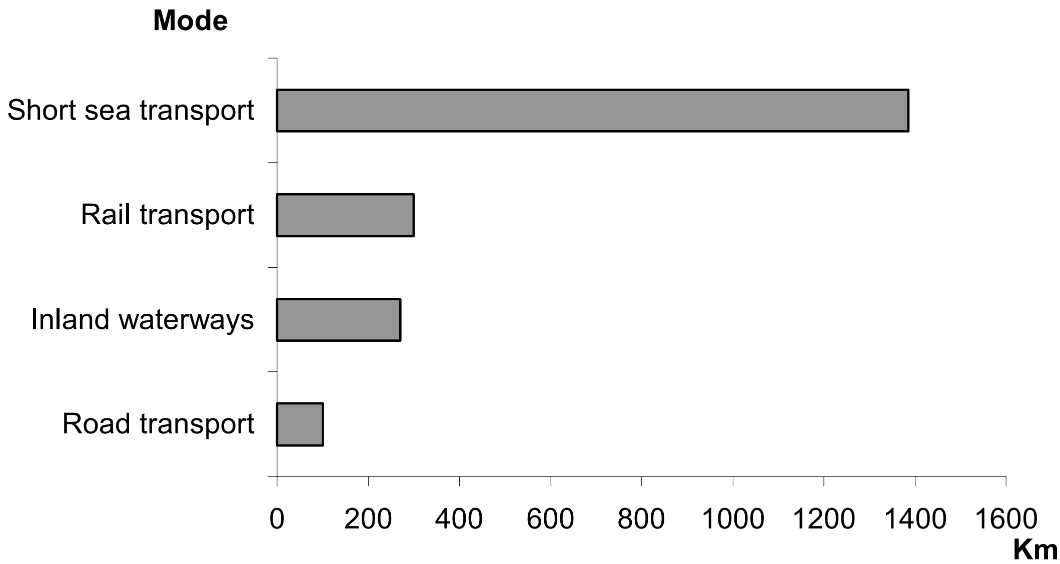


*Table 3-2, Average distance of a tonne transported by different modes in EU*[39]

The perception of shortsea shipping must be changed from its current image of a somewhat old-fashioned, slow and complex mode of transport to a modern dynamic element in the logistic door-to-door transport chain. Shipping should offer and it should be perceived to offer speed, reliability, flexibility, regularity, frequency and cargo safety to the highest degree.

For a regular shortsea shipping service to be viable, a considerable volume is needed to allow profitable capacity utilisation[40]. Shortsea shipping needs to attract volumes through better logistics organization, service level, frequency, regularity,

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[39] Average distances for sea, road, rail and inland waterways are extracted from 'European Transport in Figures', February 1999

[40] According to a feasibility study conducted in 1998, an average capacity utilisation of 51% on a 4000 tdwt Ro-Ro vessel could be the breakeven point for profitability of a regular weekly Ro-Ro service between northern Sweden and Germany. However, the breakeven point depends on several factors, such as the cargo price (value), fixed and variable costs. The cargo price in the study was set considerably lower than the corresponding road transport price. The variable costs included land legs between land terminals and ports (SeaCombi – A Feasibility Study in Combined Transport between EU Arctic and Continent, INGUN AB, Malmö, December 1998)

networking and one-stop shops for the management and pricing of the whole transport chain from door-to-door as in road transport. Shortsea shipping cannot do this alone, but needs partners who can carry out the land legs or who are ready to use shortsea shipping for a considerable part of their journeys instead of using land.

"Even if the markets for shortsea shipping and road are partly separate, shortsea shipping can still be competitive within a considerable market segment. That segment should also increase, if the attractiveness of the mode in transport over shorter distances could be enhanced. Unfortunately, the trend has been quite the opposite and the average distance of a tonne transported by shortsea shipping has increased by 65 km from 1990 to 1996, i.e., the break-even point has increased compared to road transportation. Lowering the threshold distance over which shortsea shipping is competitive, for example by integrating the mode more efficiently into the door-to-door logistic transport chains, should, among other factors, become an objective in the development of shortsea shipping. Further it could be noted that shortsea shipping and its intermodal integration may require new or specially adapted vessels and advanced and flexible ship designs."[41]

In order to be competitive an intermodal system based on sea-transportation has to improve in the following commercial and political areas:[42]

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[41] Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, *The Development of Shortsea Shipping in Europe: A Dynamic Alternative in a Sustainable Transport Chain*, Brussels, 1999

[42] ECMT, Short Sea Shipping in Europe, OECD, 2001

*Commercial aspects*

It must be a decisive aim that combined land/sea transport be carried out through mutual cooperation and agreements so as to:

- Maintain control over the complete chain from dispatching to receiving
- Guarantee delivery times
- Minimise delays in ports
- Offer maximum service frequency

Measures must be directed towards the improvement of overall logistics and also towards transparency, i.e., information sharing.

*Political aspects*

The following aspects should also be discussed, since the future development of European shipping depends on the general set-up concerning transport policy;

- Charging of road related and external traffic costs in order to favour the use of more environmentally friendly modes of transport.
- Ending discriminative treatment of inner-community shipping in favour of overland traffic by restraining complicated costumes procedures
- Harmonisation of rules for land and sea transportation of hazardous goods, including harmonisation of rules in different ports and introducing comparable legal responsibility and insurance conditions.

## 3.3 Limitations, Restrictions and Boundaries

In this chapter we describe and explain the different limitations, restrictions, requirements and boundaries that exists for an intermodal transportation system.

### 3.3.1 Quality Aspects of Transportation Services

With the goal being the creation of value, since transportation and logistics is a service, managers must identify those critical elements of quality that can be managed to help meet customer requirements.

From a customer perspective there are three main forms of quality[43]:

- *Productivity:* customers require service providers to perform that service cheaper than competitors
- *Service performance:* customers require service providers to perform better than competitors
- *Performance measurement system:* customers require access to information about the service in order to continuously improve.

In many cases, customers want service providers to deliver all of these quality dimensions and in order to be successful, excellent level of quality.

The development of the intermodal transport requires that the quality is adapted to the logistic requirements of the different

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[43] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000

market segments, the requirements for each segment may differ a lot, e.g., flexibility, reliability, safety, transit time.

#### 3.3.1.1 Quality Criteria

Quality has been defined using 7 quality criteria:[44]

- Time indicators - e.g., the total length of time between when the load unit is ready for transport and when it is delivered, e.g., lead-times, transit time
- Reliability - the absence of unforeseen lowering of performance and the ability to protect the system towards sources of variation
- Flexibility - the paste in which the system adjusts to an unexpected change in logistic requirements, e.g., change of destination
- Qualification - the capacity to cope with logistic requirements, especially complex ones, e.g., vibration, temperature etc.
- Accessibility - the ease with which the intermodal transport system can be used, this is often strongly related to the capacity of the system as well as the utilisation rate
- Monitoring - this relates to whether and to how well the cargo or load units can be monitored and the ability to obtain information about the status of the cargo throughout the entire system
- Safety and Security - the risk of losing equipment and goods in the system.

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[44] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

Price cannot be considered as an element of quality. It is, however considered in some cases when trade-offs are discussed between quality elements.

### 3.3.1.2 Segmentation

In our research it is possible to develop market segmentation since the quality dimensions differs between segments. Depending on the quality dimensions later fulfilled by our system we can determine what segments that will be attracted to the intermodal transportation system. The market segmentation for our study has to meet the following scientific and practical requirements:[45]

- It must be possible to link demand segments with requirements
- Each segment should be as homogeneous as possible and differ clearly from other segments
- There should be neither too few nor too many segments.

Since this research focuses upon a potential market the most reliable segmentation that can be done is upon commodity type. The potential market is projected to cover a large geographical area, a segmentation based upon individual clients requirements would not be realistic. The segmentation of commodity type is based upon the quality criteria's stated in chapter *Quality Criteria:*

- Monitoring and reliability is expected to be relatively important for hazardous goods and perishable goods,

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[45] Kotler, P., *Principles of Marketing*, Englewood Cliffs, N. J., cop. 1980

- Security, qualification and safety is expected to be important for hazardous goods,
- For low-value cargo, modal choice is expected to be mainly determined by price; no quality features are expected to be of more than average importance.

Although price is not a quality characteristic it should be taken into account, as it is the most important service feature for most potential users of the intermodal transport system.

Niche markets may involve considerable volumes. An example is waste logistics, whose requirements differ from all the previously mentioned segments. The same holds for the transport of empty container boxes. This research will not consider these segments in particular since they often requires specific solutions and often has very low profitability.

Hazardous goods and perishable goods are almost always Full Container Loads (FCLs), due to safety and temperature limits. The most important quality elements for this segment will most certainly be on control, security and qualification. Hazardous goods transport needs specific knowledge and skills. Transport companies and forwarders who deal with hazardous goods are specialised, often working exclusively for this segment. The approach for perishable goods can be considered as very similar to that of hazardous goods.

Transport of general cargo (low value) are often more sensitive to price and may therefore be less demanding as regards time and reliability.

It should be kept in mind that there are often many parties included in a transport chain. As previously stated, the requirements of the different parties may differ. The shipper may focus on maximum safety and reliability but is less demanding as regarding transport speed. The transport company, on the other hand, will of course make the shipper's requirements known to the intermodal operator, but also add requirements of its own, such as high transport speed so its equipment is available for the next shipment as soon as possible (early equipment restitution).

The chain is, therefore, characterised by the sum of all respective maximum quality expectations. Together, these form the logistic profile of a transport chain. These profiles differ and can be classified on the basis of quality dimensions such as transport time, reliability, control, safety, accessibility etc.

#### 3.3.1.3 Conclusions for Quality and Segments

In this chapter we will describe the general conclusions regarding quality dimension identified for intermodal transportation.

***Time***

The transport time always influences the size of the stock in transit while the goods are being moved, as well as the size of the recipient safety stock. The longer the transport time, the larger the warehoused stock and associated costs. For perishable goods the transport times can, in addition, either mean costs for obsolescence or for obsolescence-preventive measures.[46]

***Reliability***

Reliability is defined as the ability of the transport system to maintain the promised scheduled timetables for departure and

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[46] Jensen, A, *Combined Transport*, Swedish Transport Research Board, 1990

arrival. Deviations from the promised time schedule can have negative consequences on a transport system. Another consequence is the occurrence of queuing situations at the shippers and/or queuing or shortage situations at recipients.

There is a clear difference between national and international transport. National transport seldom accepts delays of more than four hours whereas international transport is much less demanding in this respect.[47]

Maritime customers are more tolerant because there is often a large time buffer before the departure or after the arrival of vessels.

The less demanding attitude of shippers (buffering stocks) can be contrasted with a very demanding shipper sub-segment, which relies on reliable just-in-time deliveries.

Dense areas are also fairly undemanding as regards delays. This is due to the daily congestion experienced in urban areas.

***Flexibility***

Flexibility corresponds to the ability of the transport system to adapt to changes in the environment. To the individual transport buyer this could be a question of changes in the size and structure of the goods flow, or of a switch to new load carriers, new packaging or new handling techniques. Good flexibility in a transport system facilitates, among other things, the total rationalisation possibilities in the logistics system, and it can therefore contribute to better economy.

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[47] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

Lack of flexibility is perceived as the supreme obstacle for intermodal transport. The rigid timetables with only one departure per day or less, and an insufficient short-term response to unexpectedly high demand force many potential customers to use road transport.

If there are minor logistic changes in the customer's system the daily departure may be missed - resulting in a delay of 24 hours or even longer. On the contrary, road transport can adapt more easily to the timing of its clients, especially when transport is required at short notice.

The commercial and sales conditions and procedures are seen as a constraint for the development of intermodal transport services. At the national, but even more, at the international level, long and complex allocation and pricing procedures prevent the combined transport operators from providing a smooth response to market requirements.[48]

***Control/Monitoring***

Controllability is defined as the ability to follow the transport process with regard to deviations from schedule and communicating these deviations to the recipient and/or shipper. Better controllability gives the recipient more time for preventive measures in goods reception, production and distribution, and thereby lower costs.

Control is another very important issue for potential intermodal customers. The lack of information in the event of unexpected

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[48] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

delays or other problems makes the use of intermodal transport too risky for quality-sensitive market segments.

A high level of control is required in logistically advanced regions because the general level of logistic services is high (e.g., Germany/Benelux/UK), in less developed regions there is also a considerable need for monitoring because reliability/safety/security levels are low and risks rather high (Eastern Europe, Italy, Greece).[49]

With respect to distance, requirements are lower for short transport distances since the situation of these is more transparent.

Requirements are often most strict for maritime related transport, due to the complexity of handling etc. Permanent real-time monitoring is usually not required, but can be a useful service surplus.[50]

***Expandability***

Expandability is defined as the ability of the transport system to take over logistic functions from the pre- or post-transport systems. This can for example be achieved by using load carriers, which can also be integrated into the internal transport system of the shippers and recipients. Another example is the use of load carriers as warehousing units at shippers or recipients. The expandability of a transport system can contribute to better total economy in a logistical system.

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[49] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

[50] Ibid.

***Safety & Security / Qualification / Commercial accessibility***

In general, intermodal transport performs well in these quality areas. Safety and staff qualification are often mentioned as reasons for preferring intermodal to road; this is often due to the use of containers as load units, which enhance the safety of the goods during transport. The container can also be useful from a marketing perspective through advertising company profile, brand etc.

***Frequency***

Frequency is the number of departures per time unit, which in turn has an influence on:[51]

- Both the safety stocks and the cycle stocks at shippers and recipients in the pre- and post-transport systems. The higher the frequency, the less the warehousing and the lower the costs, particularly for tied up capital, but also for space and other consequences of longer warehousing.
- The capacity requirements and thereby the capital costs in certain handling operations, e.g., high frequency gives fewer goods peaks, thereby less expensive handling equipment.

***Pricing***

Pricing plays a specific role in quality analysis. Although, in order to focus on quality, it is not one of the quality criteria's but it cannot be ignored in an appraisal of competitiveness. Price is the most important single reason for choosing intermodal transport. Apparently, road prices are higher on a number of long-distance links as soon as two drivers are needed, or when

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[51] Jensen, A, *Combined Transport*, Swedish Transport Research Board, 1990

using just one driver would delay the journey too much. As for prices, the lack of transparency and the frequent changes of prices can be seen as a negative influence concerning intermodal transportation.

One of the biggest potential restrictors for a truly competitive intermodal transportation and distribution system is the lack of an infrastructure capable of providing an adequate cost-quality ratio[52]. Otherwise shippers are likely to buy transport services from road-haulers, which are more often able to offer relatively fast door-to-door transport with better cost-quality ratios[53]. To improve the competitiveness of intermodal transport, a quality leap seems necessary in order to make node and link operations substantially more efficient. However, this is not just a matter of a higher quality and lower costs. Improvement of quality may in fact in some cases lead to higher costs. Most important however, is to achieve a substantial better cost-quality ratio.[54]

As far as quality is concerned, improvement should focus on the following aspects:[55]

- A reduction of the lead-time in the door-to-door transport chain. The shipper then has his products sooner at his disposal, while demanding less transport equipment and

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[52] The criteria of the cost-quality ratio are: utilisation rates, frequencies, costs, speed, cycle times and reliability (TERMINET, EU project, http://europa.eu.int/comm/ transport/extra/rep_integrated.html)

[53] Wiegmans, B., Masurel, P. and Nijkamp, E., *Intermodal Freight Terminals: An Analysis of the Terminal Market*, Free University Amsterdam, Faculty of Economics, Business Administration and Econometrics, 1998

[54] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

[55] TERMINET, EU project, http://europa.eu.int/comm/ transport/extra/rep_integrated.html

load units, due to the faster circulation time. There is a potential enlargement of the market area, as the transport radius is increased due to shorter terminal times. Also, better opportunities exist to realise more favourable departures and arrival times of transport units at terminals

- Higher transport frequencies, making the intervals between transport services smaller and thereby reducing the waiting time for freight. In addition, higher frequencies will have a positive effect on the required load facilities at terminals, as well as on the rental cost savings of shippers
- In order to play a more important role in transport markets, intermodal transport must be able to provide services for more destinations, also on relative short distances and for small flows, also in the case of pre and end haulage
- Higher reliability is vital for the necessary reduction of buffers and is therefore directly related to costs. The costs of unreliability have become of growing importance, mainly as a result of the emergence of just-in-time deliveries
- More flexibility is necessary, mainly for capacity adjustments, in time and space
- More suitable operation times are important to realise favourable interconnections between links in the transport chain and for the optimising of terminal efficiency
- More attention should be paid to sustainability, as this may become a competing quality dimension as well on the long term. Because of the usual focus on costs as a competition factor, it is generally supposed that the costs of intermodal transport need to go down. On the other hand, for time sensitive freight it is imaginable that the costs may increase, if quality improvements compensate for this.

#### 3.3.1.4 Performance Comparison: Intermodal Transport vs. Road Transport[56]

This section compares the performance of intermodal transport and road transportation with regard to quality elements.

Intermodal transport is able to compete with the road (i.e., achieve performance that equals or betters that of road) in the sectors of booking and planning. It performs least well in the areas of: length of delays, frequency of delays, transport time.

With regard to other areas of quality, i.e., where intermodal is able to compete successfully with road, support generally reaches 50% or more.

In the case of individual segments, it is clear that the hazardous and perishable goods sector, intermodal transport performs very poorly compared with road, especially in the areas of transport time and delays, but also for damage and monitoring. In the maritime sector, intermodal is generally slightly more competitive.

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[56] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

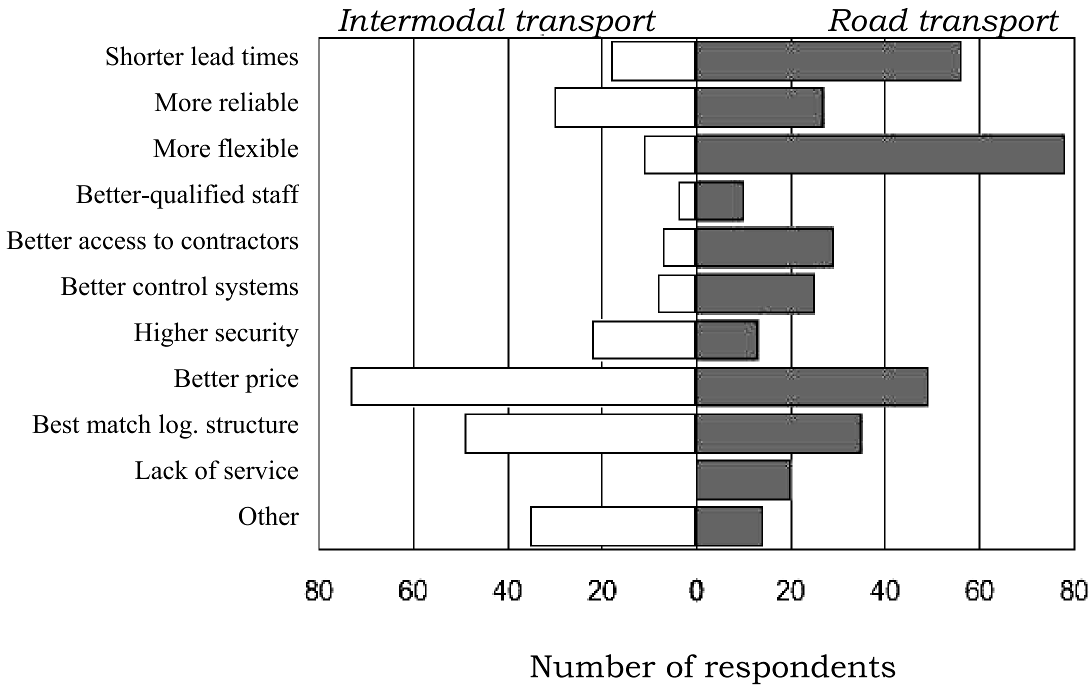


*Figure 3-2, Decisive factors in the modal choice between intermodal and road transport*

As can be seen from the figure above, price is a strong element of intermodal transport, as mentioned earlier.

### 3.3.1.5 Reasons for Choosing Intermodal Transport[57]

This chapter displays the results from a research report published by the European Commission concerning ranking of quality dimensions of intermodal transportation.

Price is the single most important reason for choosing intermodal transport. Its role is equal to or considerably greater than any of the quality aspects.

The second most important single reason is that it is able to match the customer's logistic structure. This is mainly due to its

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57 European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

ability to haul large volumes, thanks to terminals or equipment. Customers to intermodal services often also rank reliability high.

In maritime hinterland transport, price is the most important factor, followed by reliability and logistic structure (high volumes, port rail terminals)

In the hazardous goods sector, price and logistic structure (equipment) are important factors but of course also control and safety. The conclusion is that intermodal transport has good performance in this field but this is not an important reason for preferring it to road transport.

In the perishable goods sector, the reasons are more evenly distributed between reliability, flexibility, control, safety/security, price and logistic structure. Transport time is very seldom the reason for choosing intermodal transport in this segment.

In the low value goods segment, the results are particularly important because this is where the greatest potential for intermodal is to be found. Price is of paramount importance for intermodal here, followed by logistic structure and transport time.

## 3.3.2 Technical Limitations

### 3.3.2.1 Load Unit

In the middle of this century, large load carriers in the form of containers started to be used for sea borne transports as a result of the efficiency at the loading and unloading operations and the safety of goods.[58]

According to some combined transport operators such as Eurokombi, difficulties in management at operational level make it impossible to achieve a mix of maritime containers and continental units. But, according to others, for example Italian intermodal players, if the transport of continental units (e.g., pallets) and maritime containers (i.e., boxes that can be filled with cargo and can easily be transhipped from one modality to another) still constitutes two distinct markets whose integration seems to be slow, this is more due to behavioural factors affecting the users than to technical incompatibilities: established relationships between shippers and transport operators are difficult to change.[59]

#### *3.3.2.1.1 Intermodal Load Unit*

As stated in the background of this thesis the European Commission has an interest in making intermodality more attractive to transport users and endorsing it as a sustainable alternative to congested road transport. The European Parliament, Council and Commission have identified the lack of harmonisation and standardisation of loading units as an area that hampers the development of intermodality from reaching its full potential. In this chapter we have summarised the demands and prerequisites for an intermodal load unit and briefly discuss the research that is conducted in this area.

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[58] Woxenius J., *Development of Small-Scale Intermodal Freight Transportation In a Systems Context*, Chalmers University of Technology, 1998

[59] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

For intermodal transport to become attractive to customers, it needs to be simple to use and fulfil the customer requirements. It has to offer the same or better advantages than single mode transport. This could be achieved by single modes complementing each other and linking their strengths in door-to-door supply chains. Interconnections between the modes should be seamless and offer a high degree of interoperability. However, smooth transfers between modes are endangered by lack of standardisation and harmonisation in intermodal loading units.

Currently the handling characteristics of intermodal loading units differ considerably from standardised characteristics of containers to swap bodies and to diverse characteristics of purpose-build units. Considerable effort is required to identify the handling requirements of any single intermodal loading unit. Also, the handling equipment has to be frequently adjusted or even changed for certain configurations. This complicates and delays handling operations and adds unnecessary friction costs to intermodality. To solve this problem, intermodal loading units need to be made more uniform in the Community.

A degree of uniformity can be introduced in the current situation by harmonising certain characteristics of intermodal loading units. Such characteristics could include the location and design of fittings and other accessories of the intermodal load units that relate to handling and transportation. This harmonisation would decrease transfer friction costs, speed up handling and decrease the risks during transportation.

The commonly used containers in Europe (20' and 40') follow the ISO[60] standards. These containers can generally be used in all

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[60] International Organisation for Standardisation

land and waterborne modes of transport. They are usually stackable and can be lifted with spreaders. However, they do not generally offer optimum loading capacity for EUR pallets[61] or fully utilise the maximum dimensions available in land transport. This is the main reason why they are not widely used in European land transport.

Swap bodies are primarily designed for transfer between land modes. They allow good utilisation of capacity on road and rail vehicles, but they do not offer economic solutions for inland waterways or shortsea shipping. They are usually not stackable owing to their weak wall construction, cannot withstand the sea movements and cannot be lifted with a spreader. They come in different sizes and have a number of different characteristics. The European Committee for Standardisation (CEN) has elaborated certain European standards for swap bodies.

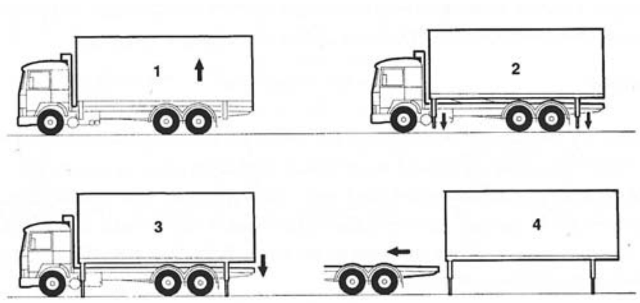


*Figure 3-3, The swap-body principle*

This diversity of designs, sizes and technical characteristics complicates intermodality and deprives it of interoperability of loading units. Handling operations are being delayed because every box has to be identified separately to choose the correct handling technique. The lifting equipment has to be frequently

[61] I.e., 800x1200 mm

fine-tuned or changed. This causes unnecessary friction costs in the transport chain. Swap bodies are confined to land transport (and short Ro-Ro journeys) while containers are mainly used in waterborne modes. This situation also complicates investments in intermodal loading units. The full capacity of the transport system cannot be utilised, and seamless intermodality does not become reality.

From the Consultation Paper *Intermodal Loading Units, Harmonisation and Standardisation Initiative,* the following quote gives a understanding about the research conducted by European Union research programmes and might give an indication of the future for intermodal loading units:

"Apart from harmonisation, Europe needs an optimal intermodal loading unit that combines the benefits of containers and swap bodies. Such a unit should be able to move freely in all land and waterborne modes of transport and between them to offer the prerequisites for maximum intermodality. Consequently, it should be stackable, suitable for top lifting and seaworthy. The unit should offer the maximum allowable space for transporting pallets, and it should also offer simple and fast charging and discharging of pallets to decrease friction costs and delays. To begin with, this European Intermodal Loading Unit could be a pallet-wide general-purpose dry-cargo box having a length of 13600 mm or 7450 mm and height of 2670 mm. Such loading units do not exist today in any significant numbers. Therefore, European standards would have to be developed under a mandate to be given to CEN. To ensure safety and minimise the risks to persons and property, all intermodal loading units in use in Europe should be subject to a maintenance obligation and periodic inspections. The procedures for those measures should be uniform and follow European standards to be designed by CEN. Obligations for maintenance and periodic inspections regarding containers in international traffic also arise from the 'Convention for Safe Containers' adopted at international level. Conformity of intermodal loading units with the relevant standards should be assessed or reassessed by notified or approved bodies. The designation of those bodies and the necessary assessment measures could follow the standard procedures arising from standards and earlier Community legislation. Corresponding procedures could be chosen for the periodic inspections. Recognition of conformity assessment, reassessment and periodic inspections and their markings would help the free movement of intermodal loading units all around Europe."[62]

The work undertaken by CEN and UTI-NORM[63] could form the base for the standard of an optimal European Intermodal Loading Unit in two versions of length: 13600 mm and 7450 mm. The first length would be chosen because of its optimal character in relation to ISO pallets and maximum allowable loading length in road transport. The latter because it is close to the maximum that can be transported in pairs on road trains without special construction of the vehicle (such as short coupling). Both lengths can also be transported by rail, shortsea shipping and inland waterways. Some problems could occur on cellular ships and barges that would need to adjust their cell guides to a new length entailing marginal friction costs (even though adjusting those guides between different lengths happens already today). In some cases when ships are designed for certain container lengths, the structural requirements might

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[62] Consultation Paper, Intermodal Loading Units, Harmonization and Standardization Initiative, European Commission, Brussels, 2002

[63] Current State of Standardization and Future Standardization Needs for Intermodal Loading Units in Europe (UTI-NORM), Final Report, September 1999, Brussels, Frankfurt/Main, Hanover, London, Paris.

result in less optimum use of cargo space. Also the capacity of current standard rail wagons, which is designed for 40' and 20' ISO containers or 7150 - 7820 mm swap bodies, could not be fully utilised with the 13600 mm unit. We will not consider these ITU's for the intermodal system in our research because they have not gained significant market position, but gives an insight to the future of intermodal load units.

#### *3.3.2.1.2 Containers as Load Carriers*

A container is a specialised box to carry freight, strengthened and stackable and allowing horizontal or vertical transfers, the technical definition of a container is:[64]

- Of a permanent character and accordingly strong enough to be suitable for repeated use;
- Specially designed to facilitate the carriage of goods, by one or more mode of transport, without intermediate reloading;
- Fitted with devices permitting its ready handling, particularly its transfer from one mode of transport to another;
- So designed as to be easy to fill and empty;
- Stackable; and,
- Having an internal volume of 1 $m^3$ or more.

In the intermodal system we use the ISO container, this has obvious advantages. It has a well-established position in the market of unit loads and is commonly used in sea transportation. Standard throughput unit in unitised cargo is

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[64] Glossary for Transport Statistics, Document prepared by the Intersecretariat Working Group on transport statistics, EUROSTAT, ECMT, UN/ECE, Second edition

the 20-foot containers, which is counted as one TEU (Twenty-foot Equivalent Unit) though the 40-foot containers are commonly used.

The basic technical specifications of an ISO container are as follows:[65]

Measures: 8 x 8 x 10, 20, 30, 40-foot.

