SUTRANET

A project within the Interreg IIIB North Sea Programme

TRANSPORT FLOW MODELLING FRAMEWORK GUIDELINES

Annex 1.2.6 to the Final Report

September 2007

AALBORG UNIVERSITY
Department of Development and Planning

PREFACE

This technical report has been written as part of the SUTRANET project (Work Package 1: Transport Research and Development Network). SUTRANET ('**Su**stainable **Tra**nsport Research & Development **Net**work in the North Sea Region') is a project within the framework of the European Commission's (EC's) Interreg IIIB North Sea Programme.

The aim of the report is to elaborate and present some guidelines for modelling and forecasting - at an aggregated level - of unitised freight transport flows between sub-regions and countries in the North Sea Region. The report feeds into the SUTRANET booklet that describes the scenario building methodology. Both the modelling framework guidelines and the scenario building are presented through a case description of the development in the Norway – Jutland - continental Europe transport corridor.

Jacob Kronbak at Department of Maritime Research and Innovation, University of Southern Denmark, has contributed the chapter about the use of GIS for modelling and visualisation.

There is a need for continued research and development, to enable the eventual launching of some user friendly, low-cost and easily accessible modelling tools and databases. Such tools will be to the benefits of all policy decision-makers and stakeholders committed to cross-border regional development and sustainable transport solutions in the North Sea Region. The guidelines and recommendations presented in this report only provide a preliminary step in this context. Any comments and recommendations for improvements and further elaboration are therefore very welcome.

July/September 2007

Jorgen Kristiansen, Department of Development and Planning
Aalborg University, Denmark

TABLE OF CONTENTS

TABLE OF CONTENTS (continued) Page

ACRONYMS AND ABBREVIATIONS

EC	European Commission
GDP	Gross Domestic Product
GIS	Geographical Information System
ITD	International Transport Denmark
Lo-Lo	Lift-on/Lift-off (e.g. of containers)
MoS	Motorways of the Sea
NSR	North Sea Region
NUTS	Nomenclature des Unités Territoriales Statistiques
OD	Origin-Destination
R&D	Research and Development
RoPax	Combined freight and passenger (ferry)
Ro-Ro	Roll-on/Roll-off (e.g. of trailers)
SIKA	Swedish Institute for Transport and Communications Analysis
SQL	Structured Query Language
STAN	Strategic Transportation Analysis Model
SUC	Spatial Unfolding of Costs
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit (for containers)
VOC	Vehicle Operating Cost
VOT	Value of Time

EXECUTIVE SUMMARY

This SUTRANET report about unitised freight transport modelling guidelines suggests that the assumptions and definition of scope etc. have to be considered in the following modelling steps:

Definition of geographical scope

Zoning

Generation and attraction of goods flows

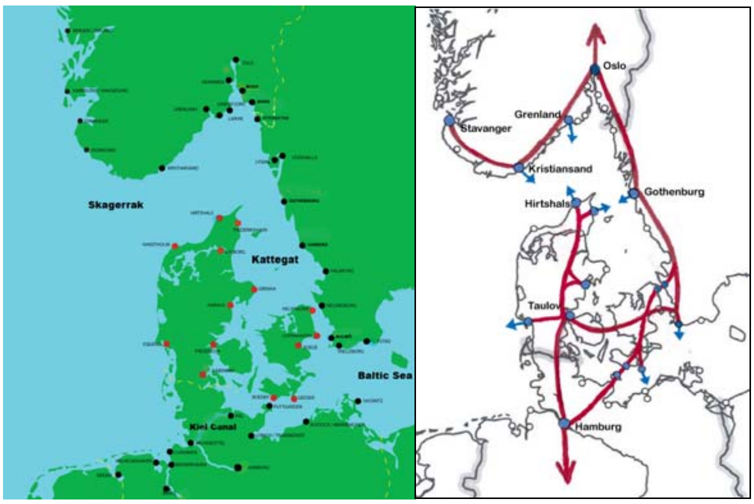
Separation on main categories of goods (bulk etc., containers etc., and Ro-Ro)