Gross Weight: 10.16, 20.32, 25.4 and 30.4 tonnes

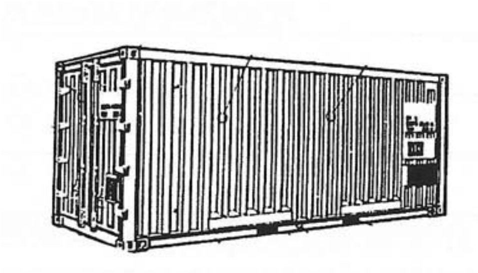

*Figure 3-4, Standardised ISO container*

In accordance with ISO standards, these containers are equipped with bottom and top corner fittings. This enables them to be handled easily by cranes and lift-trucks that are equipped with a top lifting yoke. The container can also be equipped with fork tunnels and grip-arm fittings, which enables it to be handled by a fork lift-truck or grip-arm equipped cranes and trucks.

For transport of containers there are special container ships and special container terminals that are equipped with special container cranes, as mentioned earlier. Compared to transport of cargo separately, using containers has the following advantages:[66]

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[65] http://www.isocontainers.com/specsmain.htm

[66] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

- Reduction of port time, loading/unloading speed increases because the units are bigger and stowing faster.
- Fewer personnel are required for transhipment of the cargo.
- The cargo is better protected against damage during loading, unloading and transport as well as against theft.

Combined traffic over borders using ISO containers is extensive as said earlier, particularly for sea transportation, which is a part of the intermodal system treated in this research.

### 3.3.2.2 General Cargo Vessels

The general cargo vessels can be divided into a large number of variants. The vessels range between everything from conventional general cargo ship designed for non-unitised cargo, to very specialised ships designed for certain use of unitised cargo (pallets, trailers, containers, or a combination). It is obvious that the trend is towards more and more unitisation of basically all goods types.[67]

The size of most general cargo ships is restricted by loading/unloading speed and the time spent in port. The size and shape of the vessels can range from 50 meters up to more than 300 meters. General cargo ships are often relatively small and have a size up to 25,000 Dwt (dead weight tonnes of the ship).[68]

Depending on the technique deployed in handling the general cargo, the vessels can be divided into vertical operation ships, LoLo-ships (Lift on Lift off) and horizontally operating ships,

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[67] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

[68] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

RoRo-ships (Roll on Roll off). The vertical handling procedure means that the goods are lifted on board the ship, while the horizontal handling procedure involves goods being handled by trucks, wagons or some other type of rolling handling equipment.

The LoLo technique is the one that is interesting from our research point of view since we only consider container-based traffic. Moreover, we would like to point out that Ro-Ro ships still only have a relatively weak presence on the European market. The economic explanation is the additional cost of Ro-Ro ships (construction and operating costs) due to their inevitably lower load factor compared to container ships (LoLo ships).[69]

The most important reason for the use of large load carriers as the form of containers is the efficiency at the loading and unloading operations and the safety it brings to the goods. This is the main reason why containers where developed.[70]

Container ships have box-shaped holds, fitted with cell guide, which are used for the guiding and fastening of the containers *(see Figure 3-4)*. The number of 20-foot containers (TEUs') they can carry measures the carrying capacity of the ship.

#### *3.3.2.2.1 Container Ship*

Container ships are normally designed in the form of LoLo-ships and all (or at least one) of the hatches have been equipped for transportation of containers. When the harbours are not equipped with cranes for lifting the containers, ships can be equipped with gantry cranes. Today many of the cranes have been removed and are not part of modern ship construction, this

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[69] European Conference of Ministers of Transportation (ECMT), Shortsea Shipping in Europe, 2001

[70] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

is due to the efficient cranes in harbours and the low utilisation of the ship mounted gantry cranes.

In a pure container ship, see *Figure 3-5, Container ship (LoLo)*, the containers are placed lying on top of each other in a cell system. The hold is covered with hatches in order to prevent water to permeate. On the hatches or on specially built frameworks additional containers are placed, often four in height or more. Containers are loaded depending on the weight in order to bring the ship desirable balance. The capacity for handling the containers are approximately 30 units/hour i.e., a cycle-time of 2 minutes when using a modern container crane for the loading and unloading operations.[71]

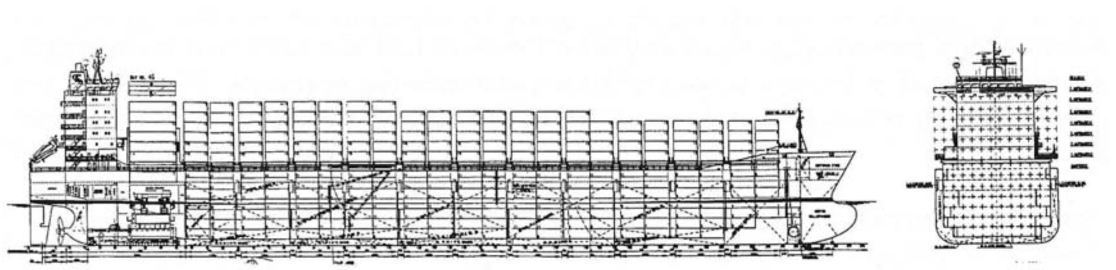

*Figure 3-5, Container ship (LoLo)*

Refrigerated cargo is to great extent transported in containers with container ship. These load carriers are then equipped with refrigeration plant of their own or connected to a central one. Refrigerated air is distributed though a channel system connected to the isolated containers. However, it is most common that the refrigerated containers are equipped with compressor, condenser, expansion valve and cooler as a built-in air circulation system that is connected to the electric mains of the ships, i.e., a self-contained unit.

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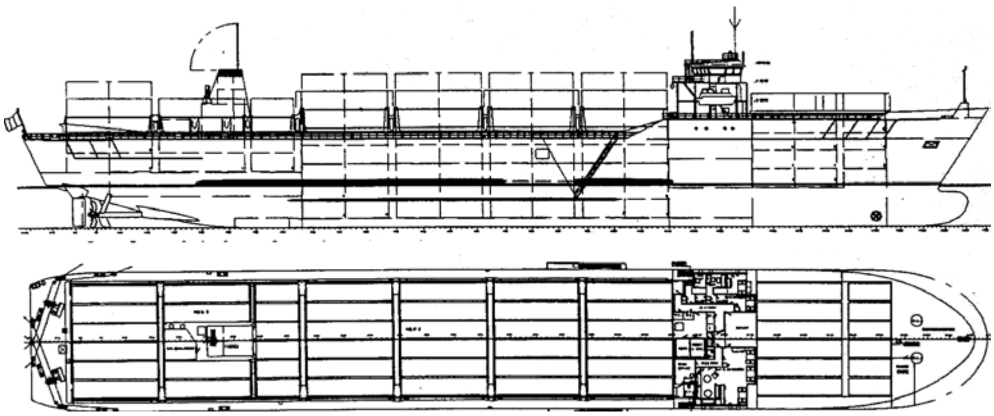
[71] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

Progress and in many cases the lack of sufficiently large unitised goods have lead to the development of ships where the transportation of containers is combined with other types of cargo, such as pallets or rolling gods, i.e., Multi-purpose ships.

In our sea-based intermodal transportation system we will use a container ship with similar characteristics as the ship in the figure below. Since our ship does not exist in reality we have chosen to describe the existing ship *Reestborg*[72] in order to provide some basic facts.



| Principal particulars | | | |
|---|---|---|---|
| Length, oa | 139.95 m | Deadweight | 7,285 t |
| Lenght, bp | 123.55 m | Main propulsion | Ulstein Bergen BRM-8 |
| Breadth | 20.00 m | Output (MCR) | 3,530 kW |
| Depth | 12.60 m | Speed | 17,50 kn |
| Draught | 6.30 m | Container capacity (TEU) | 588 |

*Table 3-3, Small open hatch container ship Reestborg*

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[72] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

### 3.3.2.3 Infrastructure

The infrastructure discussion in this chapter refers mainly to terminals. The essence of terminals is that they add value by creating an *opportunity* to transport the consignment to a place and time where its utility is larger than at its present location. *Figure 3-6* displays terminals handling more than one mode of transport.[73]

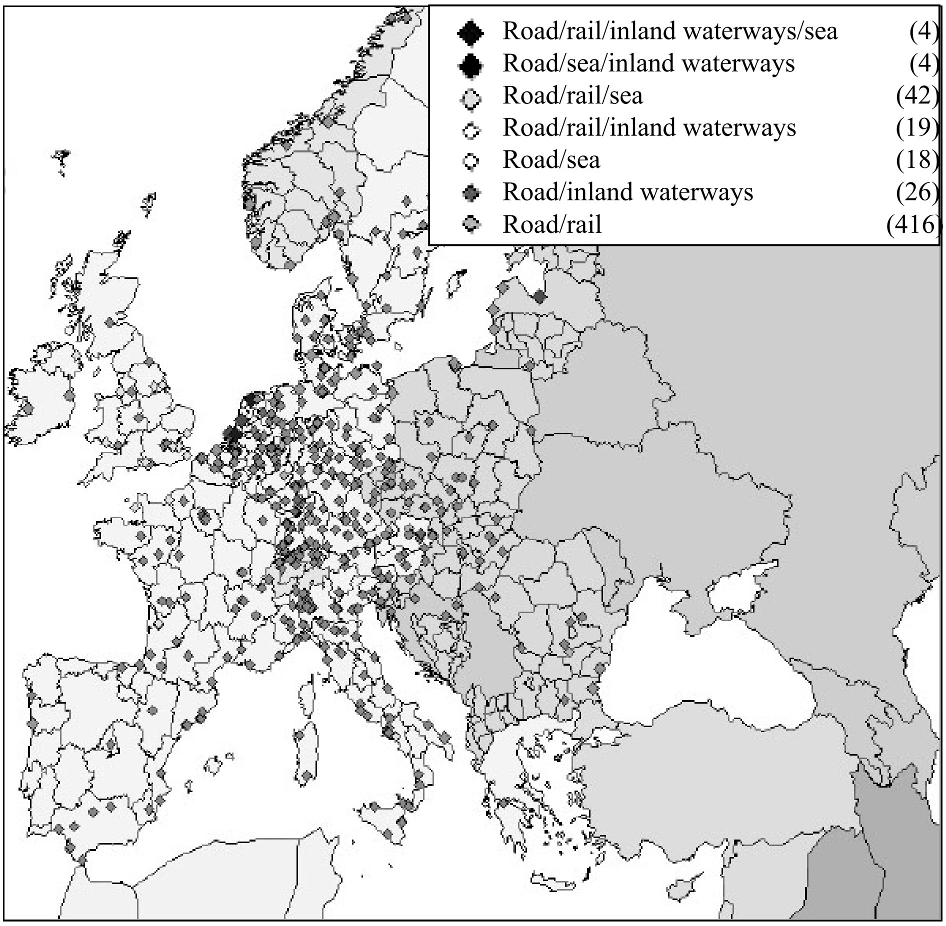


*Figure 3-6, Terminals by type of transhipment*

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[73] European Commission, *Intermodal Freight Transport, Key Statistical Data 1992-1999*, Office for Official Publications of the European Communities, Luxemburg, 2001

#### 3.3.2.3.1 Inland Terminals

A terminal is, in general, a node in a transport chain where the transport stops for a while. This stop adds additional time delays and costs to the transport. Therefore, the terminals has to be capable of delivering added value to the customer, e.g., in terms of consolidating, break-bulk, storing, sorting etc.

There are several operations that have to be carried out in an inland terminal. Some of the activities that are related to the main function of an inland terminal are:[74]

- Loading and unloading of cargo
- Inspection
- Sorting/Consignment grouping
- Cargo Storage (short-term)
- Kitting, Consolidation
- Administrative and commercial handling

Infrastructure is needed to carry out these functions, but compared to port terminals, inland terminals has some advantages concerning infrastructure investments, e.g., already existing roads, not so costly handling equipment etc. Apart from port terminals, inland terminals seldom have to switch between modes of transport, but purely to combine long-distance transports with local distribution. Although some has the possibility to switch between rail and road transport. The nature of transhipment is therefore the fundamental difference between inland terminals and port terminals. Since port terminals handles larger volumes of goods per transhipment and therefore suffers more from insufficient transhipping capacity, port

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[74] Jansen, K., *Port Terminal Modeling: Development of a Concept and Tool*, Göteborg, 2001, Chalmers University of Technology

terminals also have to store goods to a larger extent than inland terminals while waiting for transhipments of goods from one mode of transport to another.[75]

A terminal in an intermodal transport system differs from other types of terminals, since the load unit used in the intermodal transport system, by definition, has to switch mode of transport at least once. Since the purpose of intermodal transport is to use the mode of transport best suited, the added value provided by an intermodal terminal is the actual exchange of transport mode.[76]

However, the quality of the delivered service provided by the terminals is of outmost importance:

*"Intermodal terminals are crucial points of transport logistic chains. Improvement in the quality of the terminal operations is considered as a key issue for the optimisation of the overall quality of the intermodal transport system"* [77]

In order to be able to provide such a combination of cost vs. quality mentioned earlier, the availability of appropriate terminals is crucial. In theory, the more terminals, the closer to the customer, the better the service. Closely related to the decision of how many terminals to establish is the decision of where to establish them.[78] However, one of the first restrictions that come to mind when determining this is the often

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[75] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

[76] Sjögren, S., *Effektiva kombiterminaler – En tillämpning av DEA*, Göteborg, 1996

[77] Ibid. p. 6

[78] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000

considerably high cost of building and maintaining the terminals.

The infrastructure costs of an inland terminal can vary considerably from one site to another, depending on the price of land or the amount of preparatory work required. In densely populated areas, land prices can be 10 times higher than in rural areas. However, land prices rarely account for more than between 10-15% of the infrastructure cost, (although in some areas a figure of 30% can be reached). The infrastructure cost for the construction of a new terminal is very often more than 50 % of the total cost, the rest being shared between superstructure cost and other fixed costs, mainly wages (the superstructure cost and variable costs are proportionately greater for large terminals). As a consequence, it is very tempting for a transport operator not to construct a new terminal but either to try to extend existing terminals and use existing railway shunting equipment, or alternatively look for subsides which will cover at least the infrastructure cost.[79]

In addition, conventional terminals in most cases do not meet the performance requirements of the complex networks needed to increase the cost-quality ratio, because they do not have:

- The capacity and speed needed
- An appropriate layout, especially for rail-rail or barge-barge exchange
- An internal transport system, which is required for larger amounts of direct rail-rail exchange.

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[79] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

If the terminals absorb too much time and costs, the lead times and costs become too unattractive. Therefore, a substantial improvement of the cost-quality ratio of node operations can often be influenced only by the implementation of new-generation terminals, i.e., terminals that are capable of executing the complex operations required by innovative and complex networks.[80]

Since the fixed costs, and in particular the infrastructure cost, represent the major share of the cost, the profitability of the inland terminal improves with an increase in traffic, with different thresholds, for a small, medium or large terminal. Therefore, the rate of return on an investment in a terminal can only be improved by an increase in the volume of traffic or by a reduction in the cost of the investment in question. Inland terminals in Europe can seldom be profitable without public subsidies. Only an improvement in combined transport productivity could improve profitability and this would require the implementation of new techniques or a new organisation of the structure of the terminal as well as an improvement in the performance of network operating systems.[81]

#### *3.3.2.3.2 Port Terminals*

The principal function of a port terminal is to provide facilities to transfer goods between ships and other modes of transportation. In some cases there are also cargo transfers between different forms of sea transport. The value is added and created by creating opportunities to exploit economies of scale and by

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[80] TERMINET, EU project, (http://europa.eu.int/comm/transport/extra/rep_integrated.html)

[81] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

enabling the means of transport to operate independently. In addition to this, a port terminal can offer a variety of other services.[82]

There are several operations that have to be carried out in a port terminal. Some of the activities that are related to the main function of a port terminal are:[83]

- Loading and unloading of cargo
- Stevedoring
- Cargo tallying, inspection
- Sorting/Consignment grouping
- Cargo Storage
- Administrative and commercial handling

Many of the functions above are shared with inland terminals. The performing of the above activities needs some infrastructure in order to be carried out. The main infrastructure of a port terminal is seen as consisting of following major facilities and equipments:[84]

- Docking facilities
- Traffic area
- Storage/packing facility
- Transhipment equipment

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[82] Jansen, K., *Port Terminal Modeling: Development of a Concept and Tool*, Göteborg, 2001, Chalmers University of Technology

[83] Ibid.

[84] Ibid.

In order to be competitive, an intermodal system based on sea-transport has to significantly improve in the following areas:[85]

- Reduce the current time spent in ports. Whenever possible, a "round the clock service" for loading and unloading activities should be provided
- Furthermore, a great deal of ports doesn't have the latest up-to-date handling equipment at their disposal
- It is also a necessary requirement that hinterland connections of the seaports are improved.

The use of large vessels requires changes to the harbour and terminals on the marine side, and consequently the anticipated increase and change of scale in combined transport services necessitates new infrastructure and superstructure at intermodal interfaces. New harbour facilities now include plans for the development of combined transport modes (either rail or inland waterways) in their layout and organisational scheme.[86]

Both the anticipated quantitative growth in European maritime container traffic and the strategies of players in the harbour and maritime environment have imposed new constraints on inland terminals, primarily of a quantitative but also of a qualitative nature. The anticipated restructuring and investment in harbours at the interfaces with intermodal systems are crucial for the competitiveness of maritime terminals and ports as access links are increasingly considered to be key elements for the success of container terminals and ports. Such investments

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[85] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

[86] Jansen, K., *Port Terminal Modeling: Development of a Concept and Tool*, Göteborg, 2001, Chalmers University of Technology

are therefore essential for the promotion and development of competitive European intermodal transport services.

The European Commission adopted in 1997 a Green Paper on Sea Ports and Maritime Infrastructure. The Paper aims primarily at better integrating ports in the intermodal transport chain.[87]

From this paper it is said that ports should provide a corresponding level of service on commercial basis to all users without discrimination. Some ports systems have been developed to better accommodate the needs of shortsea services, for example the crucial need for shorter turn-around times. These systems include, in particular, separate terminals for shortsea shipping but also other dedicated services based on commercial considerations in ports. However, in other ports, shortsea shipping has to compete for port facilities with priority given to ocean shipping and it faces uncertainties that can be harmful to the overall quality of just-in-time transport services.

Ports should be seen as intermodal connection points in the same way as land terminals. The Commission made a proposal in 1997 to adjust the Trans-European Networks (TEN) Guidelines to this effect. This adjustment would give a specific status to inland and seaports as well as to intermodal terminals as connection points between the modes. The proposed adjustment would also emphasize the status of shortsea shipping as a main criterion for the selection of TEN actions to be supported by the Community. This is important for the future

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[87] Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, *The Development of shortsea Shipping in Europe: A Dynamic Alternative in a Sustainable Transport Chain*, Brussels, 1999

of shortsea shipping as part of intermodal transportation systems.

#### *3.3.2.3.3 Interfaces of Terminals*

Looking forward, there is considerable scope for further integration of port and rail terminal operations (for example the development of off dock container terminals in rail yards). The increasing containerisation of rail freight and associated lift on/lift off operations will release significant amounts of rail transport to, or short distances from, port terminals. This will allow for the potential development of off dock container terminals linked to marine terminals by rail shuttles.[88] This would have the following impacts:

- Reducing congestion around port areas
- Reducing trucking costs and delays
- Reducing cost of new terminal development
- Potential to integrate rail and ship stevedoring operations within a single organisation.

"*At present, harbour-rail interface costs for intermodal transport are very high*"[89]

The quality of operations at the road terminal interface with harbours is also critical. Indicators such as the opening hours of the terminals and the waiting times at the terminals, the services provided to the vehicles, goods or the driver (parking, customs) are important quality dimensions at all types of terminals.

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[88] www.tranzrail.co.nz/newsroom, 2002-10-17

[89] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000, p. 47

Generally, at railroad terminals trains are kept stationary for many hours and the maximum number of direct transfers between wagon and road vehicle are performed. In the past, terminals very often handled one train per day on each track. Nowadays large terminals tend to handle several trains per day on each track. The surface area allocation, the number and the length of the tracks and of the sidings are the subject of new requirements and opportunities for improvements.

An improvement in the performance of terminals and the transport chain is to be found in the way they interact with and between different modes of transport. The improvements associated with the "quality of terminals" are limited if we only consider terminal operations, as these account for about 7% of total transport chain costs.[90]

### 3.3.3 Capacity Constrains In Intermodal Networks

Capacity constraints are also a major problem for the service quality and performance of transportation networks. Capacity constraints can be caused by the physical characteristics of the network, in particular the existence of bottlenecks in dense areas or natural barriers, such as mountains and rivers. However, capacity constraints can also result from a lack of technical harmonisation in the face of interoperability problems (e.g., load units etc); just considering investment as they are directly related to the operating system cannot solve capacity constraints.

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[90] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

"*Capacity constraints are not only determined by the technical characteristics of the infrastructure and equipment, but also by the operating system and the institutional environment.*"[91]

Capacity constraints are clearly linked to the network infrastructure and the technical characteristics of the links and nodal points. Capacity constraints are also linked to the equipment; the availability of locomotives, vessels, lorries, drivers, wagons and ITU are the main determinants of network capacity.[92]

## 3.4 Barriers to Intermodal Transportation Systems

The work of intermodal transportation system designers and inventors of technical resources can be compared to running in a labyrinth, continuously facing a wide range of limiting factors. In order to reach the ultimate objective, measures must be taken to avoid these factors. In order to understand the nature of technical innovation in intermodal transportation systems, knowledge about these limiting factors is essential.

A *barrier* is defined as a hindrance that is impossible to change by the systems' designer or can only be changed at high costs or in a long time span. Examples of such hinders that a systems' designer must consider are physical capacity of infrastructure, laws and regulations, standards and existing technologies.

Standardisation is a key issue when analysing barriers for technological change in intermodal transportation systems.

[91] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July, p77

[92] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

Since overall performance is prioritised, the decided standard cannot be optimised for all components.

*Technological openness* is a useful conception, which in an intermodal context can be defined as the level of restriction in technical acceptance of different ITU:s, lorries, vessels, rail wagons and to some extent also transhipment equipment.[93]

Operators of links and transhipment nodes must also decide whether to form an integral part of a general transportation system or to offer end customers complete door-to-door transport services. Similar to technological openness, *commercial openness* can be defined as the level of restriction in commercial acceptance of different customers. A system with the lowest commercial openness only permits one single customer, whether it is a shipper or an intermediary transport operator. The service can be officially restricted, it might be a direct train service for one shipper or the operators can use discriminatory pricing to prevent other customers from using the service.

Technological openness is a matter for systems designers while commercial openness has traditionally been strongly influenced by government policies. Nevertheless, as a consequence of deregulation, commercial openness is changing into pure marketing and strategy decisions mainly taken within transport companies.[94]

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[93] Woxenius J., *Development of Small-Scale Intermodal Freight Transportation In a Systems Context*, Chalmers University of Technology, 1998

[94] Ibid.

## 3.4.1 Natural Barriers

In Europe there are several major natural barriers which influence the layout and capacity of the European transport network, especially rail networks: black spots are clearly identified at the Alpine and Pyrenean barriers, and recent infrastructures such as the Channel Tunnel or the fixed links between Denmark and Sweden will play a structural role in the development of European combined transport. Naturally, European geography influences the location of freight gateways.[95]

## 3.4.2 Regulative Barriers

Regulative barriers originate from laws and regulations issued by authorities primarily concerning direct interaction with governmental infrastructure but also concerning external effects such as emissions, noise, traffic accidents, working conditions for employees and recycling of goods. A further regulative barrier is that laws and regulations still are applicable to single mode transportation rather than to intermodal transportation and that the adaptation to new circumstances is slow.[96]

### 3.4.2.1 Weights and Dimensions

In order to plan and build compatible infrastructure, authorities must decide upon the permissible size of vehicles. This applies both to the permissible cross section, normally referred to as the loading profile, and to the maximum weight that bridges, road embankments and tracks are designed to endure. Length is less important, but still restricted in road transport due to

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[95] Lumsden, K., *Logistikens Grunder*, Lund, Studentlitteratur, 1998

[96] Bowersox, D., Closs, D., *Logistical Management,* McGraw-Hill, 1996

manoeuvrability in cities and to safe overtaking by other vehicles, and in rail transport due to the length of side-tracks and platforms. The size of ships is mainly restricted in terms of draught during sailing, of length by quays in ports and of width by the outreach of quay cranes. In inland navigation, the size of barges is restricted by the size of locks, width of canals as well as by the height of bridges.[97]

Permissible dimensions differ widely between transportation modes but also between links of the same transportation mode. One example important to intermodal transport is the maximum weights and dimensions allowed in road transport, which differ widely between European nations. Also the loading profiles of railways differ widely. For obvious reasons, all moving resources in intermodal transport systems must fall within the maximum dimensions at each link.

The great variety of maximum vehicle lengths and weights between European nations has induced an intense harmonisation process lead by the European Commission. The Commission has decided that the member states must allow articulated lorries being 18.75 m long, 2.55 m wide and weighing 44 tonnes for international road traffic. At last, this gives a firm framework for future technical development.[98]

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[97] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

[98] Woxenius, J., *Development of Small-Scale Intermodal Freight Transportation In a Systems Context*, Chalmers University of Technology, 1998

#### 3.4.2.2 External Effects

External effects are increasingly important in design of transportation systems. In addition to existing regulations, authorities have revealed intentions for charging the full external costs for each transportation mode. Still, proper costing is a delicate task and petitions about the costs are frequently issued. Nevertheless, higher taxes and even the prohibition of polluting, noisy and dangerous vehicles are foreseeable. Although, this might be seen as a catalyst for new cleaner and safer operations, e.g., increased use of intermodal transport, systems designers must conform to existing and preferably also to proposed future regulations when designing new technology.

Lately, environmental friendliness has become an important factor in the competition for end customers. Environmental certification of products will certainly include how the products are transported thus adding a new dimension to an issue up until now seen as a matter of obeying governmental regulations. In the future, environmental friendliness will not only be seen on the cost side of the accounts and the transport industry is expected to not only live up to the minimum level stipulated in the regulations.[99]

For intermodal transport that is often marketed with environmental arguments, a consistent environment concern is of utmost importance. Technical resources must be manufactured and operated maintaining the “green” reputation of the transportation system.

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[99] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

#### 3.4.2.3 Slow Legislative Adaptation

Despite 30 years of large-scale intermodal transport, the history of the European transportation system is the history of the single modes. The slow adaptation of legislation and liability rules to a truly mode-independent one severely hampers the technical and commercial development of European intermodal transport. The harmonisation process has begun, but it lags behind. The public bodies are not solely to blame; the slow process is also due to counteractive behaviour from the actors in the industry. Bureaucracy and the lack of proper legislation as a barrier to technological change is also a reality, e.g., the development of intermodal transport units (ITU:s).[100]

### 3.4.3 Technological Barriers

Standards and dominant technologies are of great help for innovators of technical resources, but also a limitation for new and different technical solutions. Technological barriers also stem from the fact that the capacities of vehicles are different, which means that technological change is more dramatic to modes with a small carrying capacity of each vehicle.

#### 3.4.3.1 Standards

Technical standards guide systems designers and manufacturers. Standards for equipment for intermodal transportation generally define the interfaces between system resources in terms of dimensions and positions of the fastening

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[100] Woxenius, J., Development of Small-Scale Intermodal Freight Transportation In a Systems Context, Chalmers University of Technology, 1998

points, but they also stipulate the required construction strength and design

Most significant for development of intermodal transportation systems are standards stipulating the size of ITU:s. These standards are closely linked to regulations for use of infrastructure. The obvious purpose is that vehicles loaded with suitable ITU combinations shall benefit from the maximum vehicle weights and dimensions.[101]

Technical standards are thus stipulated in order to simplify the development of complex systems, but it also implies restrictions for the systems designer. ITU standards have been established after discussions over many years meaning that some standards have been obsolete from the beginning.

### 3.4.3.2 Prevailing Technology

One example of prevailing technologies is the intermodal transport procedures of over-night traffic that dominates in Europe. Trains stand at the terminals during the day and travel between terminals over night. This has long been the prevailing way of doing things, but three trends will probably change the night-leap situation. Firstly, demand for more advanced logistics services may induce the intermodal industry to offer short and medium distance transport services during the day. Secondly, as intermodal transport is prioritised and the competition is rapid road haulage, intermodal trains have enjoyed higher priority on the railway lines during the past few years. In fact, some container trains are today given even higher priority than passenger trains. Thirdly, the extension of the European high-

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[101] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

speed train network (e.g., TEN) with dedicated tracks will leave more space on existing tracks for freight trains during the day. Therefore, a change in traffic operations is very dependent on the environment and far from always in the hands of the systems' designer.[102]

### 3.4.3.3 Lack of Formal System Leadership

As for most engineering of systems that include flows of any kind, designing intermodal transportation systems is much about identifying and removing bottlenecks along the chain. As one bottleneck is removed, however, the narrow section is moved somewhere else in the chain. What makes this continuous procedure especially difficult is that the chain is not controlled by a single actor.[103]

Consequently, technological development is obviously slowed down by the fact that no single organisation can push for it along the transport chain, and that problems arise when the benefits from the investments should be split among the actors participating in the transport chain. The problem is further aggravated by the fact that road, sea and rail transport interests compete with their single mode operations and have a long history of mutual conflicts.[104]

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[102] Woxenius, J., Development of Small-Scale Intermodal Freight Transportation In a Systems Context, Chalmers University of Technology, 1998

[103] European Commission, *IQ* (Intermodal Quality), Final Report For Publication, July 2000

[104] Woxenius, J., Development of Small-Scale Intermodal Freight Transportation In a Systems Context, Chalmers University of Technology, 1998

#### 3.4.3.4 Implementation

The full benefits of most new technologies are not utilised until they are implemented by several users or in a certain scale. This can also be referred to as "the ketchup effect" similar to what happens when a bottle of ketchup is turned upside down. Another, more scientific, term is "network externalities". This effect refrains from investments since the operators do not want to invest in technologies that cannot be fully utilised until other operators have invested in similar technologies. Another example with an intermodal connection is the ISO-container that was implemented at a slow pace until gantry cranes became prevalent in ports making the expensive and badly utilised on-board cranes obsolete.[105]

### 3.4.4 Barriers From a Market Perspective

An important element and barrier with which prospective intermodal operators are confronted is the lack of precise and comprehensive transport market information. To ensure commercial success, it is necessary to formulate very clear marketing plans. These plans should include market segmentation, a clear product and pricing strategy and a clear sales strategy covering channel, coverage and promotional activities.[106]

Another barrier is from the demand side (shippers and consignees) current negative perception of the maritime sector.