Definition of networks and services for containers, swap bodies and Ro-Ro

Modal distribution ⟷ **Distribution on routes (assignment)**

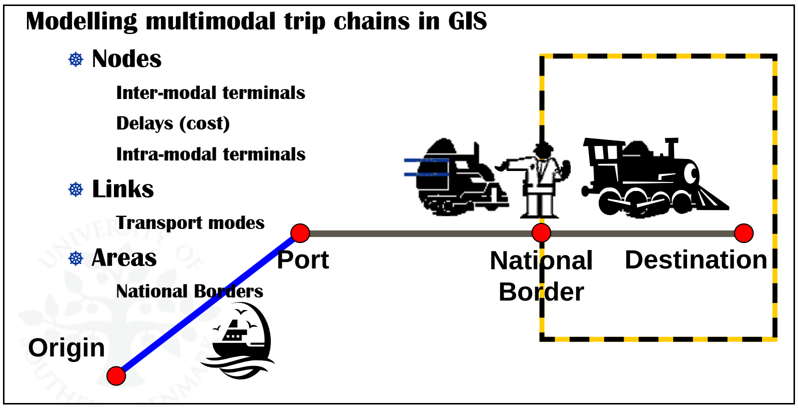
The modelling framework guidelines have been illustrated through a case description of the development in the Norway – Jutland – continental Europe transport corridor. This case description considers the competitiveness and complementarities between direct maritime routes between Norway and the continent, ferry routes between Norway and Jutland, and routes via western Sweden. The case description illustrates how these flows could be modelled, and – in combination with forecasts and scenarios - provide an overall picture to policy decision-makers and infrastructure providers.

The existing transport network in the corridor is characterised by a range of ferry routes and no or low road pricing fees. The future network has to consider new Ro-Ro routes, a renewed



Ports and future railway infrastructure in the corridor railway infrastructure, redistribution of container flows, and a new cost structure for the use of infrastructure such as increased road pricing of heavy goods traffic.

The case description also presents a modelling example of intermodal and multimodal trip chains which illustrates the cost competition between land-based routes and sea routes.



Network modelling principle (Source: Jacob Kronbak, SDU 2006)

The focus of this example, which is visualised in GIS (Geographical Information System), is on the supply side and confined to Ro-Ro traffic but the geographical scope extends to the north-western part of continental Europe.

Conclusions and Recommendations

A unitised freight transport model should be established for western Denmark and Schleswig-Holstein to complement the existing national freight transport model systems, notable the Norwegian and the Swedish models.

There is a general need to establish an adapted set of modelling data for all countries within the geographical scope of the corridor.

Cheap, user-friendly, and harmonised:
The modelling covering the corridor between Norway and continental Europe has to be less resource demanding and more user-friendly than current transport model systems. It involves a harmonised zoning and transport model networks covering southern Norway, western Sweden, Denmark, north-western Germany and part of Benelux, and includes a more aggregated zoning and network for the continental part of Europe.

Inclusion of sea routes and railways:
The modelling data should include socio-economic zone data (such as demographic figures, GDP and foreign trade figures) involving relevant parts of Norway, Sweden, Denmark, Germany and Benelux, and specific data about railway infrastructure, maritime infrastructure and maritime traffic data. This will provide a planning and policy decision-making tool based on border-crossing flow modelling in the corridor.

Shareware modelling:
The modelling tool to be elaborated must be simple to apply and aimed at supporting the policy-decision and planning levels. It could be divided into separate components or sub-models for convenience. The application of this software tool should be free of cost and not restricted by any commercial property rights. The tool should have the status of "open source shareware", and be considered complementary to the existing national transport model systems and commercial modelling software.

Improved and coordinated statistics:
The modelling has to be accompanied by the improvement and harmonisation between countries of the statistical reporting of unitised goods transport flows, such as specified in the SUTRANET brochure on 'Intermodal Transport Networks in the North Sea Region'.

There is, however, a lot of modelling development work to be done, and a particular challenge is to establish co-operation and consistency between information and research of the various countries involved in the corridor.

INTRODUCTION

The principal intention of this report is to provide guidelines for and facilitate further steps in modelling and forecasting of unitised goods transport flows at an aggregated level within specified sub-areas and themes of the North Sea Region (NSR). This is in order to illustrate alternative development scenarios for these themes or sub-areas with a view to facilitate policy decision-makers and infrastructure providers.

Several commercial modelling software tools are already available to operators and transport service provider for preliminary market analysis e.g. on specific maritime routes. However, there is a need to complement these tools with a more simple, less time consuming and costly, and less data demanding modelling tool at an appropriately aggregated level.

Within the limited scope of the SUTRANET project, it has not been realistic or the intention to develop any new modelling tools. The aim has been to focus on an assessment of realistic data requirements and to base the elaboration of guidelines on existing research work and sources.

This report will:

- ❖ Elaborate on the methodology for transport modelling of unitised goods flows within the geographical scope of the Norway - Jutland/North Sea – continental Europe corridor;
- ❖ Present a case description of the modelling of freight (unitised goods) flows in the Southern Norway – Jutland – continental Europe corridor, with a focus on the supply side and the impact of infrastructure and policy initiatives directed at network improvements;
- ❖ Review the data availability and requirements; and
- ❖ Present (ref. the Executive Summary) some recommendations with regard to the eventual establishment of a comprehensive freight transport model for unitised goods flows covering the geographical scope of the corridor.