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[105] Woxenius, J., Development of Small-Scale Intermodal Freight Transportation In a Systems Context, Chalmers University of Technology, 1998

[106] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

When specifically asking for it, the shortsea sector does offer intermodal services. Unfortunately, they do not always actively market these capabilities. Therefore, the shortsea sector can be characterised as re-active. However, shortsea is in competition with more pro-active sectors as the road hauler and rail sector.[107]

The quality of service factors is another barrier: frequency, timing of departures and arrivals, safety and reliability are decisive factors, often more important then rate charges, in the decision whether or not to use intermodal transport. Within this context, the issues of customs and pilotage also form a part of the quality of service provided.

Another important aspect is who the responsible party in the door-to-door transport is; each party involved in a part of the transport process is only responsible for his particular part of the transport process. The port terminals with respect to the control of the cargo form one aspect of this responsibility issue. When the cargo is in transit, on a truck or vessel, there is a form of inactive control; the parties have been informed that the cargo is on the way. However, at the terminal, only active control ensures the interested parties that the cargo is "safe". Another aspect of this responsibility issue is insurance rates, more often higher when a number of parties are responsible for the cargo in the door-to-door transport process. Also, relatively more documentation is often required in the situation when multiple parties are involved in the transportation process.

Furthermore, the problem of transfer of cargo from one mode to another requires handling. Since most handling equipment is geared to deep-sea vessels, a relative high handling rate is

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[107] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

charged to shortsea shipping. This can form an important bottleneck for the selection of shortsea shipping. However, there are examples of ports where the handling rates are differentiated according to the transport mode involved.[108]

These problem areas can be considered as more general problem areas, independent of the transport route and markets.

Other elements, though some of them are already mentioned (such as total transport costs, total transport time, customs documentation differing between land and sea transport modes, reliability, cargo safety, requirements of the client, and availability of transport services) are more related to a specific trade route and, more importantly, related to the commodity transported.

The barriers from a market perspective mentioned earlier can be summarised as follows:

- Lack of precise and comprehensive commercial market information
- Shippers' and consignees' current perception of the maritime sector
- The maritime sector's re-active policy
- The decentralised responsibility for the transported cargo
- High handling costs
- Documentation

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[108] Woxenius, J., Development of Small-Scale Intermodal Freight Transportation In a Systems Context, Chalmers University of Technology, 1998

## 3.5 Costs of Haulage for Different Modes

### 3.5.1 Road Haulage

When looking at the costs incurred by the road transportation, the costs are often divided into two main categories, fixed and variable costs. Another division of costs that is commonly used is: Direct and Indirect costs. Although many think that costs have a fundamental or universal definition, they do not. The following are some conventional classifications:[109]

- Fixed: include all costs that do not vary with activity for an accounting period. Fixed costs are at any time the inevitable costs that must be paid regardless of the level of output and of the resources used. Overhead is considered a fixed cost, even though it may vary somewhat according to the amount of activity.
- Variable: all other costs that are some function of activity. They are usually considered linear because the unit cost is computed by dividing the total other costs for a period or event by the amount of activity in the period. The linear assumption is a matter of convenience. As the level of activity is varied the non-linear nature of the variable costs are revealed.

  *Total costs are usually expressed as Fixed + Variable*

- Direct: costs that can be identified directly with a particular process.

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[109] http://www.unb.ca/transpo/

- Indirect: costs associated with an enterprise, etc., which are not identified as direct costs but which may be included in the accounting.

Cost structure based upon socio-economical costs can also be constructed, this with the main purpose of identifying costs towards the transportation service provider in order to enable an internalisation of costs.

***Fixed Costs***

- Capital cost of vehicle, other equipments and establishments (terminals) etc.
- Administration and salaries
- Insurances and taxes

***Variable Costs***

- Fuel cost (including taxes)
- Maintenance and repair
- Cost of tyres
- Road tolls
- Overtime

Considering the high level of variable costs in the cost structure and the fact that internalising socio-economic costs is very difficult, we have chosen a distance-based estimation for the cost of road haulage to about 0,86EUR per kilometre for transportation of a 40-foot container or two 20-foot containers, which is a reasonable assumption.[110]

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[110] Woxenius, J., Head of department at Transportation and Logistics, Chalmers University of Technology

## 3.5.2 Sea Haulage

In this section the costs of running a ship will be discussed. According to Wijnolst & Wergeland, there are four main cost categories distinguished in the running of ships. These are: [111]

- *Capital costs,* which cover the depreciation of the ship over its economic life, as well as the interest payments over the non-equity financing of the ship
- *Operating costs,* which comprise the costs necessary to enable the ship to sail, such as manning costs, stores, etc.
- *Voyage costs,* which comprise the variable costs associated with the actual sailing of the ship, such as bunkers, port charges, canal dues
- *Cargo handling costs,* which are the costs for loading and unloading the ship's cargo.

### 3.5.2.1 Capital Cost

Capital costs depend to a large extent on the new building price of the ship, which is related to the type and size of the vessel.

When a ship is purchased or built, the price of the ship is the capital value of the ship. This value can be turned into costs per year in several ways. A simple method would be to calculate the yearly payments needed to pay back the cost of the ship at a given interest rate and a given time period. This will reflect the yearly costs of recovering the capital used for the ship. As expected, the capital costs increase with the interest rate and

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[111] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

decrease with the economical life of the vessel.[112] This method is used for the economical model for sea transportation in the empirical framework.

The capital cost for a ship depends on a number of different factors. Some of these factors are:[113]

- The investment cost, i.e., either the new building or second-hand price of the ship, including broker's commission, costs related to delivery of ship, etc.
- The financial structure for the investment, which depends on how much equity (the owner's own cash) is allocated to the purchase and how much is borrowed
- The interest rate for borrowed money, which depends on the size of the loan, the solidity of the owner, the security offered and the general level of interest rates
- The economical life of the ship
- Tax regulations, which may influence depreciation rates.

When calculating capital costs, it is important to consider the cost of equity. The owner of a ship normally puts quite a lot of own capital into the project. This cash has an implicit cost, which is the alternative cost (or opportunity cost) of placing the money in some other investment project. This cost element is of particular importance for the initial investment calculations for a new project.[114]

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[112] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

[113] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

[114] Ibid.

### 3.5.2.2 Operating Costs

The operating costs of a ship are defined as those cost items that are related to the purely operational aspects of the running of the ship. The operating cost only comprises the fixed costs and not the variable costs, which depend on the actual sailing of the ship. The fixed costs of the ship, which are the costs that the ship owner should incur in order to make the ship ready to sail, constitute the following elements:[115]

- Manning costs
- Maintenance and repairs
- Stores, supplies and lubricating oils
- Insurance costs
- Management overhead, including administration.

#### *3.5.2.2.1 Manning Costs*

The manning costs of a ship are determined by a number of factors, such as the type of the vessel, the level of automation, the employment characteristics, the flag of registration, the nationality of the crews and the relieve schedule.

Different authorities determine the size of the crew and their professional qualifications. In the first place, the minimum crew requirements are set by the safety aspects of sailing a ship as defined by the International Maritime Organisation. Apart from that, the individual flag states, i.e., the countries that keep an official register of ships, may stipulate additional requirements. On top of that the ship owner, who operates the ship, may employ additional seamen onboard the ship depending on the operational requirements of the trade.

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[115] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

The nationality of the crews is another important factor for the level of crew costs (e.g., European officers are generally more expensive than their Philippine counterparts). As many flag states require the enlisting of national seamen on ships registered under their flag, this has lead to a massive flagging out of ships from the traditional western ship registers to the more exotic countries as Liberia, or Vanuatu. This is an area of great political opportunity for development.

#### *3.5.2.2.2 Repairs and Maintenance*

A ship has to be repaired when damage occurs; also preventive maintenance has to take place. Routine maintenance can be divided into items such as the main engine, cranes, cleaning and painting of the hull, and maintenance that is necessary to stay in good condition. The authorities give approval of seaworthiness of the ship. The approvals are of certificate character and have to be renewed regularly.[116]

#### *3.5.2.2.3 Stores, Supplies and Lubricating oils*

The crew needs food and the costs associated with this item are part of the supplies. Stores and supplies are expenditures that are necessary to maintain the ship such as ropes and wires, paints, grease, but also spares. These costs are usually divided into three categories: Marine stores, engine room stores and steward's stores.[117]

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[116] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

[117] Ibid.

#### *3.5.2.2.4 Insurance*

The ship has to be insured against all sorts of risks. Apart from cargo risks, which are a variable item dependent upon the specific voyage, the ship owners usually seek protection against two sorts of risk: Physical damage or loss of the hull and machinery, and liability to third party claims. In special situations the owner may insure the ship against war risks, or he takes out a loss of hire insurance, which protects him against the interruption of earnings.[118]

The hull and machinery insurance is obtained through a broker, which acts on behalf of underwriters. These are consortia of large insurance (and reinsurance) companies, which each take a part of the risk. One ship can thus be insured indirectly via twenty or more companies, all through one broker.

The protection and indemnity cover is provided by a limited number of clubs, which are in fact mutual funds. They insure the ship owner against liabilities from third parties, in case for example the ship hits a jetty or a crane, or creates an oil spill, or when seamen lose their lives while on duty.[119]

#### *3.5.2.2.5 Management*

A ship owner has to manage the commercial exploitation of the ship as well as the operational aspects, such as technical/nautical management, crew management and the various administrative functions ranging from purchasing equipment to arranging insurance. The whole of these

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[118] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

[119] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

management functions is often called ad- ministration or overhead. The management cost per ship depends on the size of the shipping company and the number of ships that are managed.[120]

### 3.5.2.3 Voyage Costs[121]

While the capital and operating costs are incurred by the ship owner irrespective of the sailing of the ship, the voyage costs only come into the picture when the ship actually starts sailing, or in other words, begins a voyage. The elements that constitute this category of costs are:

- The fuel or bunker costs for the main engine and auxiliary engines
- The port dues
- Pilotage
- Tugs and canal dues.

#### *3.5.2.3.1 Bunker Costs*

The fuel consumption of a ship is determined by many variables such as the size of the ship, the ship's hull, the laden condition (full or ballast), the speed, the weather conditions (waves, currents, wind), the type and capacity of the main engine and auxiliaries, the type of fuel, the quality of the fuel. In *Figure* 3-7 some relationships between fuel consumption, size of the ship and speed of the ship are displayed. The fuel on board a ship is called bunkers. The bunker costs of a voyage depend on the fuel

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[120] Wijnolst, N., Peeters, C., *European Shortsea Shipping*, Delft University Press, The Netherlands, 1995

[121] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

consumption during the sea voyage and in port, as well as the price of the fuel. The fuel price depends on the world oil price and the location where the bunkers are being taken onboard. At a few ports, in which major refineries exist, such as Rotterdam, the prices are the lowest as the logistical costs are low. The oil price has fluctuated considerably over the last 25 years. This has had a profound impact on the shipping industry. The bunker costs became the single largest cost item in the running of ships after the second oil crisis in 1979.

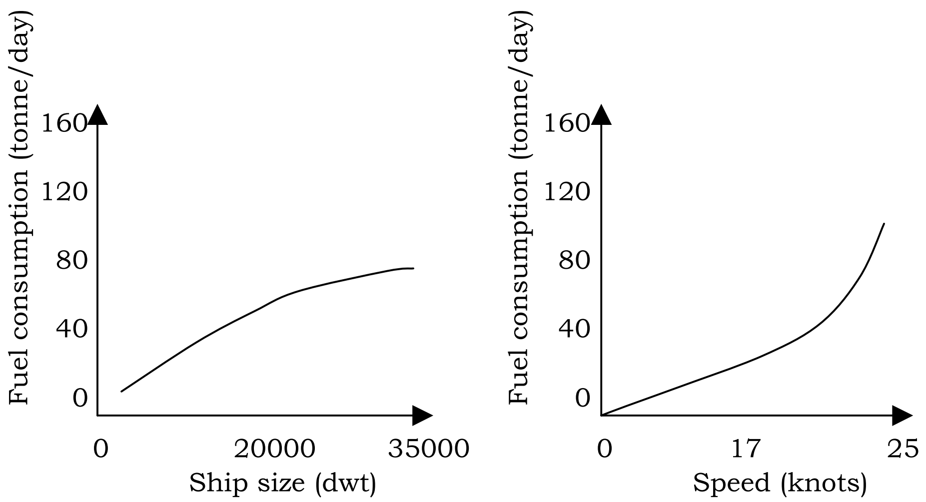


*Figure 3-7, Relationship between capacity, speed and fuel consumption*[122]

The relationship between fuel consumption and the capacity of the ship suggests a sort of linear relationship, but this also depends on the speed of the vessels. Over time the engine manufactures have achieved remarkable increases in fuel efficiency.

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[122] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

#### *3.5.2.3.2 Port Costs*

Port charges are another important cost item of the voyage costs, and these include elements such as fees for the port agency (for handling all the activities and paperwork during the port stay), the actual harbour dues (for the use of harbours, quays, mooring posts or buoys), the costs of pilotage (often divided into sea/river and harbour pilotage), tugboats and crews.[123]

A similar ship under similar loading conditions may be charged quite different costs in ports that are very close to each other. The port costs consists of many different elements and the tariffs from ports are often complex and difficult to compare.

### 3.5.2.4 Cargo Handling Costs[124]

The objective of merchant ships is to transport cargo between different ports. To achieve this, cargo has to be transferred from ship to shore or vice versa, or directly from ship to ship or other modes of transport.

The cargo handling costs are determined by a number of elements, such as the type of commodity (oil, chemicals, coal, grain, forest products, containers), the quantity, the ship type, the terminal and port characteristics. The loading and discharging of ships at the terminal is done by an independent stevedoring company or by the exporter or receiver of the cargo. There is a declining cost trend of stevedoring from a historical perspective.

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[123] The Institute of Shipping Analysis, Anlöpskostnader- Nordeuropa, 1997

[124] Wijnolst, N. & Wergeland, T., *Shipping*, Delft University Press, The Netherlands, 1996

### 3.5.3 Rail Haulage

These costs are categorised under two main heads, fixed and variable costs. The cost factors in each main head is described below:[125]

***Fixed Costs***

- Capital cost of infrastructure and equipment, e.g., terminal, locomotives and wagons
- Administrative and salary costs
- Insurances and taxes

***Variable Costs***

- Fuel cost (electricity or diesel)
- Maintenance and repair
- Overtime

## 3.6 Port of Gothenburg and the EU

The idea of a common European transport policy and infrastructure stands high on the EU agenda. The traffic situation, with bottlenecks around the major European cities and associated environmental problems, an obsolete railway network and old, rigid organisations does not offer the very best of prospects.

The European Commission therefore wishes to take a firmer grasp and reshape both the infrastructure hardware, i.e., the railway network, road network etc., and its software, such as

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[125] Coyle, Bardi & Novack, *Transportation*, Fifth edition, South-Western College Publishing, 2000

organisation, competitive devices and joint means of communication, all to facilitate transportation within and outside the EU. Transportation is thereby defined as one of the utmost important conditions for economic growth in the EU; ports play a key role in this perspective.[126]

The basic approach is to transfer more transportation from the roads to sea routes, partly for reasons of efficiency but also because of the environmental advantages.

As stated earlier, there is quite simply a wish to promote shipping and intermodal transportation at the expense of long distance road transport.

In order to increase the efficiency of the ports, the EU wishes to open them to competition. Open ports are a fundamental part of the so-called Port Package, the overall goal of which is free competition, even in the traditionally politically controlled and often monopolistic ports. Free competition on the same terms will according to theory lead to more efficient ports and thereby more efficient transport chains.

The final report of the Goods Transport Delegation, which was submitted in the middle of 2001, is in all respects a document for the future. The conclusion is that the dominant part of future goods transportation will follow the three or four main routes along the mainstream of all goods that are already being transported today. Here, the Port of Gothenburg plays an important role by virtue of its position as the central port of Scandinavia.

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[126] Olofsson, A., Manager of Regulatory Affairs, Marketing Department, Port of Gothenburg AB

As one of the principal nodes in the logistics chains of the future, the development of the port is to a large extent a matter of the development of its surroundings. Roads, railways, waterways and IT (Information Technology), i.e., the port's supply systems, must be improved if it shall be able to cope with the increasing volumes. A major investment in the surrounding infrastructure is therefore of the very highest priority if the Port of Gothenburg is to maintain and reinforce its position as the intermodal junction with non-stop transoceanic scheduled services.[127] This in order to enhance the competitiveness of Scandinavian industry and the trade with Western Europe.

From this description it is clear that Port of Gothenburg is the best choice of origin for our sea-based intermodal transportation system.

[127] Annual report 2001, Port of Göteborg AB

# 4 Research Design

*In this chapter, we explore the methodological approach to the empirical part of our research.*

Research design or methodology refers to the procedural framework within which the research is conducted. It describes an approach to a problem that can be put into practice in a research program or process, which could be formally defined as an operational framework within which the facts are placed, so that their meaning may be seen more clearly. In other words, the method is a tool used to retrieve new knowledge, i.e., the research plan is the basic plan that guides the data collection and analysis phases of a research project. The framework specifies the type of information to be collected, the sources of data and the data collection procedure.

## 4.1 The Conclusive Research Method

When it is desirable to provide information for the evaluation of alternative courses of action, conclusive research is often used.[128] This method is highly suitable for the empirical work conducted in our research, since the purpose of our thesis is to investigate the alternative method of intermodal transportation regarding transportation from Scandinavia to Western Europe.

Our study has both elements of descriptive and causal nature, which the conclusive research design is composed of. It is descriptive in the way that we have to list and describe the

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[128] Kinnear, T.C., Taylor, J.R., *Marketing Research: An Applied Approach*, McGraw-Hill, 1979

variables of an intermodal transportation system in order to understand the subject as a whole and all the elements of it. Descriptive information often provides a sound basis for the solution of marketing problems, in our case the potential of the alternative.

The causal side of our research, which is very significant, lies in the mapping of the concept of intermodality and the calculations of costs, leading to the potential geographical market.

### 4.1.1 Information and Data Collection

The human perception and mind are all but objective, we always see things from a certain perspective; in fact the interpretation is inseparable from subjective perceptions. Therefore, it is important to systematically reflect the nature of the problem from many different perspectives. When doing so the interpretation can reach a higher level of quality, which will give the empirical science a value.[129] We have therefore tried to view the concept from many different perspectives to be able to interpret the empirical situation in the best possible way.

Collecting data and information and processing the data into information as described in Section *2.1.2 The Nature of Data and Information,* can be done in three ways, either quantitative, qualitative or a combination of both.

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[129] Alvesson, M., Sköldberg, K., *Tolkning & Reflektion, Vetenskapsfilosofi & Kvalitativ metod*, Sweden, Studentlitteratur, Lund, 1994

#### 4.1.1.1 The Qualitative and Quantitative Approach

The qualitative type of investigation proceeds from the researcher's subjective perspective and the quantitative approach proceed from the researcher's ideas about which categories and dimensions should be in focus.[130] The qualitative approach allows a wide range of interpretations and perceptions of what seems to be more or less characteristic in the research, since the method is based on more of an understanding of the situation. The important thing is to increase the understanding of the research problem and be able to describe the whole in which this problem exists.[131] Quantitative methods on the other hand are more formal and structured. But this does not mean that this approach is objective as the numbers and techniques used are not always interpreted at the optimal level of objectivity. Instead, objectivity can be subordinated predetermined perceptions of the researcher.[132] In our research, we will use the strong sides of each approach to complement each other. The qualitative approach to map the complexity of the problem and concept of intermodality. The qualitative part consist of interviews with expertise in the subject and providers of statistics as well as external statistics about goods flows. This information will be used to obtain the potential of the intermodal system. By using both a quantitative and a qualitative research approach, we will obtain a more accurate shape of the whole picture illustrating the nature and complexity of intermodal transportation systems.

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[130] Silverman, D., *Interpreting Qualitative Data*, 2nd edition, Sage Publications, London, 2001

[131] Holme, I.M., Solvang, B.K., *Forskningsmetodik, om kvalitativa och kvantitativa metoder*, Sweden, Studentlitteratur, Lund, 1997

[132] Alvesson, M., Sköldberg, K., *Tolkning & Reflektion, Vetenskapsfilosofi & Kvalitativ metod*, Sweden, Studentlitteratur, Lund, 1994

## 4.2 Methodology Behind Transport Data

The method for retrieval of transport statistics at Eurostat is displayed in *Figure 4-1.*The quality of Community statistics is conditioned by the quality of the data provided to Eurostat by the member states. Eurostat, together with the National Statistical Institutes, has created a network known collectively as the European Statistical System (ESS).[133] The ultimate goal of the ESS is to meet all needs for statistics in the EU in an integrated and harmonised manner. The National Statistical Institutes for each country are the representatives in this network.[134]

#### 4.2.1.1 Methodology Behind Transport Statistics

The method for retrieving data described in *Figure 4-1*, is a complex process in many aspects. Much of the efforts in retrieving data is not the collection and analysis itself but often to prepare new proposals and to pressure member states to provide the adequate statistics that they are legally bounded to do.

[133] EFTA countries, which are parties to the European Economic Agreement, are in this context understood as being part of the ESS; thus references to EU Member States and EU National Statistical Institutes are understood as including these EFTA States.

[134] COMMISSION OF THE EUROPEAN COMMUNITIES, Proposal for a Decision of the European Parliament and of the Council on the Community statistical programme 2003 to 2007, Brussels, 28.11.2001 COM(2001) 683 final 2001/0281 (COD)

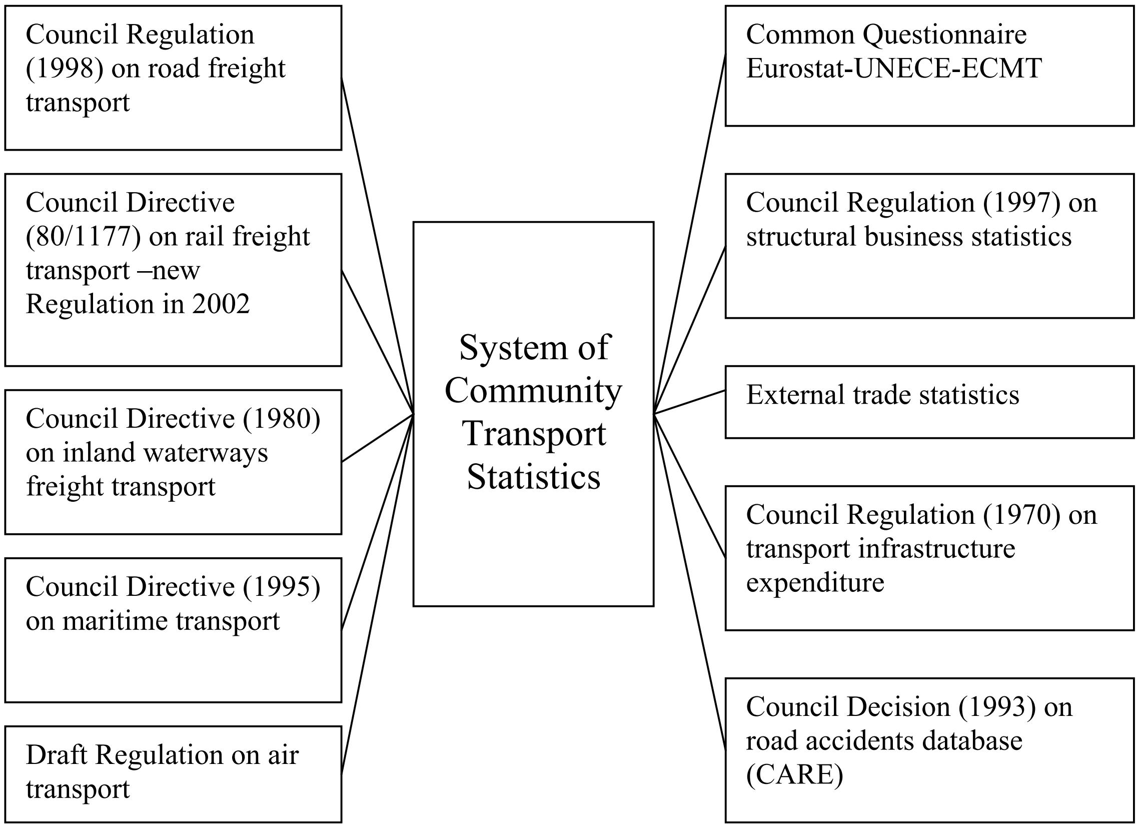


*Figure 4-1, Data collection method at the Transport Department of Statistics, Eurostat, source: Oberhausen, J. & Pasi, S.*

The data is stored in the New Cronos database in order to fulfil demands on different data requirements. The main difference between the transport statistics in the New Cronos database and the Comext database is that the Comext database collects more data. This is mainly due to the fact that the trade data is easier to provide and collect. In the next section a detailed description about the external trade statistics methodology (Comext) is presented.

#### 4.2.1.2 Methodology Behind External Trade Statistics

The statistics of trading of goods by the European Union (EU) cover both outward flows from Member States and inward flows into Member States. Methodology differs in a number of ways for external trade of the EU (extra-EU trade) or for trade between

Member States (intra-EU trade). There is a range of methodological issues relevant to the definition and measurement of these international trade flows. These are considered fully in the United Nations Statistics Divisions' publication *International Merchandise Trade Statistics: Concepts and Definitions (Series M, No 52,Rev.2)* which sets out internationally agreed recommendations for the treatment of the various issues.

Both the EU legislation and national practices are, for the most part, in line with the recent recommendations of the United Nations (1998). But there are some differences. This guide concentrates on describing the Community rules concerning data retrieval etc. Community rules differ as between intra-EU trade and extra-EU trade. The following sections describe the main features of the largely harmonised statistics on trade in goods as published by Eurostat.[135]

***General trade and special trade***

There are broadly two approaches used for the measurement of international trade in goods; the general trade system and the special trade system. These two systems are closely linked with customs procedures. The general trade system is the wider concept and under it the recorded aggregates include all goods entering or leaving the economic territory of a country with the exception of simple transit trade. In particular, all goods that are received into customs warehouses are recorded as imports at that stage whether they subsequently go into free circulation in the Member State of receipt or not. Similarly, outgoing goods

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[135] European Commission, Eurostat, *Comext User Guide*

from customs warehouses are included in the general trade aggregates at the time they leave the Member State.[136]

The special trade system, on the other hand, is a narrower concept. Goods from a foreign country, which are received into customs warehouses, are not recorded in the special trade aggregates unless they subsequently go into free circulation in the country of receipt. Similarly, outgoing goods from customs warehouses are not recorded as exports. The difference between the two systems causes mainly a time lag when the movements are recorded, but it is more than that. For example, goods from country A, placed in a customs warehouse of country B and re-exported from there to country C will appear in general trade statistics for country B (if such a system is applied) but never in special trade statistics for that country. Statistics on extra-EU trade are compiled on a special trade basis. Intra-EU trade statistics, however, do not have a direct link to customs procedures and are not compiled on a general or special trade basis. For their main national figures of extra-trade, twelve Member States use a special trade basis as required for data transmitted to Eurostat; three Member States, Denmark, Ireland and the United Kingdom, use the general trade system but provide extra-EU trade data to Eurostat on a special trade basis. All Member States base their measurement of intra-EU trade on system rules.

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[136] European Commission, Eurostat, Development of External Trade Statistics by Mode of Transport, TASK 1-4

### *Intra-European Union trade*

Intra-EU trade statistics record the arrival and dispatch of goods flowing between Member States according to the rules of the system.

Arrivals in a given Member State include: [137]

- Goods in free circulation which enter the statistical territory of the Member State
- Goods which have been placed under the customs procedure for inward processing or processing under customs control (for processing, transformation or repair) in another Member State and which enter the statistical territory of the Member State in question
- Some goods movements are included in statistics based on specific conditions. In particular, aircraft and ships whose ownership has been transferred from a person established in another Member State to a person established in the Member State in question are included in the statistics of arrivals of this latter Member State.

Dispatches from a given Member State include:[138]

- Goods in free circulation which leave the statistical territory of the Member State bound for another Member State
- Goods which have been placed under the customs procedure for inward processing or processing under customs control (for processing, transformation or repair) in the Member State and which are destined for another Member State

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[137] European Commission, Eurostat, *Comext User Guide*

[138] Ibid.

- Also in this case, some goods movements are included in statistics based on specific conditions. In particular, aircraft and ships whose ownership has been transferred from a person established in the Member State in question to a person established in another Member State are included in the statistics on dispatches of the former Member State.

Statistics do not cover goods in transit, i.e., goods that are merely passing across a Member State, by any means of transport, but are not stored there for any but transport reasons.

***Coverage***[139]

In broad terms, the aim of international trade statistics is to record all imports or exports of goods that add to or subtract from the stock of material resources of a country. There are inevitably some problems in practice in defining the precise boundary that corresponds to the theoretical aim and more so in implementing the regular, timely and detailed production of monthly data. The coverage of the statistics that are required to be sent to Eurostat follows almost entirely from Community legislation although on a few points the interpretation is implicit rather than explicit. The following paragraphs indicate some areas that may raise problems.

- Goods on operational lease are generally excluded but are included in their national figures and in the figures that they provide to Eurostat by France, Greece and Sweden
- Goods in transit (either in simple transit or transit involving transhipment) across the European Union area are not included in trade statistics. However, goods which enter the

139 European Commission, Eurostat, *Comext User Guide*

European Union area, are released into free circulation and are then transferred from the Member State of entry to another Member State

- Statistics do not generally include illegal trade, for obvious practical reasons, although figures for Germany include illegal trade that has been discovered (that may also be the practice for some other countries).

## 4.3 Research Evaluation

In this chapter we will explain the concepts of validity and reliability, which we will relate our to results and analysis.

### 4.3.1 Validity

The validity of a measure refers to the extent to which the measurement process is free from both systematic and random error. Systematic error refers to an error that causes a constant bias in the measurements, while random error involves influences that bias measurements but are not systematic.[140] In other words, validity is the measurement of the conformity of what a measuring instrument is supposed to measure and what it really measures. The main question that validity deals with is: Are we measuring what we think we are measuring?[141]

Validity can be divided into one internal and one external part. The internal validity deals with the study itself and the direct connection between the theoretical framework and the empirical

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[140] Kinnear, T.C., Taylor, J.R., *Marketing Research: An Applied Approach*, McGraw-Hill, 1979

[141] Patel, R., Davidsson, B., *Forskningsmetodikens Grunder*, Sweden, Studentlitteratur, Lund, 1994

study, i.e., the interviews shall be conducted with relevant people and the experiments shall have enough samples to answer the research questions. External validity concerns the study with all its contents in a broader perspective. This implies if it is possible to generalise from the study or not. If the study does not have internal validity, this excludes external validity as well. However, the opposite is not necessarily true.[142]

The validation process in our study consists mainly of the opinions expressed by our tutor and the comparison with other similar research projects. Our validation process has mainly been focused on the external validity since this research not only fills an intrinsic value but will also be read by others.

### 4.3.2 Reliability

Reliability is concerned with the consistency, accuracy, and predictability of the research findings. This means that the measurement must be performed several times in the same way without very different results in order for the reliability to be high.[143]

Factors that can influence reliability are interview-effects and problems with standardisation in interviews as well as problems in interpretation. To achieve higher reliability, clear definitions of the concepts used in the study are important. It is also important to have several indicators to measure a phenomenon. When obtaining information from separate sources, the data is more reliable. In a quantitative study, the demand for reliability

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[142] Eriksson, L.T., Weidersheim, F., *Att Utreda, Forska och Rapportera*, Sweden, Liber Ekonomi, Malmö, 1999

[143] Ibid.

is higher than in a qualitative, because a qualitative study is more focused on exemplifying than generalising.[144]

If a measurement is not reliable, it cannot be valid, and if it is reliable, then it may not be valid. Therefore, reliability is a necessary but not a sufficient condition for validity. Reliability is a weaker concept than validity since it involves only random errors.[145]

In order to increase the reliability of the results, we have constructed the assumptions and estimations in such a way that they do not only influence our results in a favourable manner. We have also investigated the reputation and position of the source (e.g., if it has private interest, political, governmental or official character).

Another important action to increase the reliability of the secondary data has been to collect similar data form different sources, in order to be able to compare the reliability of the data (e.g., comparison between New Cronos and Comext). To increase the reliability of the data further, we have investigated the methodology used by the source when retrieving and analysing the data so that there are no major faults in the data collecting and analysis process.

For the construction of the theoretical part we have only used well-known researchers, authors and institutions.

The reliability of the primary data (e.g., the interviews) is hard to measure; it is heavily dependent on the credibility of the person

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[144] Holme, I.M., Solvang, B.K., *Forskningsmetodik, om kvalitativa och kvantitativa metoder*, Sweden, Studentlitteratur, Lund, 1997

[145] Eriksson, L.T., Weidersheim, F., *Att Utreda, Forska och Rapportera*, Sweden, Liber Ekonomi, Malmö, 1999

interviewed, position, expertise, situation, expectation and own perception on the subject.

When conducting the interviews we have designed the questions in a non-leading manner, trying to keep the interview as open as possible with the questions functioning as guidelines. We have also interviewed as many persons as possible, relevant for our research.

# 5 Empirical Framework

*In this chapter we will present how we structured our practical work with collecting and processing data and information. We will also describe the construction of our calculation model of the intermodal transportation system. Finally, we will present our findings on the potential market and the potential amount of goods that can be conquered by the intermodal transportation system. We start this chapter with describing the point of origin of our intermodal system; Port of Gothenburg.*

## 5.1 Port of Gothenburg

The Port of Gothenburg is situated on the Swedish west coast, in Scandinavia, in Northern Europe. The port lies within the city limits of Gothenburg, Sweden's second largest city and its main port. The Port of Gothenburg developed around the mouth of the River Göta, which flows down from Lake Vänern, and which has been an important factor in the port's history.

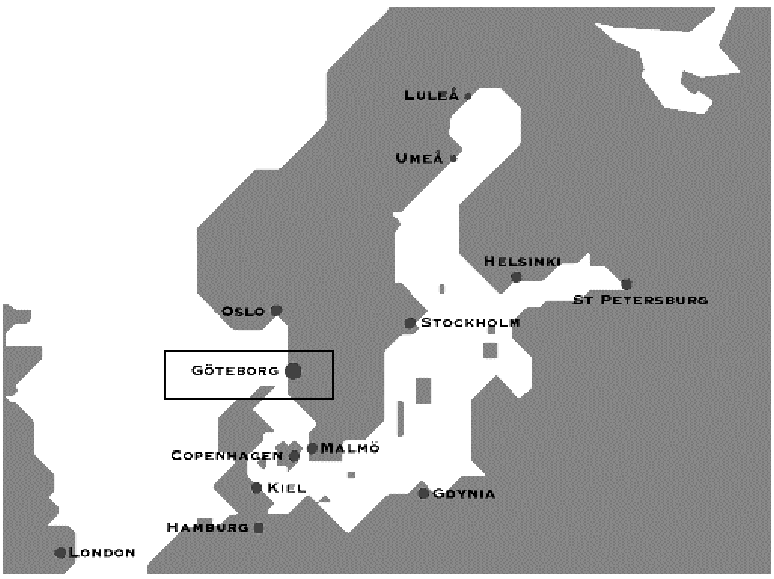


*Figure 5-1, Port of Gothenburg*

Hinterland connections, essential to a port when defining its catchment area, are of high quality and the location of the port itself is optimal; half of the Scandinavian industrial base is within 300 kilometres of the port, 70 percent within 500 kilometres. Nearly 11 million people live here out of a total of 18 million in the entire area (Sweden, Denmark and Norway).

With a cargo turnover of 33.5 million tonnes (2001), the Port of Gothenburg is by far the largest port in the Nordic area. In global terms it is by no means a giant (the world's largest ports, Singapore and Rotterdam, are each ten times bigger), but in relation to its potential catchment area (25 million people) its importance is considerable.

The ports' cargo turnover comprises about 60 percent oil and about 40 percent general cargo (95 percent of which is unitised).

Another way of measuring the size of a port is to compare its container flow. Gothenburg reached a figure of 698,000 containers in 2001 (twenty-foot equivalent units, flats and cassettes included). This puts the port in a totally dominant position in this particular area in the Nordic region. Once again, this is quite an achievement considering the catchment area (However, the world's container giants, Hong Kong and Singapore, have container flows twenty or thirty times bigger than that of Gothenburg). The future target for the Port of Gothenburg within five years is to reach a yearly capacity of 2,5 million TEU's.[146] We have chosen the Port of Gothenburg as point of origin since it fulfils the criteria upon a port terminal (see Section *3.3.2.3.2, Port Terminals*).

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[146] Annual report 2001, Port of Göteborg AB

According to Alf Olofsson, Manager of Regulatory Affairs, the cost structure and efficiency measures at the Port of Gothenburg is about the same as for the average large European port.[147]

### 5.1.1 Cargo

The Port of Gothenburg has a range of direct-call deep-sea services that is unrivalled in Scandinavia. Every week, there are three departures each for North America, the Far East and Australia, which are the most frequent deep-sea destinations. The cargo shipped deep-sea is mostly containerised; even when feeder vessels are used for transhipment via Continental ports. There are also several deep-sea RoRo services with special facilities for the transport of products such as earth-moving equipment, harvesters, helicopters and bulky cargo on ship's trailers.

Apart from containers, deep-sea cargo at Gothenburg includes trade cars, oil, and fruit. Gothenburg is by far the largest car port in the Nordic region, this is mainly due to the location of the Ford owned brand *Volvo*.[148]

Because the uniqueness of the port's deep-sea services, Gothenburg is probably thought of as a transoceanic liner port. However, the bulk of its traffic has always been intra-European. The services are either bi-lateral or feeder services with transhipment to ocean vessels at Gothenburg or at a Continental port. The sailing frequencies at Gothenburg are high, with a vessel departing for or arriving from a British port every six

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[147] Olofsson, A., Manager of Regulatory Affairs, Marketing Department, Port of Gothenburg AB, Interviewed 2002-10-24, 14.00-15.00 CET

[148] Annual report 2001, Port of Göteborg AB

hours. The Continental connection is even tighter with one vessel every four hours, excluding ferry traffic.[149]

### 5.1.2 The Port Operator

In the Port of Gothenburg, traditional port authority functions and stevedoring activities are combined within one and the same body, namely a city-owned limited company called Göteborgs Hamn AB.

This company is thus responsible for the long-term strategy formulation, planning, construction and maintenance of port facilities as well as investment in rolling stock such as cranes, trucks and tractors. It is also responsible for navigation aids and port security. The core business is the unloading and loading of vessels, trains and lorries at the intermodal interface, which constitutes the port. Furthermore the port is profitable.

The port company is a commercial enterprise, surviving on its own income and without any subsidies from national, regional or local governments. It pays tax on its profits and a dividend to its owner.

## 5.2 Economical Breakpoint and Throughput Time

In order to investigate the potential market for our intermodal transportation system we have to calculate the breakeven point concerning costs between our intermodal system and the road transportation alternative. As stated earlier, we believe that costs are the main decisive factor when choosing transportation

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[149] Olofsson, A., Manager of Regulatory Affairs, Marketing Department, Port of Gothenburg

alternative. First we start by calculating the costs for each 300-kilometre EDC[150], with origin in Gothenburg. We believe that EDC:s, 300 kilometres apart, are enough considering the level of detail in our research. We will calculate the throughput time for each transport alternative but the geographical market and potential 1 will not be based upon the limits for throughput time. This consideration will first be taken into account when potential 2 is estimated.

### 5.2.1 Road Transportation

In order to give the results higher validity, we have chosen to calculate costs for road transportation with regard to euclidian distance even though it is fully possible to calculate the distance based upon existing roads and congestion situation. Since our research focuses on an intermodal system where road transportation constitutes a small part of the transport assignment, we have chosen not to do this in-dept research due to lack of resources and time. These factors are however included to some extent in the cost per kilometre for road transportation.

Based upon the economical model described in *Appendix 2 - Economical Model* we obtained the costs for each EDC. In the figure below the calculation for the first EDC is presented, i.e., the 300-kilometre EDC. We made the assumption that a road vehicle either carries two 20-foot containers or one 40-foot container. The cost of road transportation is distance based only. The time related information is used when throughput time calculations is conducted. More information about this

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[150] EDC: Equal Distance Contour (the cost for the transportation alternatives on the determined equal distance contours)

economical model and its structure can be found in the Appendix.

Transport cost for Road

| Road | |
|---|---|
| Road distance (one way), km | 300 |
| Vehicle average speed (km/h) | 30 |
| Truck cost (EUR/km) | 0,86 |
| Handling time | 1 |
| Road transport time (one way) | 11,0 |
| Cost for road distance | 258 |

| | |
|---|---|
| **Road transport time (one way) hours** | **10** |
| **Cost for 40' container** | **258** |
| **Cost for 20' container** | **129** |

*Table 5-1, Cost for Road Transportation (300 km EDC)*

The same calculation was then repeated for other distances, i.e., the EDC:s for 600, 900, 1200, 1500, 1800, 2100 and 2400 kilometres. The throughput time is the number in the parenthesis; the throughput time follows the euclidian distance and the average speed to 30 km/h. This includes congestion, breaks etc. The cost for long distance road transportation in our case is approximated to 0,86 EUR per kilometre; this approximation is fairly good according to experts and researchers in this field.[151] The result from the economical EDC:s for road transportation is displayed in *Figure 5-2, Equal landed cost contours for Road Transportation (300 km) with Gothenburg* as origin.

[151] Floden, J. & Saxin, B., Researchers in Logistics and Transport Economics, Gothenburg School of Business and Commercial Law, Woxenius, J., Researcher in Logistics and Transportation, Chalmers University of Technology


**X** EUR **(Y)** hours

*Figure 5-2, Equal landed cost contours for Road Transportation (300 km) with Gothenburg as origin.*

## 5.2.2 The Intermodal Transportation Alternative

For the intermodal system, the economical calculations are a bit more complicated. The cost structure for the intermodal system contains three modes of transport: sea, train and road. The road calculations are similar to that described earlier. For sea transportation the same cost structure is used as described in Section *3.5.2 Sea Haulage.* The cost model for sea transportation can be found in *Appendix 2 - Economical Model.* The economical model for sea is based upon a fictive vessel that is reasonable to use for this type of shortsea transportation. The vessel has similar *characteristics* as the Small open hatch container ship Reestborg, described in Section *3.3.2.2 General Cargo Vessels.* Since the cost structure for sea transportation is very complex, it is hard to do reliable cost estimations without examining each cost element separately. No existing shipping company we have interviewed has been able to estimate the costs for our container ship, even though it has many similarities to ships of their own. Instead we had to construct an in-depth model of each cost component for sea transportation, following the cost structure described by Wijnolst and Wergeland, for further details see *Appendix 2 - Economical Model.* As mentioned in *3.5.2 Sea Haulage*, there are four main cost categories distinguished in the running of ships. According to Wijnolst and Wergeland, these are:

- *Capital costs,* which cover the depreciation of the ship over its economic life, as well as the interest payments over the non-equity financing of the ship
- *Operating costs,* which comprise the costs necessary to enable the ship to sail, such as manning costs, stores, etc.
- *Voyage costs,* which comprise the variable costs associated with the actual sailing of the ship, such as bunkers, port charges, canal dues
- *Cargo handling costs,* which are the costs for loading and discharging of the ship's cargo.

In *Figure 5-4* a principal layout of the sea/road transportation alternative is described.

The port selection in the intermodal transportation system is based upon the discussion in Chapter *3.3.2.3 Infrastructure* and displayed in *Table 5-2* and the location of the selected ports is illustrated in *Figure 5-3*.

| Port | Gothenburg |
|---|---|
| Hamburg | 760 |
| Rotterdam | 1080 |
| Antwerp | 1190 |
| Le Havre | 1350 |
| Nantes Saint-Nazaire | 2100 |
| Bilbao | 2440 |
| Sines | 3185 |
| Valencia | 4500 |
| Marseille | 5160 |

*Table 5-2, Distances between Port of Gothenburg and the selected ports (in nautical miles for round trip)*


*Figure 5-3, Location of the selected ports*

### 5.2.2.1 The Sea/Road Transportation Alternative

This transport structure of sea and road transportation is used when the distance from the port to end customer is equal or less than 300 kilometres, this assumption is partly based upon the data in *Table 3-2*. This limit is set by us and is not a calculated breakeven point between train and road transportation. In reality, the breakeven point from an economical perspective should be about 400 kilometres. However, research projects (TERMINET and SCANDINET) have shown that, under certain conditions, combined transport can be viable over a distance of

300 kilometres.[152] Since we also consider issues such as congestion and environmental effects, described in Section *3.1, External Effects and Impacts of Transportation*, it is clear that rail transportation is more preferable than road transportation when it comes to external effects and congestion. These are some reasons why we have chosen to set the breakeven point between rail and road transportation shorter than usual.

| | A | B |
|---|---|---|
| 1 | *Transport cost for Sea/Road* | |
| 2 | ***Road*** | |
| 3 | Road distance (one way) | X |
| 4 | Vehicle average speed (km/h) | Road!B4 |
| 5 | Truck cost (EUR/km) | Road!B5 |
| 6 | Cost for road distance | B3*B5 |
| 7 | Handling time | Road!B6 |
| 8 | Road transport time (one way) | B3/B4+B7 |
| 9 | Total cost for road transport (20') | (B5*B3*(Sea!B10/2)*Sea!B50) |
| 10 | Total cost for road transport (40') | B3*B5*(Sea!B11)*Sea!B50 |
| 11 | Cost for 20' container | **(B9/Sea!B10)/Sea!B50** |
| 12 | Cost for 40' container | **(B10/(Sea!B11))/Sea!B50** |
| 13 | | |
| 14 | ***Sea*** | |
| 15 | **Total cost for sea transportation** | **Sea!B79** |
| 16 | Number of 20' containers | Sea!B10+Sea!B11*2 |
| 17 | Route distance (km), one way | Sea!B45 |
| 18 | Average time (door-to-door)per container | Sea!B81 |
| 19 | **Average cost per container** | **Sea!B82** |
| 21 | *Transportation system* | |
| 22 | **Total time (door-to-door), hours** | **B18+B8** |
| 23 | **Total distance** | **B17+B3** |
| 24 | **Total cost, yearly** | **B15+(B9+B10)** |
| 25 | ***Average cost per 20' container*** | ***B24/(Sea!B80)*** |

*Table 5-3, Economical calculation for Sea/Road transportation*

[152] Eurostat, Meeting of The working Group on Intermodal Transport Statistics, Document: IM/2002/Room 2, Luxemburg, 11-12 November 2002

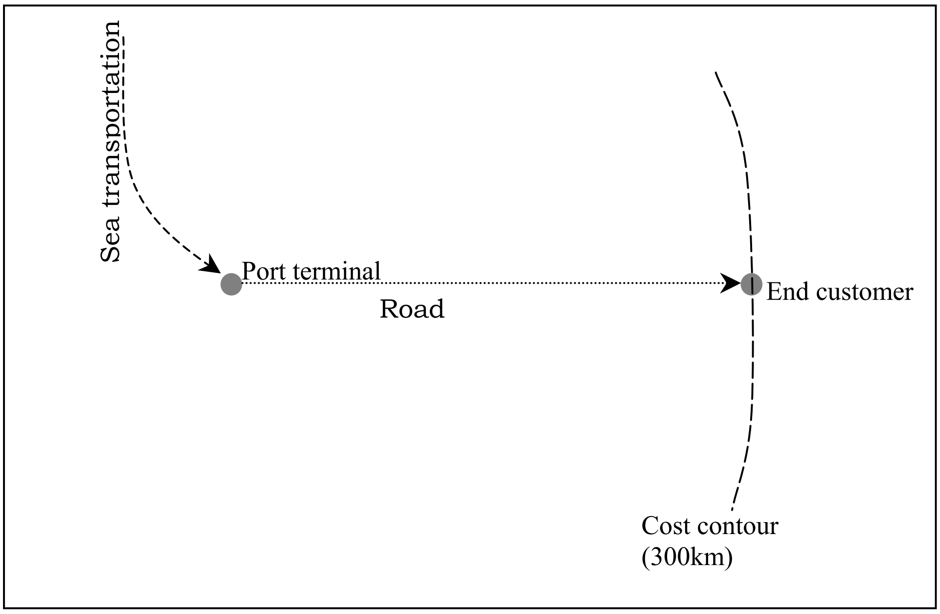


*Figure 5-4, Principal layout of Sea/Road transportation system*

Figure 5-4 gives a principal layout of the sea and road transportation system. This solution is favourable compared to sea/rail/road alternative when considering serving the market near the port. This alternative gives a fast and flexible transportation service, but when considering distances longer than 300 kilometres the trade-off between these advantages and the increased transportation costs is more feasible. In *Figure 5-5* an example of sea/road EDC is displayed with Port of Antwerp as origin.


*Figure 5-5, Sea/Road EDC (300 km) with Port of Antwerp as origin.*

### 5.2.2.2 The Sea/Rail/Road Transportation Alternative

For rail transportation it is difficult to do a good estimation of the cost per kilometre, since there are many factors to consider. Since rail transportation is a small movement compared to that of sea transportation in our system we have chosen to make a cost estimation per kilometre, although its complexity. In order to make the system more correspondent to reality, an economical breakeven distance between road- and rail transportation should be calculated. Since we have chosen to make a cost per kilometre estimation, we have chosen to determine the distance when rail transportation should be used instead of road transportation. This limit in our research is set to 300 kilometres; we have chosen this limit in order to make the cost for rail transportation more linear. How this is possible is displayed in the structure of rail transportation cost, see *Figure 5-6.*

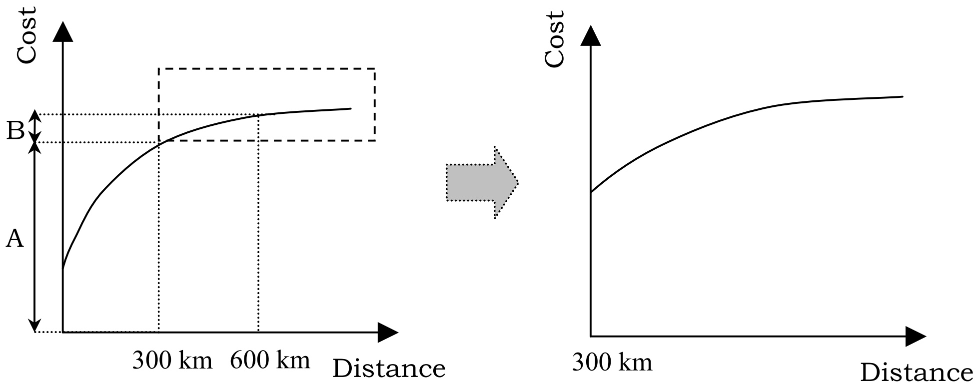


*Figure 5-6, Rail cost structure and distance limit*

The cost structure above is simplified, cost elements such as terminal stops and crossing of borders influences the shape of the cost curve.[153] The reason for this shape of the cost curve is mainly due to the high amount of fixed costs, such as investment costs. This shape of the cost curve is shared with sea transportation (see *3.5.2, Sea Haulage*).

Since we always have two stops in terminals per mode of transport we can include this in the cost per kilometre and still

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[153] Ballou, H.R., *Business Logistics Management*, Fourth edition, Prentice-Hall, New Jersey, 1999

have a fairly linear relationship between cost and distance. The longer the economical breakpoint for rail transport, the more linear the cost curve becomes (see *Figure 5-6*). This together with longer moving distance for rail transport increases the validity of making a linear assumption, due to high fixed costs (see A and B in relation to each other, *Figure 5-6*).

From the final train terminal road transportation will take over the movement of goods to the end customer. This road transportation distance is approximated to about 1-100 kilometres (in the calculations this is set to average, i.e., 50 kilometres). In order to simplify calculations for the economical model the road transportation is set to a direction that does not increases the geographical area, for example *see Figure 5-7, Principal layout of the Sea/Rail/Road transportation system.* The average road transportation distance from the inland terminal is set to 50 kilometres.

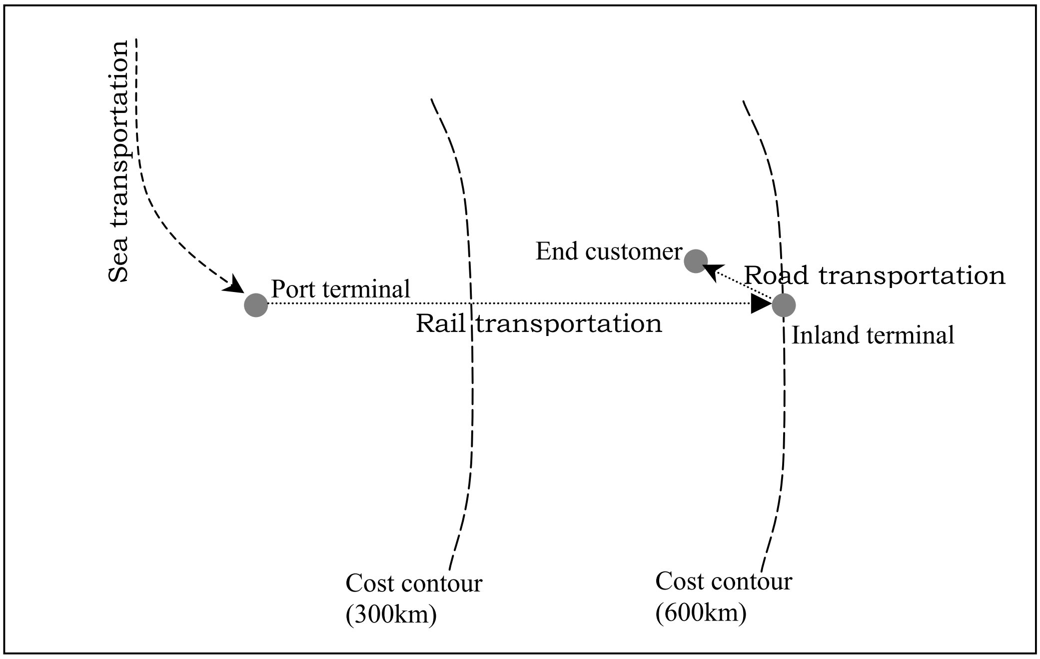


*Figure 5-7, Principal layout of the Sea/Rail/Road transportation system*

For rail transportation cost, we have interviewed different actors on the European rail transportation market. Due to secretes and confidentiality these costs cannot be explained in further detail.

The handling time in terminals for rail transportation is set to 10 hours and the average speed of rail transportation to 50km/hour. The capacity of a train is set to 50 TEU:s. *Figure 5-8* displays an example of the EDC for the sea/rail/road transportation alternative with Port of Le Havre as the origin for rail transportation.


*Figure 5-8, EDC (600 km) with Port of Le Havre as origin.*

## 5.3 Geographical Market

From the economically calculated EDC:s presented in *Appendix 4 - Maps* and by comparing the contours of the intermodal transportation system with direct road haulage, a potential geographical market for the intermodal transportation system is obtained. The exact borders of this geographical market has some uncertainty, due to the distance between the EDC:s (300 km) and the human factor involved in drawing these borders. The size of the potential market is displayed in *Figure 5-9, Geographical market, (alternative sea/rail/road & sea/road)* . This potential market is obtained through the use of both the intermodal alternatives; sea/rail/road and sea/road.


*Figure 5-9, Geographical market, (alternative sea/rail/road & sea/road)*

In the figure above the geographical market for the intermodal transportation system is presented.


*Figure 5-10, Geographical market, (alternative sea/road)*

In the figure above the geographical market for the intermodal transportation system is presented when using only the intermodal transport alternative of sea and road.


*Figure 5-11, Geographical market, (comparison between alternative sea/road and sea/rail/road)*

This comparison illustrates how the geographical market differs between the different transportation alternatives. An interesting reflection is that the geographical area between the alternatives does not differ that much in area. If one would neglect the economical breakpoint between rail and road transportation, road transportation directly from port would include whole of

Portugal and Spain compared with the alternative of road transportation with origin in Gothenburg (if distance for road transportation is set to >300 km).