The report is divided into three main chapters:

I. General methodological considerations.

II. Case description of the southern Norway – Jutland – continental Europe transport corridor.

III. The use of GIS for modelling and visualisation in the case study corridor.

I METHODOLOGY

Transport modelling within the field of passenger transport has traditionally followed the so-called "four stage model" where the four stages are:

1) trip generation and attraction;
2) trip distribution;
3) modal split; and
4) route assignment.

The **demand** side of transport is mainly reflected in step 1 and step 2), whilst the **supply** of transport infrastructure and services affects step 3) and step 4) in particular.

This approach has to be modified in relation to freight transport modelling in general, and to be simplified when it comes to unitised goods transport modelling within the framework of the selected geographical scope and aim such as the Norway – Jutland – continental Europe corridor case.

The 'Handbook of Transport Modelling' (D.A. Hensher and K.J. Button, editors. Elsevier Science Ltd. 2000) describes (in Chapter 32 by T.L. Friesz) that strategic freight transport "*models are employed primarily to forecast, months or years into the future, freight traffic over specific network links and routes and through specific network nodes and terminals. The fundamental decision variables of these models are expressed as flows (volumes per unit) and are entirely continuous in nature. The time frame is that of months and years. The perspective is generally that of a multimodal partial equilibrium of the transport market, with alternatives being evaluated according to the comparative statics paradigm*".

Some of these characteristics apply to the present modelling framework as well. The forecasting horizon for the case study corridor is, however, a number of years (in the range of 15 to 20 years) rather than months, although seasonal variations have an importance both in terms of costs and transport time.

Sources and References

The various sources and references which have been consulted are listed in the section 'References and Literature' at the end of this report. The model systems elaborated by Scandinavian countries are briefly commented upon as follows.

Modelling in Norway:
The Norwegian National Freight Transport Model system includes some sub-models such as the "PINGO" model that is a prognosis model for "Prediction of regional and interregional freight transport". The PINGO model applies a network sub-model - "NEMO" - for freight

transport in Norway, and with OD matrices for a base year as inputs it is able to forecast mode specific OD matrices for various groups of goods. The Norwegian model system applies the transport model software package "STAN" (see below) which is able to handle the shift between modes.

Modelling in Sweden:
The Swedish National Freight Model System "Samgods" is used at the national level to carry out forecasting, infrastructure planning and transport policy analysis. Like the Norwegian model system, "Samgods" is also developed based on the STAN model software package. The Samgods model application comprises the supply elements (networks and transport costs including transfer costs in ports) for national and international road, rail and sea transport services, and the demand elements (assignment procedure) for modelling modal split and route choice.

Traditionally the Swedish model system has been applied to facilitate national infrastructure planning, and several sensitivity analyses (on the supply side) have been performed. In the Swedish "Strategic Infrastructure Plan 1999", the model was used to forecast international trade in a foreign trade model, and based on foreign country specific GDP growth rates. Base-year demand matrices have been constructed both in terms of value and weight flows.

The Samgods model is considered a helpful tool for aggregated analysis performed in major freight corridor studies. An assessment of the model application has advised to recognise the different roles of production/consumption and origin/destination (OD) matrix formats and the role of logistics. Ongoing model development is being coordinated with the Norwegian freight transport model development.

Modelling in Denmark:
The 'Goods Transport Modelling' report published by the Danish Transport Council in 2002 presents an overview of data requirements and methodologies with a view to the application of goods transport models in Denmark. So far the Danish model initiatives have focused on the assessment of large infrastructure projects like the Fehmarn Belt project and on the analysis of goods transport in the Copenhagen area and the Oeresund Region. Currently there is no comprehensive Danish freight model system being developed in order to match the Norwegian and Swedish systems.

None of the Scandinavian freight transport model applications have focused specifically on unitised goods transport flows.

The STAN Model Software Package

All the above mentioned model systems - and also the modelling systems used in Finland - apply the "STAN" freight transport modelling software package that is maintained and offered at commercial conditions by the Canadian company INRO Consultants in Montreal. The aim of this software is to facilitate "Strategic Planning of Multi-Modal Multi-Product Freight Transportation".

The STAN model consists of four interconnected main components as follows (ref. STAN User's Manual Release 5, INRO 1997):

- **Network:** modes, centroids, nodes, links, transfers, connectors paths:
- **Demand:** zones, products, matrices.
- **Functions:** unit cost functions
- **Multi-product, multimode assignment:** system optimal, predicted flows and costs.

The STAN package includes both a number of supply-related modules and demand modules. STAN takes the travel time and cost into consideration through the calculation of "generalised costs" (see also Chapter III on the use of GIS for modelling and visualisation). This enables STAN to shift between different transport modes in the route assignment procedure. After assignment, STAN can convert the assigned flows in tonnes to traffic (e.g. lorry traffic on roads).