### 5.3.1 Statistical Data

In order to determine the amount of goods moving between the different regions, it is necessary to determine the population amount in the geographical area. Through population density investigation we are able to make a fairly good estimation on the number of people living in the geographical market. When the population is determined for the geographical market, we can make a distribution as the one displayed in *Table 5-4.* This distribution is then used to determine goods flows between the regions, using the data in *Appendix 5 - Statistics.*

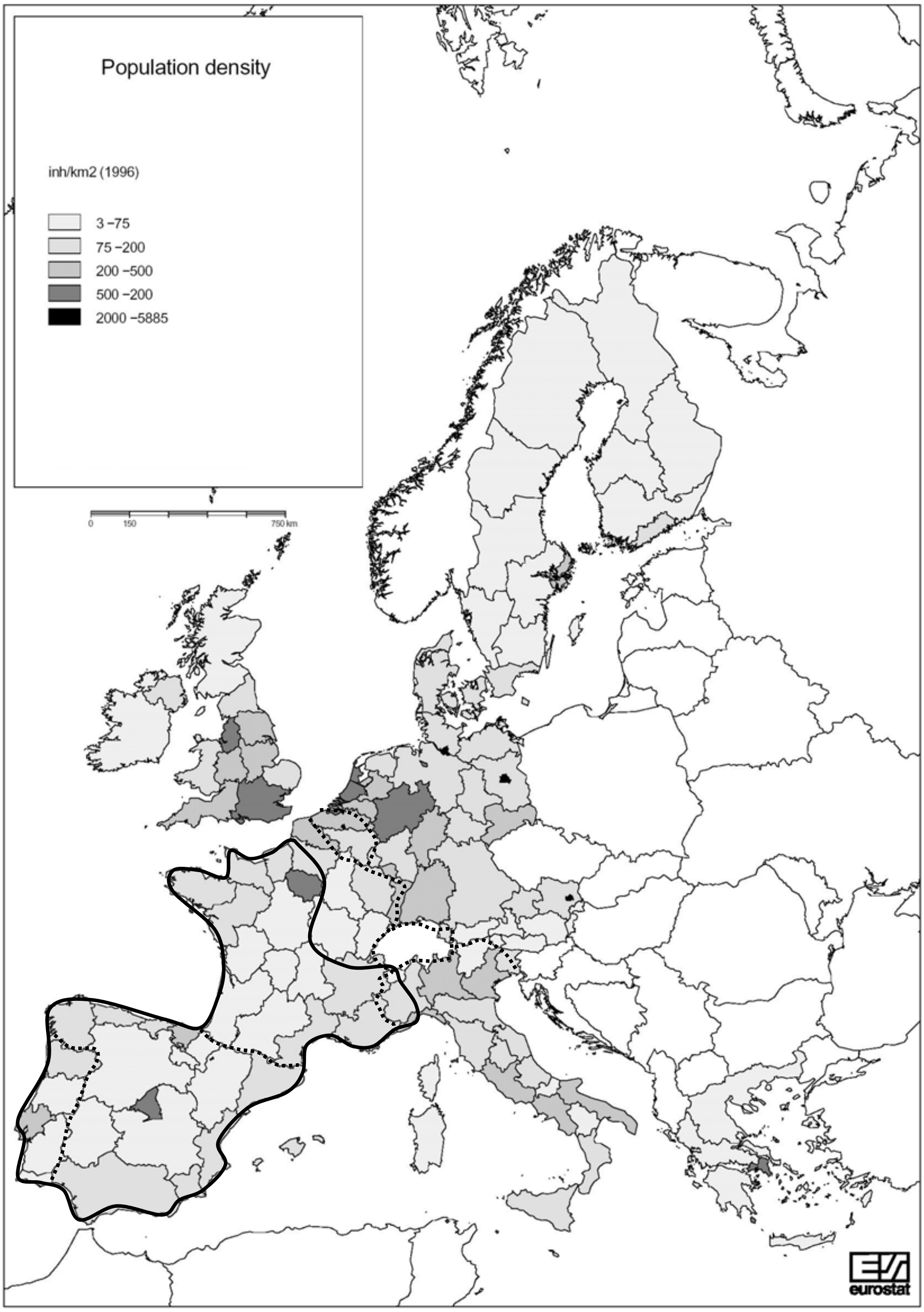


*Figure 5-12, Population density in the geographical market.* The map is made within the framework of the Eurostat study "Regional dimension of road transport statistics"

| Country of interst | Number in millions | Geo. market % | Pop. density in | Pop. in market |
|---|---|---|---|---|
| France | 59 | 70 | **75** | 44 |
| Italy | 58 | 6 | **5** | 2,9 |
| Spain | 39 | 100 | **100** | 39 |
| Portugal | 10 | 100 | **100** | 10 |
| Total | 166 | | | **95,9** |

*Table 5-4, Population density within the geographical market*

From the population density analysis, the total population in the geographical market is about 96 million people out of a total of 166 million in the unloading countries. The loading area has an aggregated population of about 11 million people (see Section *5.1, Port of Gothenburg*). The total population for the loading countries (Sweden, Norway, Denmark) are about 19 million people *(see Table 14-1).*

### 5.3.2 Potential Market (Potential 1)

The amount of goods transported from the Nordic countries, Sweden, Norway and Denmark, to the geographical area is displayed in *Appendix 5 - Statistics.* This data is retrieved trough data extraction from the New Cronos[154] and Comext databases.

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[154] New Cronos is a numerical database containing macro-economic time series. Information is available in three languages (English, French and German) and the database holds more than 70 million items of statistical data, divided into 49 domains covering the themes dealt with by Eurostat publications (theme 7: transport statistics).

| Loading country | Unloading country (1998-2001), 1000T | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Denmark | 563 | 2005 | 1625 | 59 |
| Sweden | 81 | 343 | 214 | 17 |
| Norway (1998 only) | 21 | 99 | 57 | 13 |
| | Unloading country (1998-2001), 1000T, average per year | | | |
| Denmark (New Cronos) | 140,75 | 501,25 | 406,25 | 14,75 |
| Sweden (New Cronos) | 20,25 | 85,75 | 53,5 | 4,25 |
| Norway (New Cronos) | 21 | 99 | 57 | 13 |

*Table 5-5, Data summary of road transported goods from loading country to unloading country (New Cronos)*

In the table above the data from the New Cronos extraction (*Appendix 5 - Statistics*) is summarised to fit our purpose. The total amount of goods from the loading countries to the unloading countries is about 1417000 tonnes. To simplify the data handling we assume that the amount of goods from the area of loading corresponds to the loading countries population. In Section *5.3.1 Statistical Data* we stated that the area of loading was about 11 million people out of a total population of 19 million people in the loading countries. We do not believe that this assumption influences the results in a severe manner, since the population density near the Port of Gothenburg is very high and much of the goods transferred from and to these countries goes through the surroundings of Gothenburg. This assumption is mainly influenced by the choice of catchment area for the Port of Gothenburg, which is dependent on many factors.

The data quality is better from the Comext database than the data extracted from New Cronos, however the Comext database lacks data of Norway as country of loading. Therefore we have chosen to use data for Sweden and Denmark from the Comext database and data from the New Cronos database for Norway. An analysis between the quality of data is done in Chapter 6, *Analysis*.[155]

| Loading country | Unloading country (1998-2001), 1000T | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Denmark | 460 | 1504 | 636 | 303 |
| Sweden | 256 | 735 | 527 | 50 |
| | Unloading country (1998-2001), 1000T, average per year | | | |
| Denmark (Comext) | 115,10 | 375,99 | 158,98 | 75,85 |
| Sweden (Comext) | 64,09 | 183,68 | 131,64 | 12,59 |

*Table 5-6, Comext extraction, Data summary of road transported goods from loading country (Sweden, Denmark) to unloading country*

When considering the population density in the geographical market, we obtain the numbers displayed in *Table 5-7* (combination of data both from New Cronos and Comext databases).

| | Geographical market | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Pop. Density in market | 100 | 75 | 5 | 100 |
| Loading country | Geographical market, 1000T, average per year | | | |
| Denmark (Comext) | 115,1 | 282,0 | 7,9 | 75,9 |
| Sweden (Comext) | 64,1 | 137,8 | 6,6 | 15,6 |
| Norway (New Cronos) | 21,0 | 74,3 | 2,9 | 13,0 |

*Table 5-7, Data summary of road transported goods from loading country to geographical market*

155 Oberhausen, J. & Pasi, S., Transport Statistics, Statistical Office of The European Communities, 2002-11-21, 10.00-12.00 CET., Luxemburg

Aggregation of the data in the table above provides us with the total amount of goods from the unloading countries to the geographical market, displayed in *Table 5-8*.

| | |
|---|---|
| ***Total amount of goods from origin to geographical market (potential 1)*** | ***816*** |

*Table 5-8, Potential 1 in 1000 tonnes*

The weight of the goods in a TEU is approximated to 10-12 tonnes; we have chosen to set the loading weight to 12 tonnes.[156] The total amount in tonnes transformed in terms of containers and vehicles are displayed in the table below. As stated in section *3.5.1 Road Haulage* we assume that a road vehicle either carries one 40-foot container or two 20-foot containers.

| | |
|---|---|
| ***Total amount of goods from origin to geographical market (potential 1, tonnes)*** | ***816000*** |
| ***Gross weight per 20 foot container*** | ***12 tonnes*** |
| ***Total amount of containers from origin to geographical market (potential 1)*** | ***68000,00*** |
| ***Total amount of road vehicles from origin to geographical market*** | ***34000*** |

*Table 5-9, Potential 1 in number of 20-foot containers and number of road vehicles*

This can be compared with the capacity of our intermodal system, for example the capacity of the link: Gothenburg – Port of Valencia is about 15400 containers per year. This capacity is for a one-way perspective. From this comparison it is obvious that the assumption made about one vessel operating one link is not necessary. From a scenario perspective, the intermodal transportation system has the possibility of operating more than

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[156] Eurostat, Meeting of the working Group on Intermodal Transportation Statistics, Document: IM/2002/Room 1, Luxemburg, 11-12 November 2002

one link per vessel. With this reflection in mind, trade between different ports and regions in Western Europe could be considered and exploit.

| ***Capacity in 20 foot containers for our intermodal system (geographical market)*** | | | | | | |
|---|---|---|---|---|---|---|
| | Le Havre | Nantes Saint-Nazaire | Bilbao | Sines | Valencia | Marseille |
| Gothenburg | 35600 | 27100 | 24500 | 20200 | 15400 | 13700 |

*Table 5-10, Capacity in 20-foot containers for our intermodal system to each port located in the geographical market.*

## 5.4 Limitations Concerning the Market

### 5.4.1 Countries of Origin

| | Geographical market | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Pop. Density in market | 100 | 75 | 5 | 100 |
| Loading country | Geographical market, 1000T, average per year | | | |
| Denmark (Comext) | 0,0 | 0,0 | 0,0 | 0,0 |
| Sweden (Comext) | 64,1 | 137,8 | 6,6 | 15,6 |
| Norway (New Cronos) | 21,0 | 74,3 | 2,9 | 13,0 |

*Table 5-11, Data summary of road transported goods from loading country to geographical market (excluding Denmark)*

| | |
|---|---|
| ***Potential 1*** | ***816*** |
| ***Total amount of goods from origin 2 to geographical market 1*** | ***335,2*** |

*Table 5-12, Total amount of goods (1000T) from origin (Sweden & Norway) to geographical market 1 in 1000 tones*

From a comparison of potential 1 (see *Table 5-12*) the exclusion of Denmark as country of loading more than halves the amount of goods transported to the geographical market.

## 5.4.2 Commodity Types

For database extraction in New Cronos the possibility of obtain data based upon the commodity types exist. For our purpose one of the more simplified division, namely NST/R24 is enough (see *Table 5-13*). This information will help us construct a commodity type distribution function. This function will be used to exclude the commodity types we see not fitting the service of our intermodal system.

| ***NST/R24*** |
|---|
| 25 Total from group 01 to 24 |
| 01 Cereals |
| 02 Potatoes, other fresh or frozen fruits and vegetables |
| 03 Live animals, sugar beet |
| 04 Wood and cork |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials |
| 06 Foodstuff and animal fodder |
| 07 Oil seeds and oleaginous fruits and fats |
| 08 Solid minerals fuels |
| 09 Crude petroleum |
| 10 Petroleum products |
| 11 Iron ore, iron and steel waste and blast furnace dust |
| 12 Non-ferrous ores and waste |
| 13 Metal products |
| 14 Cement, lime, manufactured building materials |
| 15 Crude and manufactured minerals |
| 16 Natural and chemical fertilizers |
| 17 Coal chemicals, tar |
| 18 Chemicals other than coal chemicals and tar |
| 19 Paper pulp and waste paper |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof |
| 21 Manufactures of metal |
| 22 Glass, glassware, ceramic products |
| 23 Leather, textile, clothing, other manufactured articles |
| 24 Miscellaneous articles |

*Table 5-13, NST/R 24 code for different commodity types for New Cronos database extraction*

As can be displayed in the extraction from Comext and especially New Cronos (*see Appendix 5 - Statistics*) there are many cells lacking data. This is due to the difficulties National Statistical Institutes and Eurostat have concerning data availability and retrieval. Therefore we have chosen to make the commodity type distribution function from the goods flow from Sweden to the EU15 countries (see *Table 5-14*).

| geo | se Sweden |
|---|---|
| unit | 1000t Thousands of tonnes |
| carriage | tot Total |
| unload | eu15 European Union (15 countries) |

| nstr24 | 2001a00 | 2000a00 | 1999a00 | 1998a00 | Total | Percentage |
|---|---|---|---|---|---|---|
| 25 | 1482 | 1510 | 1156 | 1051 | 5199 | 100 |
| 1 | 27 | : | 1 | 0 | 28 | 0,54 |
| 2 | 9 | 0 | 2 | 5 | 16 | 0,31 |
| 3 | 3 | 2 | 0 | 0 | 5 | 0,10 |
| 4 | 34 | 53 | 93 | 51 | 231 | 4,44 |
| 5 | 2 | : | 4 | 6 | 12 | 0,23 |
| 6 | 52 | 82 | 64 | 93 | 291 | 5,60 |
| 7 | 50 | 48 | 31 | 39 | 168 | 3,23 |
| 8 | : | 1 | 2 | 0 | 3 | 0,06 |
| 9 | : | : | : | 0 | 0 | 0,00 |
| 10 | 18 | 4 | 10 | 16 | 48 | 0,92 |
| 11 | : | 7 | 12 | 11 | 30 | 0,58 |
| 12 | 0 | 1 | 0 | 0 | 1 | 0,02 |
| 13 | 92 | 82 | 69 | 86 | 329 | 6,33 |
| 14 | 18 | 24 | 10 | 26 | 78 | 1,50 |
| 15 | : | 22 | 8 | 3 | 33 | 0,63 |
| 16 | : | : | : | 0 | 0 | 0,00 |
| 17 | 4 | 4 | 5 | 0 | 13 | 0,25 |
| 18 | 158 | 195 | 147 | 119 | 619 | 11,91 |
| 19 | 10 | 46 | 8 | 15 | 79 | 1,52 |
| 20 | 171 | 196 | 95 | 93 | 555 | 10,68 |
| 21 | 42 | 26 | 25 | 26 | 119 | 2,29 |
| 22 | 6 | 5 | 7 | 4 | 22 | 0,42 |
| 23 | 248 | 213 | 199 | 188 | 848 | 16,31 |
| 24 | 537 | 497 | 364 | 270 | 1668 | 32,08 |

*Table 5-14, Commodity type distribution from Sweden to the EU15 countries*

Since each of the individual tables between country of origin and country of destination lacks much data, we have chosen to use the distribution function for the table above to be representative for commodity types transported. This assumption can easily be debated but, on the other hand, it influences the final result *(potential 2*) to a low extent. The commodity types excluded from a market perspective are displayed in *Table 5-15*. The selection is mainly based upon the perishable nature of the commodity type (time sensitive goods), the value of it and its ability to be loaded into load units. This selection is made from the theories displayed and explained in Section *3.3.1 Quality Aspects of Transportation Services*.

| ***NST/R24*** |
|---|
| 25 Total from group 01 to 24 |
| 01 Cereals |
| **02 Potatoes, other fresh or frozen fruits and vegetables** |
| **03 Live animals, sugar beet** |
| 04 Wood and cork |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials |
| 06 Foodstuff and animal fodder |
| 07 Oil seeds and oleaginous fruits and fats |
| 08 Solid minerals fuels |
| **09 Crude petroleum** |
| **10 Petroleum products** |
| 11 Iron ore, iron and steel waste and blast furnace dust |
| 12 Non-ferrous ores and waste |
| 13 Metal products |
| 14 Cement, lime, manufactured building materials |
| 15 Crude and manufactured minerals |
| 16 Natural and chemical fertilizers |
| **17 Coal chemicals, tar** |
| **18 Chemicals other than coal chemicals and tar** |
| 19 Paper pulp and waste paper |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof |
| 21 Manufactures of metal |
| 22 Glass, glassware, ceramic products |
| 23 Leather, textile, clothing, other manufactured articles |
| 24 Miscellaneous articles |

*Table 5-15, Commodity types excluded*

By combination of the data in *Table 5-14* with the selection made in *Table 5-15*, the commodity type distribution function is obtained. The function is displayed in *Table 5-16.* Note the large share miscellaneous articles has in this function, a reasonable conclusion to be drawn from this is that the commodity type division (NST/R24) functions with questionable accuracy. However this is the lowest level of detail when extracting data about transported goods based upon commodity types. Further research in this subject should consider the opportunity of using commodity type division that has a higher level of detail than the NST/R24 system.

| nstr24 | Percentage | nstr24 | Percentage |
|---|---|---|---|
| 1 | 0,54 | 13 | 6,33 |
| ***2*** | ***0,31*** | 14 | 1,50 |
| ***3*** | ***0,10*** | 15 | 0,63 |
| 4 | 4,44 | 16 | 0,00 |
| 5 | 0,23 | ***17*** | ***0,25*** |
| 6 | 5,60 | ***18*** | ***11,91*** |
| 7 | 3,23 | 19 | 1,52 |
| 8 | 0,06 | 20 | 10,68 |
| ***9*** | ***0,00*** | 21 | 2,29 |
| ***10*** | ***0,92*** | 22 | 0,42 |
| 11 | 0,58 | 23 | 16,31 |
| 12 | 0,02 | 24 | 32,08 |
| **Total (%)** | | | **13,48** |

*Table 5-16, Commodity type distribution function (in percentage)*

Through combination of the total amount of goods from origin 2 to geographical market 1 and the excluded commodity types we obtain a potential amount of goods, considering origin 2 and the excluded commodity types (see *Table 5-17*).

| | |
|---|---|
| ***Total amount of goods from origin 2 to geographical market 1*** | ***335,2*** |
| ***Commodity type (decreasing potential) in %*** | ***13,48*** |
| ***Total amount of goods from origin to geographical market excluding Denmark and commodity types*** | ***290,0*** |

*Table 5-17,Total amount of goods (1000T) from origin to geographical market excluding Denmark and unfavourable commodity types*

From the table above it is clear that excluding Denmark as loading country has far more negative impact on the potential than excluding commodity types.

### 5.4.3 Throughput Time

Concerning potential 2 we have made the limitation that the throughput time for the intermodal transportation system is maximum one week, this is due to the quality dimension of time discussed in *3.3.1 Quality Aspects of Transportation Services*. This limitation is connected with the commodity type selection made in *Table 5-15*. Through this throughput time limitation we can serve segments more sensitive to transport time. This enables the intermodal transportation system to carry goods with higher value, e.g., transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof (number 20 in *Table 5-13*).


*Figure 5-13, Geographical market 2 (excluding port of Valencia and Marseille), alternative sea/road & sea/rail/road*

From *Appendix 4 - Maps* and the limitation stated above with a throughput time less or equal to 168 hours it is clear that port of Valencia and Marseille is out of reach. This results in a new geographical market excluding these two ports.


*Figure 5-14, Geographical market 2 (excluding port of Valencia and Marseille) comparison with geographical market 1*

From the comparison made in *Figure 5-14,* the conclusion can be made that the intermodal transportation system is not that sensitive to small changes in throughput time requirements. Throughput time requirements mainly affect the sea transportation movement since this is the link in the transport chain consuming the largest amount of time. From *Figure 5-14* and the increasing requirement for throughput time, the intermodal transportation system is no longer able to serve Italy with transportation service and the potential geographical market in France decreases with about 5-10 percentages, however this area has not very high population density.

| | Geographical market | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Pop. Density in market | 100 | **(75-10)=65** | **0** | 100 |
| Loading country | Geographical market, 1000T, average per year | | | |
| Denmark | 0,0 | 0,0 | 0,0 | 0,0 |
| Sweden | 64,1 | 119,4 | 0,0 | 15,6 |
| Norway (1998 only) | 21,0 | 64,4 | 0,0 | 13,0 |

*Table 5-18, Data summary of road transported goods from loading country to geographical market 2 (excluding Denmark)*

| | |
|---|---|
| ***Total amount of goods from origin to geographical market 2 (throughput time)*** | ***297,4*** |

*Table 5-19, Total amount of goods from origin to geographical market 2 in 1000 tones*

### 5.4.4 Potential Market (Potential 2)

Summary of the limitations made in the Sections *5.4.1, Countries of Origin, 5.4.2, Commodity Types* and *5.4.3, Throughput Time* provides us with potential 2, displayed in *Table 5-20*.

| | |
|---|---|
| ***Total amount of goods from origin to geographical market 2 (potential 2)*** | ***297,4*** |
| ***Commodity type (loss) in percentage*** | ***13,48*** |
| ***Gross weight per 20 foot container*** | ***12 tonnes*** |
| ***Total amount of containers from origin to geographical market (potential 2)*** | ***21442,54*** |
| ***Total amount of road vehicles from origin to geographical market 2*** | ***10721*** |

*Table 5-20, Potential 2 in number of 20-foot containers and number of road vehicles*

Compared with potential 1, potential 2 is about one third of the amount of road vehicles from origin to geographical market. The far most important limitation made in the process of obtaining potential 2 is the exclusion of Denmark as loading country. On the other hand as stated in Section *2.2, Research Model*, by adding limitations we increase the reliability of the potential of the intermodal transportation system.

# 6 Analysis

*In this chapter, we will analyse our results and test our calculation models by doing alterations of various variables. The sensitivity analysis later described in this chapter aims to display the impact of different sets of conditions and changes (mainly of cost and time characteristics) have to the models and results. Comparison of some specific cost components of special interest will also be conducted. The sensitivity analysis is made with restrictions to available time and resources. The aim is also review our work from the concepts of validity and reliability covered in Section 4.3, Research Evaluation.*

We start this chapter with a data quality analysis of the transport statistics used in our model for the potential market, this in order to examine the reliability of the data.

Secondly, we construct a model of the most influencing factors, from our perspective, based on the theoretical framework and empirical study. The model is divided into two parts; one part has the possibility of being influenced by the systems' designer, the other part is states-of-nature that the systems' designer must consider but cannot change in the short-term perspective.

## 6.1 Data Quality Analysis

From Section *4.2, Methodology Behind Transport Data* the differences in methodology between transport statistics retrieval and external trade data retrieval are displayed. Considering our purpose, external trade data from the Comext database can be considered as the most reliable source of statistical data. The main reason behind this statement is that the statistics in the

Comext database has larger contents of data concerning our extractions. The statistics for transportation in the New Cronos database is more of a "sample" character (see Section *4.2.1.1, Methodology Behind Transport Statistics*). The process of collecting external trade data could be considered as less complex than that of collecting transport statistics. This is due to the nature of the data collection method as well as the nature of the data itself. External trade statistics is commonly used and has a more solid data collection infrastructure, i.e., external trade statistics have been collected and used for a longer period of time than transport statistics. We focus this data quality analysis by doing a brief data comparison on the extractions collected for our research from the New Cronos database and the Comext database. The comparison is illustrated in *Table 6-1*.

| Loading country (New Cronos) | Unloading country (1998-2001), 1000T | | | | |
|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Total |
| Denmark | 563 | 2005 | 1625 | 59 | 4252 |
| Sweden | 81 | 343 | 214 | 17 | 655 |
| Total | | | | | 4907 |
| Loading country (Comext) | | | | | |
| | Spain | France | Italy | Portugal | |
| Denmark | 460 | 1504 | 636 | 303 | 2904 |
| Sweden | 256 | 735 | 527 | 50 | 1568 |
| Total | | | | | 4472 |
| | | Difference | | 4907-4472 = | 435 |
| Loading country | Difference per link (1000T) New Cronos - Comext | | | | |
| | Spain | France | Italy | Portugal | |
| Denmark | 103 | 501 | 989 | -244 | |
| Sweden | -175 | -392 | -313 | -33 | |
| Total difference | 2750 | ***Total difference /per year*** | | | ***687,5*** |

*Table 6-1, Data comparison of road transported goods from loading country to unloading country between New Cronos and Comext*

From the data comparison between New Cronos and the Comext database made above, note that there are significant differences between Denmark and Sweden. From the years 1998-2001 the difference in tonnes between the countries reaches a value of 2750 thousand tonnes for the unloading countries specified in *Table 6-1*. Norway is not included in this analysis since the data for Norway is only retrieved through the New Cronos database, because it is not a member of the European Union. This is probably also the reason why data for Norway only exists for year 1998 in the New Cronos database (see *Table 14-12*). These transport statistics for Norway also have suspiciously low values.

We believe that the data collected from the databases New Cronos and Comext is underestimated compared to the actual goods flows. If we make the assumption that the three loading countries (Denmark, Sweden, Norway) have the same amount of goods flow to the unloading countries and use the data about Denmark's goods flow, the results would be as showed in *Table 6-2*.

| | Unloading country (1998-2001), 1000T | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Pop. Density in market | 100 | 75 | 5 | 100 |
| Loading country | Geographical market, 1000T, average per year | | | |
| Denmark (Comext) | 115,1 | 282,0 | 7,9 | 75,9 |
| Sweden | 115,1 | 282,0 | 7,9 | 75,9 |
| Norway | 115,1 | 282,0 | 7,9 | 75,9 |
| Total amount of goods from origin to geographical market | | | | **1442,7** |

*Table 6-2, Data analysis: total amount of goods from loading countries to geographical market in 1000T*

| | |
|---|---|
| ***Total amount of goods from origin to geographical market (potential 1, tonnes)*** | ***1443000*** |
| ***Gross weight per 20 foot container*** | ***12 tonnes*** |
| ***Total amount of containers from origin to geographical market (potential 1)*** | ***120250,00*** |
| ***Total amount of road vehicles from origin to geographical market*** | ***60125*** |

*Table 6-3, Data analysis: total amount of goods from loading countries to geographical market in number of 20-foot containers and number of road vehicles*

This amount of goods compared with potential 1 is almost twice as much (see *Table 5-9*). This analysis can be debated since we do not completely know the reliability of the data, however we do know one thing for sure; the data in New Cronos and Comext is inaccurate, but the best possible data available.

## 6.2 Intermodal System - Model

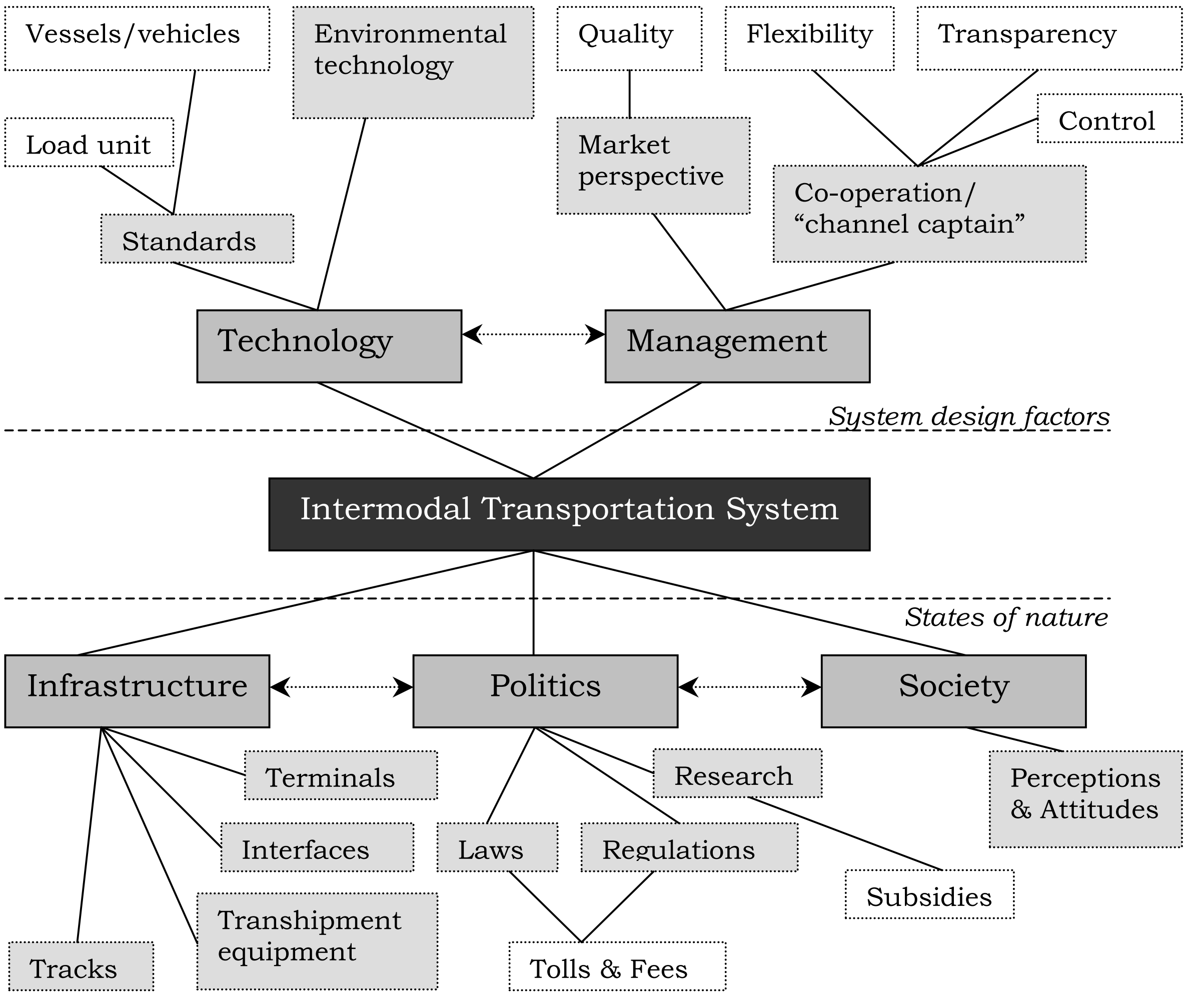


*Figure 6-1, Important factors influencing the design of the intermodal transportation system.*

The model illustrated in *Figure 6-1* is our perception on the most important factors considering sea-based intermodal transportation. We have divided the factors into two categories, *system design factors* and *states of nature*. States of nature are factors that changes slowly but has great impact on the intermodal transportation system. States of nature cannot be influenced by the system designer, at least not with reasonable efforts. The *system design factors* are factors that the system designer can influence and affect to a high extent. We believe this mapping is essential in order for the resources available are focused upon those things, which they are able to influence and control. We continue this section by describing some of the factors that we believe are especially important, or have great development opportunities or are crucial for the intermodal transportation system.

## Technology

From a technological perspective the systems' highest priority is total commercial technology openness (see Section *3.4, Barriers to Intermodal Transportation Systems*), no matter where subsidies come from or who the main actor in the system is. This is due to the essentiality of economies of scale (see Section *3.5, Costs of Haulage for Different Modes*).

### *Standards*

Standardisation is a key issue when analysing barriers for technological change in intermodal transportation systems. Since overall performance is prioritised, the decided standard cannot be optimised for all components. This is a very important influencing factor that is very difficult to change (see Section *3.4.3.1, Standards*).

#### Load unit

The size, shape, weight etc. are all very restricted measures strongly related to standardisation, however there is a great demand for a intermodal transportation unit (ITU), see Section *3.3.2.1.1, Intermodal Load Unit.*

To enable transportation of commodity types of perishable character, the possibility of refrigerated cargo and containers should be explored (see Section *3.3.2.2.1, Container Ship*).

Vehicles/vessels

Requirements are often most strict for maritime related transport, due to the complexity of handling etc. Permanent real-time monitoring could be a useful service and increase the transparency and control of the transportation chain, see Section *3.3.1.3, Conclusions for Quality and Segments*.

Over time the engine manufactures have achieved remarkable increases in fuel efficiency, see Section *3.5.2.3.1, Bunker Costs*. Also the development of environmental technology such as catalysts for cleaning vessel engines has achieved remarkable improvements.

**Management**

As for most engineering of systems that include flows of any kind, designing intermodal transportation systems is much about identifying and removing bottlenecks along the chain. As one bottleneck is removed, however, the narrow section is moved somewhere else in the chain. What makes this continuous procedure especially difficult is that the chain is not controlled by a single actor (see Section *3.4.3.3, Lack of Formal System Leadership*). Our opinion is that this problem is the very cornerstone for a successful intermodal transportation system.

In order to get a high degree of utilisation for the sea vessels one measurement in order to achieve this could be to involve more than one port to each link, for example Port of Bilbao and Port of Sines.

Apart from containers, deep-sea cargo at Gothenburg includes trade cars, oil, and fruit. Gothenburg is by far the largest car port in the Nordic region, this is mainly due to the location of the Ford owned brand *Volvo* (see Section *5.1.1, Cargo*). This might constitute an opportunity for co-operation with an intermodal transportation system and its land legs.

*Market perspective*

Our intermodal transportation system is expected to foremost attract large businesses with large shipping volumes and with average or low goods value, e.g., the Swedish furniture company IKEA, but also companies that want an environmental logistical profile (see Sections *3.3.1.2, Segmentation* and *3.1, External Effects and Impacts of Transportation*).

From *Table 5-17*, it is clear that excluding Denmark as loading country has far more negative impact on the potential than excluding commodity types. Therefore the system is far more sensitive to be able to attract a larger market than to provide transport services to many commodity types. Therefore the system should focus on competition based upon economical terms instead of wide commodity type service.

Quality

Operators of links and transhipment nodes must decide whether to form an integral part of a general transportation system or to offer end customers complete door-to-door transport services. Our opinion is that a door-to-door service is a fundamental degree of quality for the intermodal transportation system in order to attract customers and to be successful (see Section *3.3.1, Quality Aspects of Transportation Services*).

The intermodal transportation system should have the highest possible commercial openness (see Section *3.4.4, Barriers From a Market Perspective*), due to the essentiality of economies of scale (see Section *3.5, Costs of Haulage for Different Modes*)

## Infrastructure

The infrastructure costs of an inland terminal can vary considerably from one site to another, depending on the price of land or the amount of preparatory work required. In densely populated areas, land prices can be 10 times higher than in rural areas. The infrastructure cost for the construction of a new terminal is very often more than 50 % of the total cost. As a consequence, therefore our recommendation is to use existing terminals and, from a scenario perspective, extend existing terminals and use existing railway shunting equipment, or alternatively look for subsides which will cover some of the infrastructure cost (see Section *3.3.2.3, Infrastructure*)

*Terminals*

An improvement in the performance of terminals and the transport chain is to be found in the way they interact with and between different modes of transport. The improvements associated with the "quality of terminals" are limited if we only consider terminal operations, as these account for about 7% of total transport chain costs. Hence, it is clear that the interfaces between modes of transport in an intermodal transportation terminal are crucial; see Section *3.3.2.3.3, Interfaces of Terminals*.

The loading and discharging of ships at the terminal is done by an independent stevedoring company or by the exporter or receiver of the cargo. There is however a declining cost trend of stevedoring from a historical perspective, see section *3.5.2.4, Cargo Handling Costs*. We believe that economies of scale and regular transhipments could decrease these costs further.

## Politics

Regulative barriers originate from laws and regulations issued by authorities primarily concerning direct interaction with governmental infrastructure but also concerning external effects such as emissions, noise, traffic accidents, working conditions for employees and recycling of goods. A further regulative barrier is that laws and regulations still are applicable to single mode transportation rather than to intermodal transportation and that the adaptation to new circumstances is slow (see Section *3.4.2, Regulative Barriers*). These are issues crucial to solve from an intermodal transportation perspective.

The increased use of political instruments as road tolls, directly influences the competitiveness of intermodal transportation from an economical perspective (see Section *3.5.1, Road Haulage*).

The nationality of the crews is another important factor for the level of crew costs (e.g., European officers are generally more expensive than their Philippine counterparts). We believe this is an area of great political opportunity for development (see Section *3.5.2.2.1, Manning Costs*) and of huge importance to solve for sea-based intermodal transportation in order to keep the vessels under European flag.

## Society

EU has to take a big role in the work of negative perceptions of foremost maritime transport but also the rail sector (see Section *3.2.4, Shortsea Shipping Needs to Become Part of Intermodal Thinking*). This could be done through numerous actions, e.g., subsidies, regulations, research, promotion and general support. Although EU is not single responsible, the sectors themselves have to take joint responsibility to enhance peoples' perception of their business and industry. In addition, perceptions are seldom based entirely without facts.

## 6.3 Sensitivity Analysis

In this section we conduct seven different sensitivity analyses, six of them are cost analyses and the last one is a trade balance sensitivity analysis. The characteristics of the first seven analyses are described in *Table 6-4*. We will do sensitivity analyses through 10, 20 and 30% cost manipulation. The trends indicate that road transportation costs increases while the development of rail transportation costs are decreasing (this is mainly due to privatisation of railroads etc.).

| **Cost Sensitivity Analysis** | | | | |
|---|---|---|---|---|
| | Road | | | |
| Rail | 0 | 10% | 20% | 30% |
| 0 | X | 1 | 2 | 3 |
| -10% | 4 | | | |
| -20% | 5 | | | |
| -30% | 6 | | | |

*Table 6-4, Cost sensitivity analysis*

### 6.3.1 Sensitivity Analysis of Road Transportation Costs

As stated in Section *1.1.1, Congestion – A Time to Decide,* congestion is severe in many regions in Europe. As a result of this, increased road tolls and fees are a reality for the future. Hence road transportation becomes expensive. We have explored the scenarios of increased costs for direct long haulage in the ranges: 10%, 20% and 30%. The sensitivity analyses of these scenarios are illustrated as cost sensitivity analyses *1,2 and 3.*

### 6.3.1.1 Cost Sensitivity Analysis 1

We start each cost sensitivity analysis with calculating the new costs for the EDC:s. Similar to the process in the empirical framework for the geographical market, we get a geographical market. Through statistical analysis the total amount of goods from origin to the geographical market is obtained.


**X** EUR **(Y)** hours

*Figure 6-2, Cost sensitivity analysis (1), +10% to road transportation cost, EDC:s (300 km) with Gothenburg as origin.*


*Figure 6-3, Sensitivity analysis (1), geographical market compared with original geographical market*

| | Geographical market | | | | | |
|---|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland | Belgium |
| Pop. Density in market | 100 | 100 | 20 | 100 | 50 | 100 |
| Loading country | Geographical market, 1000T, average per year | | | | | |
| Denmark (Comext) | 115,1 | 376,0 | 31,8 | 75,9 | 48 | 190 |
| Sweden (Comext) | 64,1 | 183,7 | 26,3 | 15,6 | 25 | 68 |
| Norway (New Cronos) | 21,0 | 99,0 | 11,4 | 13,0 | X | X |
| | | | | | | |
| Total amount of goods from origin to geographical market | | | | | | **1363,8** |

*Table 6-5, Cost sensitivity analysis (1), data summary of road transported goods from loading country to geographical market*

## 6.3.1.2 Cost Sensitivity Analysis 2


**X** EUR **(Y)** hours

*Figure 6-4, Cost sensitivity analysis (2), +20% to road transportation cost, EDC:s (300 km) with Gothenburg as origin.*


*Figure 6-5, Sensitivity analysis (2), geographical market compared with original geographical market*

| | Geographical market | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland | Belgium | Germany | Austria |
| Pop. Density in market | 100 | 100 | 85 | 100 | 100 | 100 | 50 | 5 |
| Loading country | Geographical market, 1000T, average per year | | | | | | | |
| Denmark (Comext) | 115,1 | 376,0 | 135,1 | 75,9 | 96 | 190 | 557 | 2,2 |
| Sweden (Comext) | 64,1 | 183,7 | 111,9 | 15,6 | 50 | 68 | 307 | 2,5 |
| Norway (New Cronos) | 21,0 | 99,0 | 48,5 | 13,0 | X | X | X | X |
| | | | | | | | | |
| Total amount of goods from origin to geographical market | | | | | | | | **2531,5** |

*Table 6-6, Cost sensitivity analysis (2), data summary of road transported goods from loading country to geographical market*

## 6.3.1.3 Cost Sensitivity Analysis 3


**X** EUR **(Y)** hours

*Figure 6-6, Cost sensitivity analysis (3), +30% to road transportation cost, EDC:s (300 km) with Gothenburg as origin.*


*Figure 6-7, Sensitivity analysis (3), geographical market compared with original geographical market*

| | Geographical market | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland | Belgium | Germany | Austria |
| Pop. Density in market | 100 | 100 | 95 | 100 | 100 | 100 | 60 | 10 |
| Loading country | Geographical market, 1000T, average per year | | | | | | | |
| Denmark (Comext) | 115,1 | 376,0 | 151,0 | 75,9 | 96 | 190 | 668 | 4,4 |
| Sweden (Comext) | 64,1 | 183,7 | 125,1 | 15,6 | 50 | 68 | 369 | 5 |
| Norway (New Cronos) | 21,0 | 99,0 | 54,2 | 13,0 | X | X | X | X |
| | | | | | | | | |
| Total amount of goods from origin to geographical market | | | | | | | | **2743,9** |

*Table 6-7, Cost sensitivity analysis (3), data summary of road transported goods from loading country to geographical market*

## 6.3.2 Sensitivity Analysis of Rail Transportation Costs

Rail transportation networks throughout Europe are being developed in order to provide better services and performance, e.g., the Trans-European Networks. Privatisation of railways is another reality, further enhancing the opportunity of better performance and lower costs for rail transportation in the future. We have therefore chosen to examine the scenarios of decreased costs for rail transportation by –10%, -20% and –30%. The sensitivity analyses of these scenarios are illustrated as cost sensitivity analyses *4, 5 and 6.*

| **Transport cost (rail transportation cost analysis)** | | | | |
|---|---|---|---|---|
| ***Port*** | **Cost** | **(4) Cost (-10%)** | **(5) Cost (-20%)** | **(6) Cost (-30%)** |
| ***Hamburg*** | 540 | 515 | 490 | 466 |
| ***Rotterdam*** | 549 | 524 | 499 | 475 |
| ***Antwerp*** | 552 | 527 | 502 | 478 |
| ***Le Havre*** | 557 | 532 | 507 | 482 |
| ***Nantes Saint-Nazaire*** | 578 | 553 | 528 | 504 |
| ***Bilbao*** | 587 | 563 | 538 | 513 |
| ***Sines*** | 608 | 584 | 559 | 534 |
| ***Valencia*** | 646 | 621 | 596 | 571 |
| ***Marseille*** | 664 | 640 | 615 | 590 |

*Table 6-8, Cost sensitivity analysis (rail transportation), EDC (600 km)*

### 6.3.2.1 Cost Sensitivity Analysis 4


*Figure 6-8, Sensitivity analysis (4), -10% to rail transportation cost, geographical market compared with original geographical market*

| | Geographical market | | | | |
|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland |
| Pop. Density in market | 100 | 80 | 10 | 100 | 5 |
| Loading country | Geographical market, 1000T, average per year | | | | |
| Denmark (Comext) | 115,1 | 300,8 | 15,9 | 75,9 | 4,8 |
| Sweden (Comext) | 64,1 | 146,9 | 13,2 | 15,6 | 2,5 |
| Norway (New Cronos) | 21,0 | 79,2 | 5,7 | 13,0 | X |
| | | | | | |
| Total amount of goods from origin to geographical market | | | | | **873,6** |

*Table 6-9, Cost sensitivity analysis (4), data summary of road transported goods from loading country to geographical market*

## 6.3.2.2 Cost Sensitivity Analysis 5


*Figure 6-9, Sensitivity analysis (5), -20% to rail transportation cost, geographical market compared with original geographical market*

| | Geographical market | | | | |
|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland |
| Pop. Density in market | 100 | 90 | 15 | 100 | 40 |
| Loading country | Geographical market, 1000T, average per year | | | | |
| Denmark (Comext) | 115,1 | 338,4 | 23,8 | 75,9 | 38,4 |
| Sweden (Comext) | 64,1 | 165,3 | 19,7 | 15,6 | 20 |
| Norway (New Cronos) | 21,0 | 89,1 | 8,6 | 13,0 | X |
| | | | | | |
| Total amount of goods from origin to geographical market | | | | | **1008,0** |

*Table 6-10, Cost sensitivity analysis (5), data summary of road transported goods from loading country to geographical market*

### 6.3.2.3 Cost Sensitivity Analysis 6


*Figure 6-10, Sensitivity analysis (6), -30% to rail transportation cost, geographical market compared with original geographical market*

| | Geographical market | | | | | |
|---|---|---|---|---|---|---|
| | Spain | France | Italy | Portugal | Switzerland | Austria |
| Pop. Density in market | 100 | 96 | 20 | 100 | 100 | 2 |
| Loading country | Geographical market, 1000T, average per year | | | | | |
| Denmark (Comext) | 115,1 | 361,0 | 31,8 | 75,9 | 96 | 0,88 |
| Sweden (Comext) | 64,1 | 176,3 | 26,3 | 15,6 | 50 | 1 |
| Norway (New Cronos) | 21,0 | 95,0 | 11,4 | 13,0 | X | X |
| | | | | | | |
| Total amount of goods from origin to geographical market | | | | | **1154,4** | |

*Table 6-11, Cost sensitivity analysis (6), data summary of road transported goods from loading country to geographical market*

### 6.3.3 Sensitivity Analysis (7) of Balanced Flows

In this sensitivity analysis we will include the amount of goods going from the geographical market to the loading areas (Sweden and Denmark). Norway is not included in this analysis since we lack data of trade flows from the geographical market towards Norway. *Table 6-12* is an extraction from the Comext database, containing the imported goods from the geographical market to Sweden and Denmark.

***Table generation of Extraction from Plan 'trans'***

| | |
|---|---|
| Produced: | 03/12/2002 |
| PRODUCT(B): | TOT |
| FLOW(L): | IMPORT |
| TRANSPORT_MODE(L): | Road |
| CONTAINER_CODE(L): | (+Total2) |
| TRANSPORT_MEANS_NAT(L): | +WORLD |
| INDICATORS(L): | (QUANTITY_TON) |
| PARTNER(L): | Y Axis (1) |
| PERIOD(L): | X Axis (1) |
| DECLARANT(L): | X Axis (2) |

| Average/year | |
|---|---|
| Denmark | Sweden |
| | |
| 196306 | 89512 |
| 134412 | 82382 |
| 8811 | 9652 |
| 106328 | 36739 |

| | Jan.-Dec. 1998 | | Jan.-Dec. 1999 | | Jan.-Dec. 2000 | | Jan.-Dec. 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden |
| | | | | | | | | |
| France | 235244 | 81516 | 216516 | 121359 | 232304 | 142356 | 101158 | 12816 |
| Italy | 152193 | 65968 | 142336 | 107745 | 156075 | 132065 | 87042 | 23748 |
| Portugal | 11817 | 5786 | 10404 | 20933 | 10080 | 11187 | 2941 | 700 |
| Spain | 81413 | 26193 | 93664 | 46912 | 136886 | 66408 | 113349 | 7443 |

*Table 6-12, Comext extraction - geographical market (Sweden, Denmark – Import), source: Comext2 k0610962.txt, extracted: 03/12/2002*

| | Geographical Market | | | |
|---|---|---|---|---|
| | Spain | France | Italy | Portugal |
| Pop. Density in market | 100 | 75 | 5 | 100 |
| Export | Geographical market, 1000T, average per year | | | |
| Denmark (Comext) | 115,1 | 282,0 | 7,9 | 75,9 |
| Sweden (Comext) | 64,1 | 137,8 | 6,6 | 15,6 |
| Import | Geographical market, 1000T, average per year | | | |
| Denmark (Comext) | 106,0 | 147,0 | 6,7 | 106,0 |
| Sweden (Comext) | 37,0 | 66,8 | 4,1 | 37,0 |
| | | | | |
| ***Total amount of goods between (Sweden, Denmark) and geographical market*** | | | | **1215,5** |

*Table 6-13, Cost sensitivity analysis (7), data summary of balanced flows goods between (Sweden & Denmark) to geographical market*

### 6.3.4 Summary of Cost and Flow Sensitivity Analyses

| Sensitivity Analysis | Amount of goods (1000T) | Increase (%) | TEU | Vehicles |
|---|---|---|---|---|
| Potential 1 | 816 | 0% | 68000 | 34000 |
| 1(road +10%) | 1364 | 67% | 113667 | 56833 |
| 2(road +20%) | 2531 | 210% | 210917 | 105458 |
| 3 (road +30%) | 2744 | 236% | 228667 | 114333 |
| 4 (rail -10%) | 874 | 7% | 72833 | 36417 |
| 5 (rail -20%) | 1008 | 24% | 84000 | 42000 |
| 6 (rail -30%) | 1154 | 41% | 96167 | 48083 |
| 7 (balanced flow) | 1216 | 49% | 101333 | 50667 |

*Table 6-14, Summary of cost and flow sensitivity analyses*


*Figure 6-11, Summary of sensitivity analysis (1, 2, 3), road transportation cost analysis, comparison with original geographical market*


*Figure 6-12, Summary of sensitivity analysis (4, 5, 6), rail transportation cost analysis, comparison with original geographical market*

### 6.3.5 Sensitivity Analysis of Throughput Time

The sea-based intermodal transportation system is totally inferior compared to direct road haulage from Gothenburg concerning throughput time. The intermodal transportation movement is mainly conducted by sea transport; the opportunities to decrease the transit time for this movement are rather limited. In order for the intermodal transportation system to be more beneficial than road transportation concerning throughput time, it has to either decrease the throughput time with about 50% or road transportation has to increase its throughput time with at least 100%, which we believe is unreasonable. Therefore we believe that the need for a sensitivity analysis regarding throughput time is insignificant. The competitive strength of the sea-based intermodal transportation system is its cost superiority, not throughput time.

# 7 Conclusions

*In this chapter, our goal is to draw conclusions and recommendations based on the findings from our empirical study and the analysis.*

A sea-based intermodal transportation system is essential for logistic connections between Scandinavia and Western Europe, both from a trade perspective and environmental perspective, see Section *1.1.3, Intermodal Freight Transport – A Prerequisite for Sustainability*. This intermodal transportation system provides a cost efficient and environmentally friendly opportunity for transport of goods between Scandinavia and Western Europe.

Congestion, leading to longer road transportation time, is not enough of a reason for choosing the intermodal transportation system. The intermodal system has to be able to provide additional service quality, see Section *3.3.1, Quality Aspects of Transportation Services.* We believe that reliability and control are the most important quality criteria to fulfil for the intermodal transportation system, in addition to cost superiority.

We believe that the Port of Gothenburg is an excellent choice of point of origin due to its location and catchment area, service quality, infrastructure, development and expansion plans and its focus on environmental aspects and customer service. The port is especially suitable for feeder traffic due to the current nature of feeder lines and routes (see Section *5.1, Port of Gothenburg*).

From the intermodal transportation model in the analysis (see *Figure 6-1*), we state that the two main areas with the greatest possible development from an intermodal transportation perspective are:

- Load unit, through higher utilisation of vehicles, vessels and easier transhipments (see Section *3.3.2.1.1, Intermodal Load Unit*)
- Politics: regulations, laws, rules (see Section *3.4.2, Regulative Barriers*), subsidies, guidelines, research, standards (see Section *3.4.3.1, Standards*) and promotion.

Load units, especially intermodal load units, are an area of many problems and difficulties. However, there would be a great performance improvement for intermodal transportation if there would be a standardised intermodal load unit, allowing high load factor of vessels and vehicles and fast transhipments between modes of transport. This aspect is strongly related to political issues, since no single actor controls the whole transport chain and is therefore able to introduce a new standardised load unit (see section *3.4.3.3, Lack of Formal System Leadership*). It is essential that clearer and better laws, rules and standards are implemented and applicable for all actors within the transportation industry in order to maximise the overall performance.

Technological development is obviously slowed down by the fact that no single organisation can push for it along the transport chain, and that problems arise when the benefits from the investments should be split among the actors participating in the transport chain. The problem is further enhanced by the fact that the interests of road, sea and rail transport collide with their single mode operations and have a long history of mutual conflicts (*3.4.3.3, Lack of Formal System Leadership*).

These problems are related to the fact that there is a lack of a channel captain. We believe that a prerequisite for an intermodal transportation system is that one party takes an overall responsibility and top management position (see Section *3.4, Barriers to Intermodal Transportation Systems*).

An important element and barrier with which prospective intermodal operators are confronted is the lack of precise and comprehensive transport market information. To ensure commercial success, it is necessary to formulate very clear marketing plans. These plans should include market segmentation, a clear product and pricing strategy and a clear sales strategy covering channel, coverage and promotional activities (see Section *3.4.4, Barriers From a Market Perspective*). We believe that a united front, clear market information, plans and price strategy are all aspects of a good customer perception of the intermodal transportation system.

EU has to take a big role in the work of negative perceptions of foremost maritime transport, but also the rail sector (see Section *3.2.4, Shortsea Shipping Needs to Become Part of Intermodal Thinking*). This could be done through numerous actions, e.g., subsidies, regulations and general support. Although EU is not single responsible, the sectors themselves have to take joint responsibility to enhance peoples' perception of their business and industry.

From *Table 5-11*, it is clear that excluding Denmark as loading country has far more negative impact on the potential than excluding commodity types. Therefore, the system is far more sensitive when it comes to attracting a larger market than to provide transport services to many commodity types. Therefore the system should focus on competition based upon economical terms instead of wide commodity type service. From the sensitivity analysis (see Section *6.3, Sensitivity Analysis*), the potential market for the intermodal transportation system is foremost sensitive for the cost development of road transportation. According to our opinion, road transportation costs will continue to increase, putting intermodal transportation in a more favourable position.

We believe that the potential amount of goods that can be conquered by our intermodal transportation system is underestimated. The data used for obtaining this potential is of questionable accuracy, we believe that reality hides a large amount of transported goods by road transportation. However, the possibility of conquering this potential amount of goods is promising. According to our opinion, the advantages of the intermodal system, such as cost efficiency, environmental friendliness and the level of quality services are of such character and strategic importance that customers will be attracted of the intermodal transportation service. This implies that there are a potential to decrease the road transport network in Western Europe with 34 000 vehicles on a yearly basis, see Section *5.3.2, Potential Market (Potential 1).*

Our final recommendation is to construct a pilot project of this sea-based intermodal transportation system and to realise it as soon as possible, for the sake of the economy in Europe, its population and the environment.

# 8 Suggestions for Further Research

*In this chapter we present concepts for further research that we believe would be interesting to pursue, not only from an academic approach but also for the interests of the European Union and the future of sustainable development and intermodal transportation.*

From this potential-capacity comparison (see Section *5.3.2, Potential Market (Potential 1)*) it is obvious that the assumption made about one vessel operating one link is not necessary. From a scenario perspective, the intermodal transportation system has the possibility of operating more than one link per vessel. With this reflection in mind, trade between different ports and regions in Western Europe could be considered and exploit.

For further research the possibility of extending the study to include the transport alternative of inland waterway transportation could be useful to explore. The opportunity of using commodity type division that has a higher level of detail than NST/R24 should also be considered.

Further explore the possibilities of appointing a channel captain, analyse the required prerequisites and suggest an appropriate solution focused on maximising the performance of the whole transport chain.

An in-depth market research and a thorough study of what regions should be served trough which ports should be useful before realising an intermodal transportation system of this nature.

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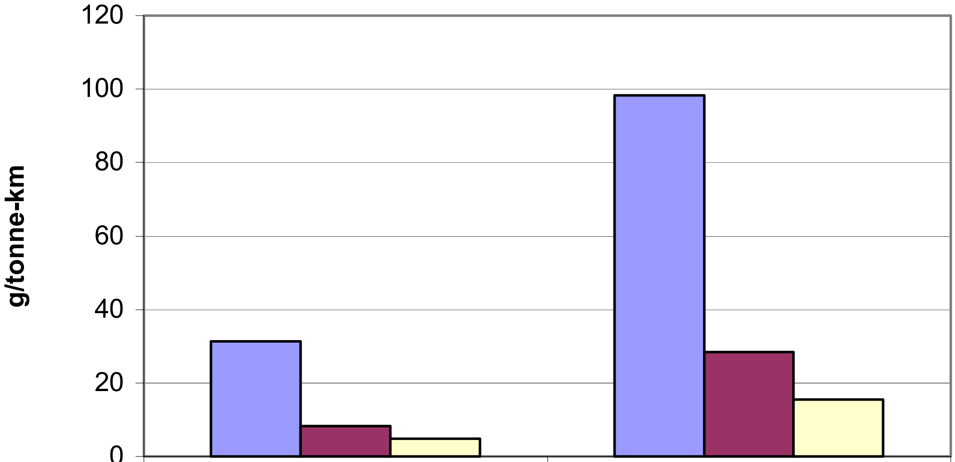
# 10 Appendix 1 - Environmental Indicators

The following estimates have been compiled under the auspices of the European Commission (Eurostat), and they are based on a couple of assumptions that are detailed below.[157]




| | Fuel consumption | CO2 |
|---|---|---|
| Road | 31,33 | 98,3 |
| Rail | 8,311 | 28,338 |
| SSS | 4,828 | 15,45 |

*Table 10-1, Estimated average fuel consumption and $CO_2$ emissions for road, rail and shortsea shipping (SSS) in grams/tonne-kilometre*

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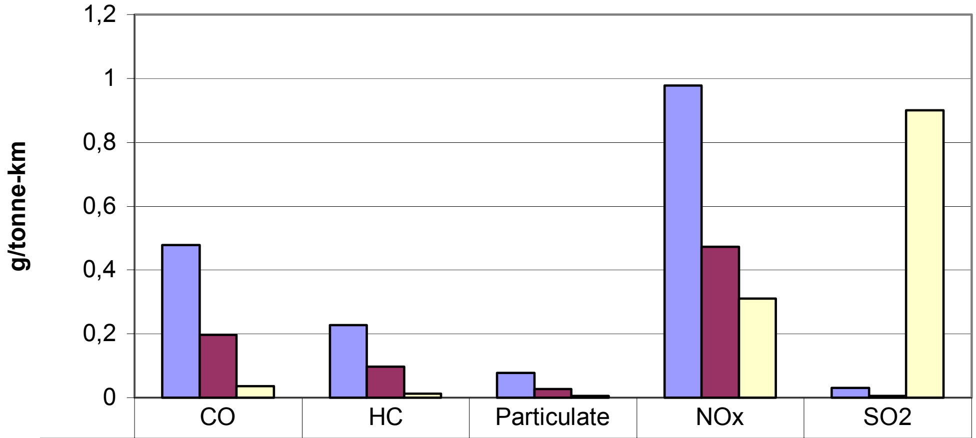
[157] Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions, The Development of Shortsea Shipping in Europe: *A Dynamic Alternative in a Sustainable Transport Chain*, Brussels, 1999




| | CO | HC | Particulate | NOx | SO2 |
|---|---|---|---|---|---|
| Road | 0,479 | 0,227 | 0,078 | 0,978 | 0,031 |
| Rail | 0,196 | 0,098 | 0,027 | 0,472 | 0,006 |
| SSS | 0,036 | 0,012 | 0,006 | 0,311 | 0,9 |

*Table 10-2, Estimated average CO, hydrocarbon, particulate, $NO_x$ and $SO_2$ emission from road transport, rail transport and shortsea shipping in grams/tonne-kilometre*

The basic assumptions used in the calculations are as follows:

**Road**: Vehicle weight categories: 5,5-36 tonnes; Representative speeds: rural areas 50 km/h, highways 80 km/h (emission factors speed dependent); Load carrying capacity: (Gross vehicle weight-1,5921)/1,3228; Loading factors 50% and 100%; Lower heating value of diesel 42,5 MJ/kg; Sulphur content in diesel 0,0005 kg/kg. Emission factors for a 36 t vehicle loaded 100% (COPERT methodology): fuel consumption: 350,908; $CO_2$: 1101,007; CO: 2,151; VOC (HC): 0,858; Particulate: 0,564; $NO_x$: 13,590; and $SO_2$: 0,351 g/km.

**Rail**: Gross train weight: 250-2500 t; Proportion of train available for freight by mass: 0,6; Loading factors 65% and 100%; Lower heating value of diesel 42,5 MJ/kg; Energy consumption: EC=15,313*Gross weight^-0,6489 MJ/tkm. Emission factors: $CO_2$: 3,18; CO: 0,022; HC: 0,011; Particulate: 0,003; $NO_x$ 0,053; and $SO_2$ 0,004 g/g diesel.

**Shortsea shipping**: Container and bulk ships in categories 5000-10.000 gt; Average service speeds 19,09 (container carrier) and 14,32 (bulk carrier) knots; Fraction of dead weigh available for freight: 0,95; Typical loading factors 65% and 100% for container carriers and 50% and 100% for bulk carriers; Energy consumption (tonnes a day) for container carriers: EC=8,0552+0,00235*GT and for bulk carriers EC=0,9724+0,0019*GT; Assumed energy consumption reduction factor when running in ballast condition: 0,8; sulphur content of fuel 3%. Emission factors: $CO_2$: 3,2; CO: 0,0074; HC: 0,0024; Particulate: 0,0012; $NO_x$: 0,0645.

### *Land take (use)*

Transport infrastructure covers 1.2% of total available land area in the EU, ranging from about 0.5% to 4.5 % between the individual countries. During 1990-1996, 25000 ha, this is about 10 ha every day, were taken for motorway construction alone. Many areas in the EU are highly fragmented by transport infrastructure. The average size of contiguous land units that are not cut through by major transport infrastructure is 130 $km^2$, ranging from 20 $km^2$ in Belgium to 600 $km^2$ in Finland, with 7 EU countries lying far below the average. Depending on the type of infrastructure the land "affected" by transport infrastructure may be up to three times the direct land take. In many European areas land resources are relatively scarce. Land take in natural areas may lead to a decrease in biodiversity, as may fragmentation by linear infrastructure. Negative visual impacts on landscape also have to be taken in account.

### *Noise*

About 120 million people in the EU (32 % of population) are exposed to road traffic noise levels above 55 Ldn dB. More than

50 million people are exposed to levels above 65 Ldn dB (13 % of population). Some 10% of the EU population are exposed to rail traffic noise above 55 Ldn dB, and 1% is highly annoyed by rail traffic noise. Some 10 % of the total EU population may be highly annoyed by air transport noise.[158] Due to these facts this is of course a significant external effect, but there are much technical improvement done in this field and compared to the limits in noise, this can nowadays be considered as a limited problem. There are unfortunately still problems concerning air traffic and the noise arising from take-offs and landing, especially within "city-located" airports.

***Air emissions***

Regarding air pollution from transport there is a positive trend to be seen in recent years. In the period 1990 – 1996 $NO_x$ emissions have decreased by 12 %, and VOC emissions by 24 %. By 2020 $NO_x$ emissions from road transport are expected to diminish to 17 %, and VOC emissions to 11 % of 1990's figures. Thus $NO_x$ and VOC emissions are in line with the targets set in the *5th Environmental Action Programme* of the EU as well as the Protocol to the Convention on long-range transboundary air pollution to abate acidification, eutrophication and ground-level ozone.

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158 European Environment Agency, *Are we moving in the right direction? Indicators on transport environment integration in the EU*, Brussels, Belgium, 1999, European Communities

| Pullutant | | Total emissions EU 15 (1000 tonnes) | of which: transport (1000 tonnes) | | of which: Road transport (1000 tonnes) | |
|---|---|---|---|---|---|---|
| $NO_x$ | 1990 | 13257 | 7080 | 53% | 5549 | 42% |
| | 1996 | 11932 | 6255 | 52% | 4791 | 40% |
| | Evolution 1990-96 | *-10%* | *-12%* | | *-14%* | |
| CO | 1990 | 51218 | 33265 | 65% | 31394 | 61% |
| | 1996 | 40964 | 25449 | 62% | 23124 | 56% |
| | Evolution 1990-96 | *-20%* | *-23%* | | *-26%* | |
| VOC | 1990 | 15950 | 6287 | 39% | 5726 | 36% |
| | 1996 | 13807 | 4785 | 35% | 4267 | 31% |
| | Evolution 1990-96 | *-13%* | *-24%* | | *-25%* | |
| $SO_2$ | 1990 | 16459 | 693 | 4% | 467 | 3% |
| | 1996 | 9386 | 557 | 6% | 371 | 4% |
| | Evolution 1990-96 | *-43%* | *-20%* | | *-21%* | |

*Table 10-3, Emissions by type of pollutant*[159]

[159] Eurostat; "EEA Data Service, compiled by ETC/AE, October 1999"

# 11 Appendix 2 - Economical Model

### Economical calculation for Road transportation (Sheet: Road)

eko_kalkyl_formler3

| | A | B | C |
|---|---|---|---|
| 1 | *Transport cost for Road* | | |
| 2 | *Road* | | |
| 3 | Road distance (one way), km | X | |
| 4 | Vehicle average speed (km/h) | X | |
| 5 | Truck cost (EUR/km) | X | |
| 6 | Handling time | X | |
| 7 | Road transport time (one way) | B3/B4+B6 | |
| 8 | Cost for road distance | B3*B5 | |
| 9 | | | |
| 10 | **Road transport time (one way) hours** | **B3/B4** | |
| 11 | **Cost for 40' container** | **B8** | |
| 12 | **Cost for 20' container** | **B8/2** | |
| 13 | | | |
| 14 | | | |

*Table 11-1, Economical calculation for Road transportation*

### Economical calculation for Sea transportation (Sheet: Sea)

| | A | B |
|---|---|---|
| 1 | *Container Vessel (EUR)* | |
| 2 | Vessel characteristics | |
| 3 | Ship size (dwt) | X |
| 4 | Ship size (GT) | X |
| 5 | Ship size (NT) | X |
| 6 | Newbuilding price (EUR) | X |
| 7 | Economic life of ship | X |
| 8 | Interest rate % | X |
| 9 | Capacity (TEU) | X |
| 10 | Nr. of 20' containers handled | X |
| 11 | Nr. of 40' containers handled | X |
| 12 | Average service speed | X |
| 13 | Bunker cost (EUR/tonne) | X |
| 14 | Fuel consumption (tonne/day) | (B3/(0,49*1000))*(B12/14) |
| 15 | Utilisation rate (%) | ((B11*2+B10)/(B9*2)) |
| 16 | | |
| 17 | Crew data | |
| 18 | No. of crew | X |
| 19 | Leave factor | X |
| 20 | Cost /crew member | X |
| 21 | Days vessel is operational (excl. R&M) | X |

| | A | B |
|---|---|---|
| 21 | Days vessel is operational (excl. R&M) | X |
| 22 | | |
| 23 | **Port data (port of Gothenburg)** | |
| 24 | Crane capacity per hour | X |
| 25 | Nr. of cranes | X |
| 26 | Total handling time (hours) | ((B10+B11)/((B24*B25))) |
| 27 | Pilotage time | X |
| 28 | ***Fairway due (EUR/GT)*** | |
| 29 | Environmental dues (EUR/gt)) | X |
| 30 | Fairway dues on goods (EUR/nt) | X |
| 31 | ***Harbour dues for container ship (EUR/gt)*** | X |
| 32 | ***Harbour dues for cargo*** | |
| 33 | 20 foot container (EUR/unit) | X |
| 34 | 40 foot container (EUR/unit) | X |
| 35 | ***Agency fee (EUR/call)*** | X |
| 36 | ***Average stevedore's tariffs*** | |
| 37 | 20' container (EUR/unit) | X |
| 38 | 40' container (EUR/unit) | X |
| 39 | ***Pilotage dues*** | X |
| 40 | ***Boatmen*** | X |

| | A | B |
|---|---|---|
| 41 | | |
| 42 | **Route data** | |
| 43 | Route distance (Nautical miles) | X |
| 44 | Number of stops in ports | 2 |
| 45 | Route distance (km), one way | (B43*1,852)/2 |
| 46 | Route time on sea (hours) | (B43)/B12 |
| 47 | Time in ports (hours) | B26*B44 |
| 48 | Fairway time (2*pilotage time*nr.of ports) hours | 2*B27*B44 |
| 49 | Cycle time (hours) | B46+B47+B48 |
| 50 | Routes/year | (B21*24)/B49 |
| 51 | | |
| 52 | | |
| 53 | | |
| 54 | ***Sea Transport costs*** | |
| 55 | | |
| 56 | | |
| 57 | ***Capital cost*** | |
| 58 | Annuity factor | (B8/(1-(1+B8)^(-B7))) |
| 59 | Yearly capital cost | **B6*B58** |

| | A | B |
|---|---|---|
| 61 | *Voyage cost* | |
| 62 | Fuel cost, yearly (EUR) | ((B50*B46)/24)*B14*B13 |
| 63 | Port cost (per route) | ((B29+B31)*B4+B30*B5+B35+B39+B40)*B44 |
| 64 | Port cost (yearly) | B63*B50 |
| 65 | Yearly voyage cost | **B62+B64** |
| 66 | | |
| 67 | *Operating cost* | |
| 68 | Costs for Repair & Maintenance | X |
| 69 | ***Insurance costs*** | |
| 70 | H&M (EUR) | X |
| 71 | P&I (EUR) | X |
| 72 | Cost of crew (yearly) | B18*B19*B20 |
| 73 | Yearly operating cost | **B68+B70+B71+B72** |
| 74 | | |
| 75 | *Cargo handling cost* | |
| 76 | Harbour dues for cargo and costs of stevedoring/per route | ((B33+B37)*B10+(B34+B38)*B11)*2 |
| 77 | Yearly cargo handling cost | **B76*B50** |
| 78 | | |
| 79 | **Total cost, yearly** | **B59+B65+B73+B77** |
| 80 | **Container capacity per year (20')** | **B50*((B10+B11))** |
| 81 | **Average time (dock-to-dock) per container** | **B46/2+B47*(3/4)+B48/2** |
| 82 | **Average route cost per container (20')** | **B79/B80** |

*Table 11-2, Economical calculation for Sea transportation*

## Pilotage tariffs (Sheet: port-tariffs)

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **Pilotage Dues (EUR)** | | | |
| 2 | | ***Gross tonnage*** | | |
| 3 | ***Piloted time, h*** | 5001-8000 | 8001-12000 | 12001-20000 |
| 4 | 1 | 377 | 424 | 471 |
| 5 | 1,5 | 445 | 500 | 556 |
| 6 | 2 | 512 | 577 | 641 |
| 7 | 2,5 | 580 | 653 | 725 |
| 8 | 3 | 648 | 729 | 810 |
| 9 | 3,5 | 716 | 805 | 895 |
| 10 | | | | |
| 11 | | | | |
| 12 | **Boatmen (EUR)** | | | |
| 13 | ***GT*** | ***Arrival*** | ***Departure*** | ***Total*** |
| 14 | 6101-6800 | 123 | 62 | 185 |
| 15 | 6801-10200 | 156 | 78 | 234 |
| 16 | 10201-14000 | 187 | 93 | 280 |
| 17 | 14001-21000 | 221 | 111 | 332 |
| 18 | 21001-26000 | 273 | 137 | 410 |

*Table 11-3, Pilotage tariffs for Port of Gothenburg*

## *Economical calculation for Sea/Road transportation (Sheet: Sea & Road)*

| | A | B |
|---|---|---|
| 1 | *Transport cost for Sea/Road* | |
| 2 | ***Road*** | |
| 3 | Road distance (one way) | X |
| 4 | Vehicle average speed (km/h) | Road!B4 |
| 5 | Truck cost (EUR/km) | Road!B5 |
| 6 | Cost for road distance | B3*B5 |
| 7 | Handling time | Road!B6 |
| 8 | Road transport time (one way) | B3/B4+B7 |
| 9 | Total cost for road transport (20') | (B5*B3*(Sea!B10/2)*Sea!B50) |
| 10 | Total cost for road transport (40') | B3*B5*(Sea!B11)*Sea!B50 |
| 11 | Cost for 20' container | **(B9/Sea!B10)/Sea!B50** |
| 12 | Cost for 40' container | **(B10/(Sea!B11))/Sea!B50** |
| 13 | | |
| 14 | ***Sea*** | |
| 15 | **Total cost for sea transportation** | **Sea!B79** |
| 16 | Number of 20' containers | Sea!B10+Sea!B11*2 |
| 17 | Route distance (km), one way | Sea!B45 |
| 18 | Average time (door-to-door)per container | Sea!B81 |
| 19 | **Average cost per container** | **Sea!B82** |
| 21 | ***Transportation system*** | |
| 22 | **Total time (door-to-door), hours** | **B18+B8** |
| 23 | **Total distance** | **B17+B3** |
| 24 | **Total cost, yearly** | **B15+(B9+B10)** |
| 25 | ***Average cost per 20' container*** | ***B24/(Sea!B80)*** |

*Table 11-4, Economical calculation for Sea/Road transportation*

## *Economical calculation for Sea/Rail/Road transportation (Sheet: Sea & Rail & Road)*

| | A | B |
|---|---|---|
| 1 | *Transport cost for Sea/Rail/Road* | |
| 2 | ***Road*** | |
| 3 | Road distance (one way) km | X |
| 4 | Vehicle average speed (km/h) | Road!B4 |
| 5 | Truck cost (EUR/km) | Road!B5 |
| 6 | Cost for road distance | B3*B5 |
| 7 | Handling time | Road!B6 |
| 8 | Road transport time (one way) | B3/B4+B7 |
| 9 | **Total cost for road transport (20')** | **(B5*B3*(Sea!B10/2)*Sea!B50)** |
| 10 | **Total cost for road transport (40')** | B3*B5*(Sea!B11)*Sea!B50 |
| 11 | Cost for 20' container | B6/2 |
| 12 | Cost for 40' container | B6 |
| 13 | | |
| 14 | ***Sea*** | |
| 15 | **Total cost for sea transportation** | **Sea!B79** |
| 16 | Number of 20' containers | Sea!B10+Sea!B11*2 |
| 17 | Route distance (km), one way | Sea!B45 |
| 18 | Average time (door-to-door)per container | Sea!B81 |
| 19 | Average cost per 20' container | Sea!B82 |
| 21 | ***Train*** | |
| 22 | Capacity (20' containers) | X |
| 23 | Rail distance, one way (km) | X |
| 24 | Vehicle average speed (km/h) | X |
| 25 | Rail cost (EUR/km) | X |
| 26 | Average handling time per container (hour) | X |
| 27 | Total cost for rail distance | B23*B25*(B16/B22) |
| 28 | Rail transport time (one way) hours | B23/B24+B26 |
| 29 | **Total cost for rail transport** | **(B27*Sea!B50)** |
| 30 | Average cost per 20' container | B29/Sea!B80 |
| 31 | | |
| 32 | ***Transportation system*** | |
| 33 | **Total time (door-to-door), hours** | **B8+B18+B28** |
| 34 | **Total distance** | **B3+B17+B23** |
| 35 | **Total cost, yearly** | **B9+B10+B15+B29** |
| 36 | ***Average cost per 20' container*** | **B35/(B16*Sea!B50)** |

*Table 11-5, Economical calculation for Sea/Rail/Road transportation*

# 12 Appendix 3 – List of Assumption

In this appendix we list all the main assumptions made in our research and some of the approximations and estimations important for the structure and result of our research.

- As stated in Section *3.5.1 Road Haulage* we assume that a road vehicle either carries one 40-foot container or two 20-foot containers.
- The point of origin is set to the Port of Gothenburg; the reason for this is that the Port of Gothenburg is the biggest and most developed port in the Scandinavian area.
- Cost for transportation from Gothenburg does not include transportation costs for bringing the goods to the point of origin (Gothenburg). Since every transportation alternative includes this movement this consideration is not necessary because we are only interested in comparing the different alternatives.
- We assume that on every route the vessels will travel non-stop during a whole year (365 days per year).
- The flows between the origin in Scandinavia and the end customer in Western Europe are not balanced, however we have chosen to calculate the costs for our intermodal transportation system from the total capacity of the system, i.e., both ways (route capacity).
- The breakeven point between rail and road transportation is set to 300 kilometres. This might be perceived as an assumption favouring rail transportation, which is true. This assumption is set from an economical, social and environmental perspective, not only from an economical point of view. This assumption is partly based upon the data in Table 3-2 (For more information about this

assumption see Section *5.2.2.1 The Sea/Road Transportation Alternative*).

- For the calculation of the geographical area the interval between the economical EDC:s is set to 300 kilometres. This gives us a desirable level of detail and a reasonable demand for time and resources.
- To simplify the data handling we assume that the amount of goods from the area of loading corresponds to the loading countries population. In Section *5.3.1 Statistical Data* we stated that the area of loading was about 11 million people out of a total population of 19 million people in the loading countries. We do not believe that this assumption influences the results in a severe manner, since the population density near the Port of Gothenburg is very high and much of the goods transferred from and to these countries goes through the surroundings of Gothenburg. This assumption is mainly influenced by the choice of catchment area for the Port of Gothenburg, which is dependent on many factors.
- When considering the alternative of Sea/Rail/Road transportation the road transportation movement is approximated to an average of 50 kilometres.
- For rail transportation we assume that a train set leaving the port consist of 50 twenty-foot containers.
- The data quality is better from the Comext database than the data extracted from New Cronos, however the Comext database lacks data of Norway as country of loading. Therefore, we have chosen to use data for Sweden and Denmark from the Comext database and data from the New Cronos database for Norway. An analysis between the quality of data is done in Chapter 6*, Analysis*.
- Since each of the individual tables between country of origin and country of destination lacks much data, we have

chosen to use the distribution function for *Table 5-14, Commodity type distribution from Sweden to the EU15 countries* to be representative for commodity types transported. This assumption can easily be debated but on the other hand it influences the final result (potential 2) to a low extent.

- Concerning potential 2 we have made the limitation that the throughput time for the intermodal transportation system is maximum one week, which is due to the quality dimension of time, discussed in *3.3.1 Quality Aspects of Transportation Services*. We assume that the transportation service will not be competitive if the throughput time is longer than one week.

# 13 Appendix 4 - Maps

In the table below the distances for a round trip between Gothenburg and different ports are specified. The distance is calculated from a digital Atlas (*Universal Auto Atlas for Windows).* The distance for road transportation is calculated as a euclidian distance, the road transportation distance in our research is therefore shorter than the actual distance. This approximation favours the reliability of our intermodal system, resulting in a smaller potential geographical market and a smaller potential amount of goods. On the other hand this approximation increases the validity of our final result, namely the potential amount of goods that can be transferred to the intermodal system.

| Port | Gothenburg |
|---|---|
| **Hamburg** | 760 |
| **Rotterdam** | 1080 |
| **Antwerp** | 1190 |
| **Le Havre** | 1350 |
| **Nantes Saint-Nazaire** | 2100 |
| **Bilbao** | 2440 |
| **Sines** | 3185 |
| **Valencia** | 4500 |
| **Marseille** | 5160 |

*Table 13-1, Distance between Port of Gothenburg for the selected ports (in nautical miles for round trip)*


*Figure 13-1, Map of Europe, source: http://3dworldmap.com/Europe.html*


**X** EUR **(Y)** hours

*Figure 13-2, EDC:s (300 km) with Gothenburg as origin (road transportation).*


*Figure 13-3, EDC:s (300 km) with Port of Hamburg as origin.*


*Figure 13-4, EDC:s (300 km) with Port of Rotterdam as origin.*


*Figure 13-5, EDC:s (300 km) with Port of Antwerp as origin.*


*Figure 13-6, EDC:s (300 km) with Port of Le Havre as origin.*


*Figure 13-7, EDC:s (300 km) with Port of Nantes Saint-Nazaire as origin.*


*Figure 13-8, EDC:S (300 km) with Port of Bilbao as origin.*


*Figure 13-9, EDC:s (300 km) with Port of Sines as origin.*


*Figure 13-10, EDC:s (300 km) with Port of Valencia as origin.*


Figure 13-11, EDC:s (300 km) with Port of Marseille as origin.


**X** EUR **(Y)** hours

*Figure 13-12, Economical break-point between the different transport alternatives (1st. port)*


**X** EUR **(Y)** hours

*Figure 13-13, Economical break-point between the different transport alternatives (2nd. port)*


**X** EUR **(Y)** hours

*Figure 13-14, Economical break-point between the different transport alternatives (3rd. port)*


**X** EUR **(Y)** hours

*Figure 13-15, Economical break-point between the different transport alternatives (4th. port)*


**X** EUR **(Y)** hours

*Figure 13-16, Economical break-point between the different transport alternatives (5th. port)*


**X** EUR **(Y)** hours

*Figure 13-17, Economical break-point between the different transport alternatives (6th. port)*


X EUR (Y) hours

*Figure 13-18, Economical break-point between the different transport alternatives (7th. port)*


**X** EUR **(Y)** hours

*Figure 13-19, Economical break-point between the different transport alternatives (8th. port)*


**X** EUR **(Y)** hours

*Figure 13-20, Economical break-point between the different transport alternatives (9th. port)*

# 14 Appendix 5 - Statistics

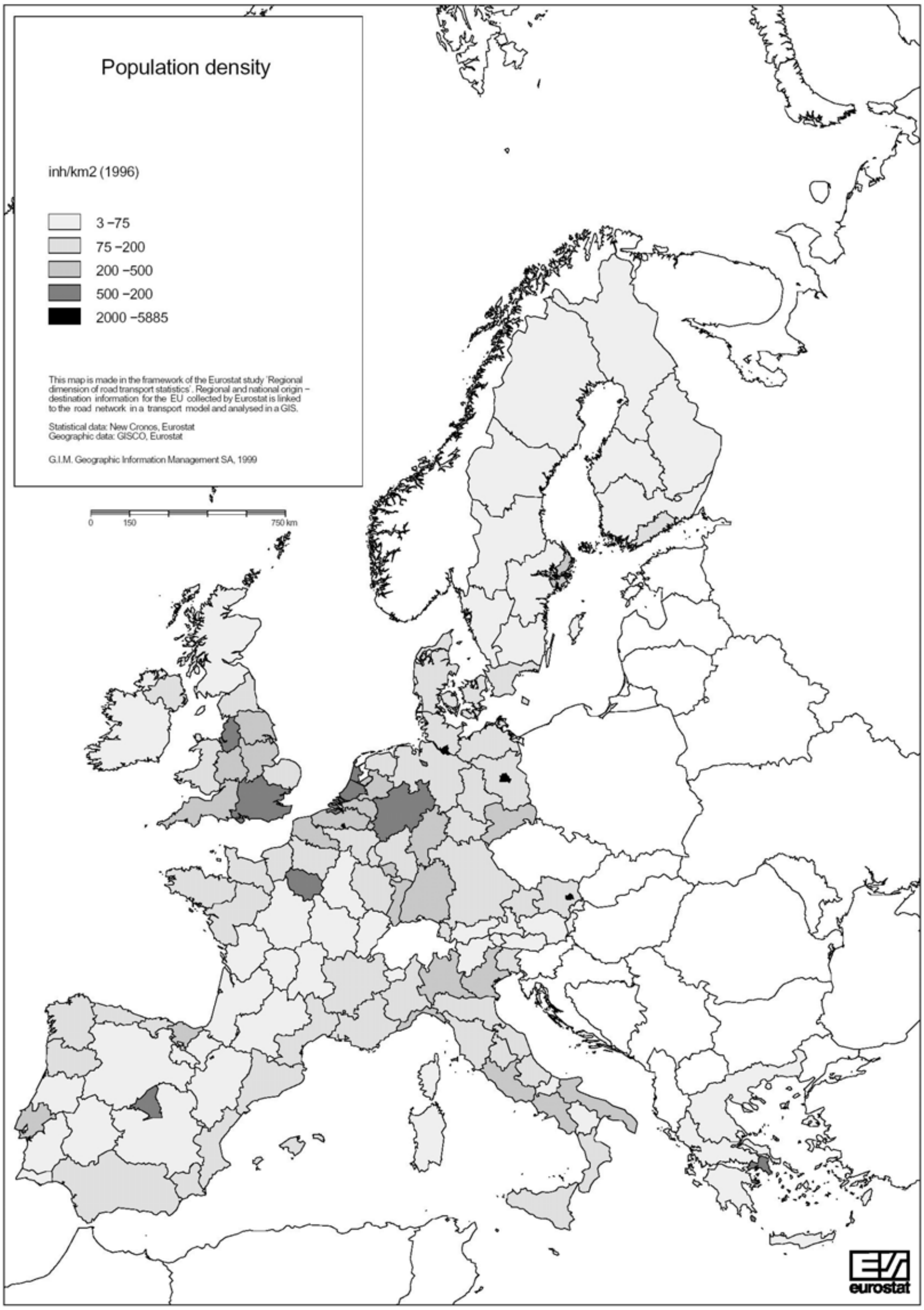


*Figure 14-1, Population density,* This map is made within the framework of the Eurostat study "Regional dimension of road transport statistics"

## Population distribution in the EU-countries and candidate countries 2000

| Country | Number |
|---|---|
| Germany | 82 |
| Turkey | 64 |
| Great Britain | 60 |
| France | 59 |
| Italy | 58 |
| Spain | 39 |
| Poland | 39 |
| Rumania | 22 |
| The Netherlands | 16 |
| Greece | 11 |
| Czech Republic | 10 |
| Belgium | 10 |
| Hungary | 10 |
| Portugal | 10 |
| Sweden | 9 |
| Belarus | 8 |
| Austria | 8 |
| Slovenia | 5 |
| Denmark | 5 |
| Finland | 5 |
| Ireland | 4 |
| Latvia | 4 |
| Lithuania | 2 |
| Slovenia | 2 |
| Estonia | 1 |
| Cyprus | 1 |
| Luxemburg | 0 |
| Malta | 0 |
| *(Norway)* | *4,5* |
| | |
| Total | 376 |
| Total | 170 |

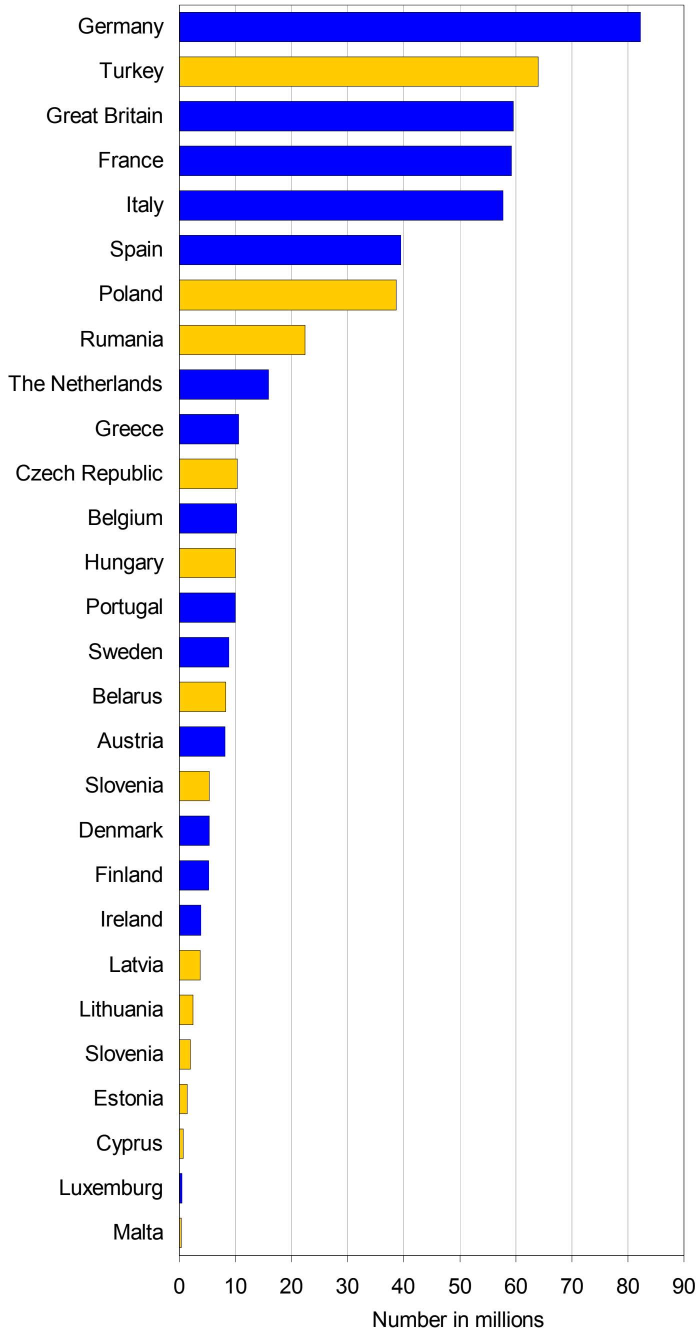


*Table 14-1, European population distribution, source: http://www.scb.se/internationellt / eu/befolkning.asp*

## New Cronos Data Extraction

***Released date : Wed, 27 Nov 02 01:14:06***

| | | |
|---|---|---|
| **theme** | theme7 | Transport |
| **domain** | road | B. Road transport |
| **collect** | romegood | B.V3. Transport measurement - goods |
| **table** | rogoiult | 03. International annual transport by link with unloading country, by group of goods and type of carriage (1000 T) |

| | |
|---|---|
| geo | dk Denmark |
| unit | 1000t Thousands of tonnes |
| carriage | tot Total |
| unload | eu15 European Union (15 countries) |

| nstr24 | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
|---|---|---|---|---|---|
| 25 Total from group 01 to 24 | | 6789 | 7628 | 7636 | 6293 |
| 01 Cereals | | 59 | 58 | 80 | 55 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | 184 | 192 | 256 | 218 |
| 03 Live animals, sugar beet | | 119 | 52 | 59 | 41 |
| 04 Wood and cork | | 208 | 244 | 301 | 258 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | 25 | 49 | 28 | 24 |
| 06 Foodstuff and animal fodder | | 1535 | 2237 | 2026 | 1890 |
| 07 Oil seeds and oleaginous fruits and fats | | 30 | 38 | 81 | 38 |
| 08 Solid minerals fuels | | : | 43 | : | 3 |
| 09 Crude petroleum | | 7 | 3 | 5 | 3 |
| 10 Petroleum products | | 6 | 17 | 16 | 10 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | 65 | 155 | 95 | 97 |
| 12 Non-ferrous ores and waste | | 45 | 64 | 47 | 62 |
| 13 Metal products | | 278 | 280 | 289 | 262 |
| 14 Cement, lime, manufactured building materials | | 411 | 511 | 628 | 324 |
| 15 Crude and manufactured minerals | | 536 | 386 | 360 | 286 |
| 16 Natural and chemical fertilizers | | 6 | 29 | 11 | 35 |
| 17 Coal chemicals, tar | | 23 | 20 | 20 | 16 |
| 18 Chemicals other than coal chemicals and tar | | 169 | 206 | 176 | 271 |
| 19 Paper pulp and waste paper | | 224 | 185 | 228 | 184 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 411 | 337 | 336 | 256 |
| 21 Manufactures of metal | | 134 | 121 | 166 | 225 |
| 22 Glass, glassware, ceramic products | | 54 | 70 | 83 | 48 |
| 23 Leather, textile, clothing, other manufactured articles | | 679 | 584 | 490 | 458 |
| 24 Miscellaneous articles | | 1583 | 1748 | 1853 | 1226 |

*Table 14-2, International annual transport from Denmark to EU15 by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | dk Denmark | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | es Spain | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 101 | 137 | 178 | 147 |
| 01 Cereals | | 0 | 3 | 2 | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | 3 | 2 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | 0 | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | 2 | : | 2 | 0 |
| 06 Foodstuff and animal fodder | | 49 | 76 | 85 | 84 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | 2 | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | 0 | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | 4 | : | 1 | 0 |
| 14 Cement, lime, manufactured building materials | | : | 1 | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 3 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | 2 | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 4 | 7 | 3 | 13 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 4 | 11 | 10 | 7 |
| 21 Manufactures of metal | | : | : | 6 | 1 |
| 22 Glass, glassware, ceramic products | | 4 | : | 6 | 1 |
| 23 Leather, textile, clothing, other manufactured articles | | 9 | 4 | 8 | 6 |
| 24 Miscellaneous articles | | 24 | 32 | 51 | 30 |

*Table 14-3, International annual transport from Denmark to Spain by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | dk Denmark | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | fr France | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 409 | 534 | 562 | 500 |
| 01 Cereals | | 1 | : | 4 | 3 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | 12 | 11 | 18 | 9 |
| 03 Live animals, sugar beet | | : | : | 3 | 0 |
| 04 Wood and cork | | 8 | 10 | 5 | 10 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | 4 | 1 | 3 | 1 |
| 06 Foodstuff and animal fodder | | 139 | 220 | 198 | 197 |
| 07 Oil seeds and oleaginous fruits and fats | | 5 | 7 | 7 | 3 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | 0 | 2 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | 3 | : | 2 |
| 13 Metal products | | 31 | 28 | 21 | 15 |
| 14 Cement, lime, manufactured building materials | | 3 | 5 | 6 | 2 |
| 15 Crude and manufactured minerals | | 1 | 9 | 20 | 10 |
| 16 Natural and chemical fertilizers | | : | 2 | 1 | 3 |
| 17 Coal chemicals, tar | | : | 0 | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 13 | 13 | 17 | 27 |
| 19 Paper pulp and waste paper | | 2 | 1 | 11 | 3 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 34 | 25 | 35 | 22 |
| 21 Manufactures of metal | | 14 | 9 | 9 | 11 |
| 22 Glass, glassware, ceramic products | | 4 | 8 | 5 | 6 |
| 23 Leather, textile, clothing, other manufactured articles | | 50 | 74 | 62 | 67 |
| 24 Miscellaneous articles | | 87 | 109 | 135 | 107 |

*Table 14-4, International annual transport from Denmark to France by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | dk Denmark | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | it Italy | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 413 | 424 | 386 | 402 |
| 01 Cereals | | : | 0 | 3 | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | 13 | 10 | 10 | 19 |
| 03 Live animals, sugar beet | | 3 | 1 | 0 | 4 |
| 04 Wood and cork | | 2 | 0 | 2 | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | 6 | 9 | 6 | 6 |
| 06 Foodstuff and animal fodder | | 231 | 247 | 218 | 225 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | 2 | : | 0 |
| 10 Petroleum products | | 2 | 2 | 0 | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | 3 | : | 2 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | 4 | 3 | 7 |
| 14 Cement, lime, manufactured building materials | | : | 2 | : | 2 |
| 15 Crude and manufactured minerals | | 4 | : | : | 1 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | 2 | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 9 | 14 | 5 | 7 |
| 19 Paper pulp and waste paper | | : | 0 | 1 | 1 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 31 | 22 | 19 | 11 |
| 21 Manufactures of metal | | 4 | 4 | 3 | 8 |
| 22 Glass, glassware, ceramic products | | 1 | 4 | 5 | 2 |
| 23 Leather, textile, clothing, other manufactured articles | | 30 | 20 | 24 | 30 |
| 24 Miscellaneous articles | | 74 | 80 | 86 | 77 |

*Table 14-5, International annual transport from Denmark to Italy by group of goods in (1000T)*

| | |
|---|---|
| geo | dk Denmark |
| unit | 1000t Thousands of tonnes |
| carriage | tot Total |
| unload | pt Portugal |

| nstr24 | time 2001a00 | 2000a00 | 1999a00 | 1998a00 |
|---|---|---|---|---|
| 25 Total from group 01 to 24 | 20 | 18 | 14 | 7 |
| 01 Cereals | : | 0 | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | : | 2 | : | 0 |
| 03 Live animals, sugar beet | 1 | : | : | 0 |
| 04 Wood and cork | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | : | : | : | 0 |
| 06 Foodstuff and animal fodder | 19 | 15 | 9 | 3 |
| 07 Oil seeds and oleaginous fruits and fats | : | : | : | 0 |
| 08 Solid minerals fuels | : | : | : | 0 |
| 09 Crude petroleum | : | : | : | 0 |
| 10 Petroleum products | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | : | : | : | 0 |
| 12 Non-ferrous ores and waste | : | : | : | 0 |
| 13 Metal products | : | : | : | 0 |
| 14 Cement, lime, manufactured building materials | : | : | : | 0 |
| 15 Crude and manufactured minerals | : | : | : | 0 |
| 16 Natural and chemical fertilizers | : | : | : | 0 |
| 17 Coal chemicals, tar | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | : | : | : | 0 |
| 19 Paper pulp and waste paper | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | : | 1 | 1 | 1 |
| 21 Manufactures of metal | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | : | 0 | : | 0 |
| 24 Miscellaneous articles | : | : | 4 | 2 |

*Table 14-6, International annual transport from Denmark to Portugal by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | se Sweden | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | eu15 European Union (15 countries) | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 1482 | 1510 | 1156 | 1051 |
| 01 Cereals | | 27 | : | 1 | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | 9 | 0 | 2 | 5 |
| 03 Live animals, sugar beet | | 3 | 2 | 0 | 0 |
| 04 Wood and cork | | 34 | 53 | 93 | 51 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | 2 | : | 4 | 6 |
| 06 Foodstuff and animal fodder | | 52 | 82 | 64 | 93 |
| 07 Oil seeds and oleaginous fruits and fats | | 50 | 48 | 31 | 39 |
| 08 Solid minerals fuels | | : | 1 | 2 | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | 18 | 4 | 10 | 16 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | 7 | 12 | 11 |
| 12 Non-ferrous ores and waste | | 0 | 1 | 0 | 0 |
| 13 Metal products | | 92 | 82 | 69 | 86 |
| 14 Cement, lime, manufactured building materials | | 18 | 24 | 10 | 26 |
| 15 Crude and manufactured minerals | | : | 22 | 8 | 3 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | 4 | 4 | 5 | 0 |
| 18 Chemicals other than coal chemicals and tar | | 158 | 195 | 147 | 119 |
| 19 Paper pulp and waste paper | | 10 | 46 | 8 | 15 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 171 | 196 | 95 | 93 |
| 21 Manufactures of metal | | 42 | 26 | 25 | 26 |
| 22 Glass, glassware, ceramic products | | 6 | 5 | 7 | 4 |
| 23 Leather, textile, clothing, other manufactured articles | | 248 | 213 | 199 | 188 |
| 24 Miscellaneous articles | | 537 | 497 | 364 | 270 |

*Table 14-7, International annual transport from Sweden to EU15 by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | se Sweden | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | es Spain | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 40 | 10 | 13 | 18 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 0 |
| 03 Live animals, sugar beet | | 3 | : | : | 0 |
| 04 Wood and cork | | : | : | : | 1 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 0 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | 19 | : | 3 | 3 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 1 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 2 | 4 | 2 | 2 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | 0 | 1 | 1 |
| 21 Manufactures of metal | | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | 17 | 6 | 4 | 8 |
| 24 Miscellaneous articles | | : | : | 3 | 2 |

*Table 14-8, International annual transport from Sweden to Spain by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | se Sweden | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | fr France | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 63 | 100 | 78 | 102 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | 0 | : | : | 0 |
| 03 Live animals, sugar beet | | : | : | 0 | 0 |
| 04 Wood and cork | | 1 | : | 5 | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 1 |
| 06 Foodstuff and animal fodder | | 1 | 17 | 9 | 13 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 2 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | 5 | 9 | 4 | 6 |
| 14 Cement, lime, manufactured building materials | | 1 | : | 1 | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | 0 | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 13 | 1 | 9 | 5 |
| 19 Paper pulp and waste paper | | : | : | : | 2 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 14 | 23 | 7 | 9 |
| 21 Manufactures of metal | | : | 2 | 1 | 3 |
| 22 Glass, glassware, ceramic products | | 1 | 1 | 0 | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | 13 | 27 | 12 | 33 |
| 24 Miscellaneous articles | | 13 | 20 | 30 | 28 |

*Table 14-9, International annual transport from Sweden to France by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | se Sweden | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | it Italy | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 63 | 58 | 40 | 53 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 2 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | 3 | 2 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | 5 | 10 | 3 | 3 |
| 07 Oil seeds and oleaginous fruits and fats | | 1 | 1 | 1 | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | 9 | 8 | 8 | 11 |
| 14 Cement, lime, manufactured building materials | | 0 | : | 0 | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 1 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | 0 | 0 | 3 | 4 |
| 19 Paper pulp and waste paper | | : | : | 0 | 1 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | 32 | 20 | 2 | 7 |
| 21 Manufactures of metal | | : | : | 1 | 1 |
| 22 Glass, glassware, ceramic products | | : | : | 0 | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | 1 | 8 | 10 |
| 24 Miscellaneous articles | | 15 | 18 | 11 | 11 |

*Table 14-10, International annual transport from Sweden to Italy by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | se Sweden | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | pt Portugal | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | 1 | 12 | 3 | 1 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 0 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 0 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | 1 | 0 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 0 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | 12 | : | 0 |
| 21 Manufactures of metal | | 1 | : | 0 | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | 1 | 0 |
| 24 Miscellaneous articles | | : | : | 1 | 1 |

*Table 14-11, International annual transport from Sweden to Portugal by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | no Norway | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | eu15 European Union (15 countries) | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | : | : | : | 1862 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 11 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 257 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 3 |
| 06 Foodstuff and animal fodder | | : | : | : | 397 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 2 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 16 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 11 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | : | 238 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 6 |
| 15 Crude and manufactured minerals | | : | : | : | 21 |
| 16 Natural and chemical fertilizers | | : | : | : | 11 |
| 17 Coal chemicals, tar | | : | : | : | 19 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 219 |
| 19 Paper pulp and waste paper | | : | : | : | 43 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | : | : | 96 |
| 21 Manufactures of metal | | : | : | : | 3 |
| 22 Glass, glassware, ceramic products | | : | : | : | 7 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | : | 223 |
| 24 Miscellaneous articles | | : | : | : | 280 |

*Table 14-12, International annual transport from Norway to EU15 by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | no Norway | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | es Spain | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | : | : | : | 21 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 0 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 7 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | : | 2 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 1 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | : | : | 6 |
| 21 Manufactures of metal | | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | : | 2 |
| 24 Miscellaneous articles | | : | : | : | 4 |

*Table 14-13, International annual transport from Norway to Spain by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | no Norway | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | fr France | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | : | : | : | 99 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 1 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 68 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | : | 4 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 11 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | : | : | 2 |
| 21 Manufactures of metal | | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | : | 7 |
| 24 Miscellaneous articles | | : | : | : | 6 |

*Table 14-14, International annual transport from Norway to France by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | no Norway | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | it Italy | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | : | : | : | 57 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 0 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 14 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | : | 19 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 10 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | : | : | 2 |
| 21 Manufactures of metal | | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | : | 3 |
| 24 Miscellaneous articles | | : | : | : | 8 |

*Table 14-15, International annual transport from Norway to Italy by group of goods in (1000T)*

| | | | | | |
|---|---|---|---|---|---|
| geo | no Norway | | | | |
| unit | 1000t Thousands of tonnes | | | | |
| carriage | tot Total | | | | |
| unload | pt Portugal | | | | |
| | time | 2001a00 | 2000a00 | 1999a00 | 1998a00 |
| nstr24 | | | | | |
| 25 Total from group 01 to 24 | | : | : | : | 13 |
| 01 Cereals | | : | : | : | 0 |
| 02 Potatoes, other fresh or frozen fruits and vegetables | | : | : | : | 0 |
| 03 Live animals, sugar beet | | : | : | : | 0 |
| 04 Wood and cork | | : | : | : | 0 |
| 05 Textiles, textile articles and man-made fibres, other raw animal and vegetable materials | | : | : | : | 0 |
| 06 Foodstuff and animal fodder | | : | : | : | 12 |
| 07 Oil seeds and oleaginous fruits and fats | | : | : | : | 0 |
| 08 Solid minerals fuels | | : | : | : | 0 |
| 09 Crude petroleum | | : | : | : | 0 |
| 10 Petroleum products | | : | : | : | 0 |
| 11 Iron ore, iron and steel waste and blast furnace dust | | : | : | : | 0 |
| 12 Non-ferrous ores and waste | | : | : | : | 0 |
| 13 Metal products | | : | : | : | 1 |
| 14 Cement, lime, manufactured building materials | | : | : | : | 0 |
| 15 Crude and manufactured minerals | | : | : | : | 0 |
| 16 Natural and chemical fertilizers | | : | : | : | 0 |
| 17 Coal chemicals, tar | | : | : | : | 0 |
| 18 Chemicals other than coal chemicals and tar | | : | : | : | 0 |
| 19 Paper pulp and waste paper | | : | : | : | 0 |
| 20 Transport equipment, machinery, apparatus, engines, whether or not assembled, and parts thereof | | : | : | : | 0 |
| 21 Manufactures of metal | | : | : | : | 0 |
| 22 Glass, glassware, ceramic products | | : | : | : | 0 |
| 23 Leather, textile, clothing, other manufactured articles | | : | : | : | 0 |
| 24 Miscellaneous articles | | : | : | : | 0 |

*Table 14-16, International annual transport from Norway to Portugal by group of goods in (1000T)*

# *Extraction from the Comext Database (Extracted 2002-12-03)*

Table generation of Extraction from Plan 'trans'

| | |
|---|---|
| PRODUCT(B): | TOT |
| FLOW(L): | IMPORT |
| TRANSPORT_MODE(L): | Road |
| CONTAINER_CODE(L): | (+Total2) |
| INDICATORS(L): | (tonne) |

| | Jan.-Dec. 1998 | | Jan.-Dec. 1999 | | Jan.-Dec. 2000 | | Jan.-Dec. 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden |
| +WORLD | 4472285 | 4264821 | 4920342 | 5140428 | 4929582 | 5401755 | 3337739 | 3235337 |
| +EXTRA-EUR | 781090 | 2540203 | 934417 | 2749829 | 1028792 | 2655741 | 1215286 | 3038783 |
| +INTRA-EUR | 3691195 | 1724618 | 3985925 | 2390599 | 3900790 | 2746014 | 2122453 | 196554 |
| France | 235244 | 81516 | 216516 | 121359 | 232304 | 142356 | 101158 | 12816 |
| Belg.-Luxbg | 216824 | 85892 | * | * | * | * | * | * |
| Netherlands | 407760 | 136126 | 765736 | 216273 | 394011 | 268439 | 237591 | 24133 |
| Fr Germany | 1405914 | 434901 | 1237826 | 581848 | 1416546 | 781334 | 824341 | 63550 |
| Italy | 152193 | 65968 | 142336 | 107745 | 156075 | 132065 | 87042 | 23748 |
| Utd. Kingdom | 136234 | 95476 | 160552 | 138678 | 179404 | 158044 | 91823 | 17342 |
| Ireland | 6508 | 7908 | 6639 | 11053 | 14902 | 17374 | 7764 | 1369 |
| Denmark | * | 207888 | * | 309373 | * | 325436 | * | 12576 |
| Greece | 4203 | 1296 | 3323 | 3055 | 5274 | 4686 | 5400 | 215 |
| Portugal | 11817 | 5786 | 10404 | 20933 | 10080 | 11187 | 2941 | 700 |
| Spain | 81413 | 26193 | 93664 | 46912 | 136886 | 66408 | 113349 | 7443 |
| Belgium | * | * | 166123 | 106302 | 186715 | 129268 | 73661 | 8100 |
| Luxembourg | * | * | 10278 | 13379 | 10636 | 6528 | 2376 | 669 |
| Iceland | 52 | 461 | 99 | 348 | 4653 | 35 | 1801 | 532 |
| Norway | 63719 | 2246821 | 58073 | 2416605 | 89674 | 2347844 | 119515 | 2645262 |
| Sweden | 883794 | * | 945003 | * | 913763 | * | 424757 | * |
| Finland | 106978 | 554294 | 161268 | 671119 | 195750 | 655822 | 117446 | 22637 |
| Liechtenstein | 78 | 754 | 46 | 946 | 26 | 962 | 426 | 929 |
| Austria | 42301 | 21373 | 66228 | 42570 | 48438 | 47068 | 32776 | 1256 |
| Switzerland | 52166 | 26140 | 51728 | 32207 | 54483 | 34296 | 58213 | 37376 |
| Malta | 63 | 39 | 36 | 44 | 29 | 44 | 53 | 69 |
| San Marino | 79 | 34 | 70 | 30 | 78 | 77 | 38 | 43 |
| Turkey | 14185 | 4909 | 14714 | 7400 | 19868 | 7687 | 26361 | 8303 |
| Estonia | 11161 | 10880 | 14709 | 35669 | 14167 | 15760 | 17502 | 22314 |
| Latvia | 12094 | 11298 | 9902 | 9024 | 14917 | 28813 | 31339 | 25299 |
| Lithuania | 22387 | 4117 | 28403 | 7132 | 31353 | 4443 | 34804 | 15493 |
| Poland | 217198 | 23009 | 290532 | 40459 | 310159 | 26345 | 327874 | 13709 |
| Czech Rep. | 41216 | 31566 | 64120 | 33646 | 70442 | 39781 | 68890 | 47032 |
| Slovakia | 12456 | 4182 | 20292 | 4761 | 24244 | 6658 | 35200 | 8832 |
| Hungary | 25162 | 7192 | 34320 | 7038 | 36044 | 10866 | 37664 | 13169 |
| Romania | 5624 | 1045 | 6220 | 1668 | 8826 | 2672 | 15487 | 2956 |
| Bulgaria | 5463 | 2544 | 4866 | 2020 | 5548 | 1522 | 6474 | 1567 |
| Albania | 136 | * | 186 | 2 | 160 | 3 | 65 | 1 |
| Ukraine | 5208 | 515 | 7456 | 566 | 11240 | 223 | 13901 | 769 |
| Belarus | 7107 | 491 | 7967 | 916 | 9258 | 372 | 9648 | 223 |
| Moldova | 102 | * | 190 | 5 | 126 | 32 | 169 | * |
| Russia | 9800 | 56243 | 11135 | 77360 | 37865 | 46838 | 27135 | 65961 |
| Slovenia | 13904 | 5902 | 17252 | 6063 | 22465 | 8225 | 22238 | 10800 |
| Croatia | 1074 | 2348 | 2273 | 2370 | 2872 | 2266 | 3977 | 2376 |
| Bosnia and Herz. | 60 | 269 | 204 | 399 | 337 | 503 | 1051 | 771 |
| Serb.Monten. | 1518 | 669 | 1330 | 654 | 1828 | 630 | 1302 | 1243 |

*Table 14-17, Comext extraction (Sweden, Denmark – Import)*

Table generation of Extraction from Plan 'trans'

PRODUCT(B): TOT
FLOW(L): EXPORT
TRANSPORT_MODE(L): Road
CONTAINER_CODE(L): (+Total2)
INDICATORS(L): (tonne)

| | Jan.-Dec. 1998 | | Jan.-Dec. 1999 | | Jan.-Dec. 2000 | | Jan.-Dec. 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden |
| +WORLD | 9256571 | 6098227 | 4016654 | 8507737 | 5189765 | 8391198 | 3218284 | 4848253 |
| +EXTRA-EUR | 1109673 | 4051820 | 1315947 | 4859988 | 1033580 | 4296991 | 1146151 | 4440189 |
| +INTRA-EUR | 8146898 | 2046407 | 2700707 | 3647749 | 4156185 | 4094206 | 2072133 | 408063 |
| France | 751392 | 146139 | 242051 | 243858 | 281663 | 298042 | 228848 | 46674 |
| Belg.-Luxbg | 190641 | 68056 | * | * | * | * | * | * |
| Netherlands | 1378263 | 145580 | 179692 | 259656 | 210988 | 303182 | 135709 | 23038 |
| Fr Germany | 1296734 | 439737 | 1070273 | 941125 | 1198148 | 985409 | 891337 | 93622 |
| Italy | 168656 | 96174 | 111810 | 177998 | 166548 | 202300 | 188890 | 50077 |
| Utd. Kingdom | 578747 | 125065 | 188644 | 258940 | 902367 | 302051 | 108056 | 46209 |
| Ireland | 9131 | 10663 | 7719 | 22129 | 7578 | 31201 | 6008 | 3013 |
| Denmark | * | 490179 | * | 805805 | * | 919039 | * | 45790 |
| Greece | 17985 | 7865 | 17582 | 16512 | 21384 | 14104 | 14002 | 1254 |
| Portugal | 254867 | 10768 | 17185 | 19997 | 16514 | 16933 | 14848 | 2674 |
| Spain | 91617 | 36045 | 113380 | 86592 | 151132 | 117332 | 104268 | 16405 |
| Belgium | * | * | 103171 | 128196 | 79716 | 152863 | 44073 | 16534 |
| Luxembourg | * | * | 4194 | 3340 | 3053 | 3103 | 2073 | 74 |
| Iceland | 1756 | 4055 | 1005 | 3480 | 1205 | 4585 | 2444 | 7253 |
| Norway | 50450 | 3540753 | 204564 | 4224887 | 113648 | 3468206 | 178268 | 3662611 |
| Sweden | 1650022 | * | 537562 | * | 973973 | * | 257353 | * |
| Finland | 1706000 | 437742 | 66148 | 609994 | 90280 | 668650 | 44419 | 47661 |
| Liechtenstein | 663 | 2417 | 876 | 3061 | 663 | 2500 | 931 | 847 |
| Austria | 52832 | 32394 | 41203 | 73608 | 52804 | 79997 | 32151 | 15040 |
| Switzerland | 89380 | 100340 | 100436 | 112055 | 104350 | 124464 | 91730 | 144348 |
| Malta | 1701 | 72 | 870 | 247 | 758 | 235 | 950 | 291 |
| San Marino | 6 | 227 | 37 | 980 | 92 | 1357 | 17 | 2035 |
| Turkey | 17711 | 15117 | 17533 | 16940 | 16094 | 24157 | 12712 | 15128 |
| Estonia | 5197 | 19276 | 9982 | 21303 | 11537 | 19719 | 11174 | 18184 |
| Latvia | 8586 | 11920 | 6840 | 12639 | 6689 | 15059 | 10762 | 15841 |
| Lithuania | 18781 | 16410 | 17926 | 18384 | 19283 | 13511 | 23403 | 13261 |
| Poland | 229332 | 81091 | 223664 | 83537 | 236075 | 98935 | 247889 | 93999 |
| Czech Rep. | 36517 | 52825 | 50475 | 97315 | 58960 | 72285 | 55648 | 79845 |
| Slovakia | 10630 | 5523 | 8484 | 7904 | 13256 | 12497 | 13816 | 15983 |
| Hungary | 30085 | 27332 | 28995 | 24390 | 42178 | 31031 | 55014 | 31620 |
| Romania | 7074 | 7818 | 8642 | 5455 | 9948 | 6468 | 11030 | 7241 |
| Bulgaria | 9511 | 3554 | 8477 | 8558 | 12877 | 8322 | 12819 | 3056 |
| Albania | 875 | 246 | 1434 | 445 | 426 | 276 | 263 | 300 |
| Ukraine | 9436 | 2520 | 4297 | 4942 | 7913 | 8602 | 9992 | 11307 |
| Belarus | 2034 | 378 | 1272 | 336 | 2092 | 567 | 3443 | 564 |
| Moldova | 446 | 167 | 188 | 306 | 303 | 100 | 560 | 12 |
| Russia | 106099 | 43432 | 82251 | 39257 | 79666 | 38549 | 100293 | 55978 |
| Slovenia | 13904 | 5902 | 17252 | 6063 | 22465 | 8225 | 22238 | 10800 |
| Croatia | 1074 | 2348 | 2273 | 2370 | 2872 | 2266 | 3977 | 2376 |
| Bosnia and Herz. | 60 | 269 | 204 | 399 | 337 | 503 | 1051 | 771 |
| Serb.Monten. | 1518 | 669 | 1330 | 654 | 1828 | 630 | 1302 | 1243 |

*Table 14-18, Comext extraction (Sweden, Denmark – Export)*

Table generation of Extraction from Plan 'trans'

| | |
|---|---|
| Produced: | 03/12/2002 |
| PRODUCT(B): | TOT |
| FLOW(L): | IMPORT |
| TRANSPORT_MODE(L): | Road |
| CONTAINER_CODE(L): | (+Total2) |
| TRANSPORT_MEANS_NAT(L): | +WORLD |
| INDICATORS(L): | (QUANTITY_TON) |
| PARTNER(L): | Y Axis (1) |
| PERIOD(L): | X Axis (1) |
| DECLARANT(L): | X Axis (2) |

| | Jan.-Dec. 1998 | | Jan.-Dec. 1999 | | Jan.-Dec. 2000 | | Jan.-Dec. 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden |
| France | 235244 | 81516 | 216516 | 121359 | 232304 | 142356 | 101158 | 12816 |
| Italy | 152193 | 65968 | 142336 | 107745 | 156075 | 132065 | 87042 | 23748 |
| Portugal | 11817 | 5786 | 10404 | 20933 | 10080 | 11187 | 2941 | 700 |
| Spain | 81413 | 26193 | 93664 | 46912 | 136886 | 66408 | 113349 | 7443 |

Source: Comext2 k0610962.txt Extracted: 03/12/2002
DataSet: TRANSPORT SINCE 1989

*Table 14-19, Comext extraction - geographical market (Sweden, Denmark – Import)*

Table generation of Extraction from Plan 'trans'

| | |
|---|---|
| Produced: | 03/12/2002 |
| PRODUCT(B): | TOT |
| FLOW(L): | EXPORT |
| TRANSPORT_MODE(L): | Road |
| CONTAINER_CODE(L): | (+Total2) |
| TRANSPORT_MEANS_NAT(L): | +WORLD |
| INDICATORS(L): | (QUANTITY_TON) |
| PARTNER(L): | Y Axis (1) |
| PERIOD(L): | X Axis (1) |
| DECLARANT(L): | X Axis (2) |

| | Jan.-Dec. 1998 | | Jan.-Dec. 1999 | | Jan.-Dec. 2000 | | Jan.-Dec. 2001 | |
|---|---|---|---|---|---|---|---|---|
| | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden | Denmark | Sweden |
| France | 751392 | 146139 | 242051 | 243858 | 281663 | 298042 | 228848 | 46674 |
| Italy | 168656 | 96174 | 111810 | 177998 | 166548 | 202300 | 188890 | 50077 |
| Portugal | 254867 | 10768 | 17185 | 19997 | 16514 | 16933 | 14848 | 2674 |
| Spain | 91617 | 36045 | 113380 | 86592 | 151132 | 117332 | 104268 | 16405 |

Source: Comext2 k0610962.txt Extracted: 03/12/2002
DataSet: TRANSPORT SINCE 1989

*Table 14-20, Comext extraction - geographical market (Sweden, Denmark – Export)*