Findings of relevant R&D projects carried out within the European Commission's (EC's) Framework Programmes – such as the STEMM and INTERMODA projects - should be consulted as they may include substantial elements of freight modelling of interest also to the southern Norway –Jutland corridor.

Main Components in Freight Transport Modelling

Data constraints and the aggregated level (policy decision-making level etc.) of the corridor modelling require that demand modelling and forecasts will need to be based on a simplified approach.

Less data demanding procedures are required as concerns the model component that could provide an estimate of the distribution of freight generation and attraction between zones according to a simple travel distance function. Other parts of the demand components in a complete freight transport model may be simplified or even excluded as well in the context of unitised goods transport flows and the chosen corridor case.

The model should, however, be able to depict how transport policy measures and infrastructure investment initiatives will affect the development of unitised goods transport demand and traffic pattern. This is illustrated on Figure I.1:

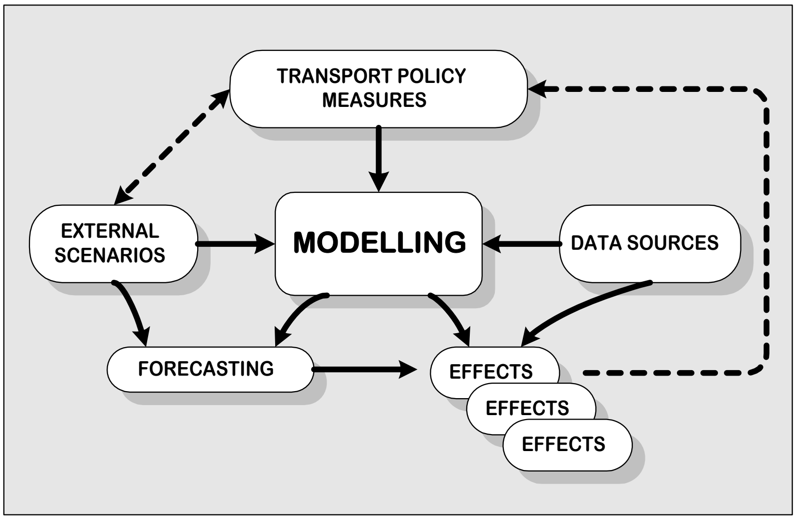


Figure I.1: Relations between modelling, data sources, policy measures and scenarios
(Source: Kristiansen et al, 2001)

The main steps and components in formulation of guidelines for freight transport modelling and forecasting tools are:

- specification of the corridor and/or area in question;
- market partitioning, i.e. the modelling is confined to unitised goods flows;
- network identification, i.e. description of the transport network including nodes (ports and terminals) and routes serving unitised goods flows in the corridor;
- division of the corridor and its catchment areas into zones ("zoning");
- identification of crucial cause-effect relationships regarding goods generation within each zone and the flow distribution between the zones, with a view to the freight transport market partitioning;
- model variables and flows (measures in units or tonnes per year, and optionally in value per year);
- establishment of OD[1] matrices;
- definition and estimation of the "distance" or "generalised cost";
- modal and route distribution;
- calibration of the base-year OD matrices against transport flow data, and forecasting of OD matrix and transport flows.

To some extend these steps and components are interrelated or overlapping each other. The modelling steps are specified in the following Chapter II for the Norway – Jutland – continental Europe transport corridor.

[1] OD is an abbreviation for "Origin-Destination".

Zoning Principles

Figure I.2 illustrates the types of goods flows between zones in two neighbouring countries A and B.

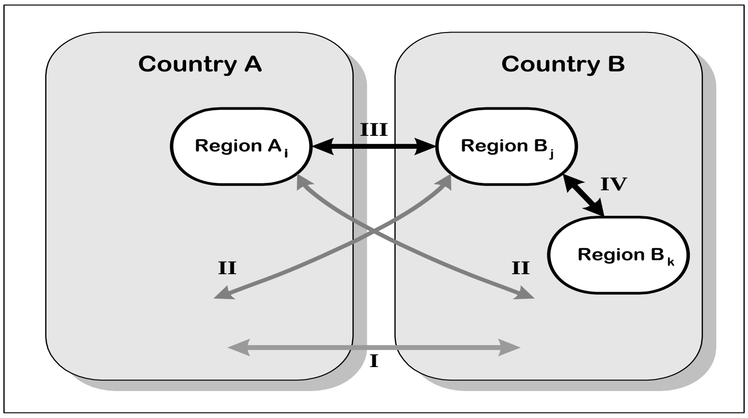


Figure I.2: Types of cross-country (interregional) trade flows
(Source: Kristiansen et al, 2001)

The zones in the specified corridor are normally smaller than the country level (NUTS[2] 0 level). Thus, in order to facilitate freight transport modelling, there is a need to break down the GDP and foreign trade flows into the geographical units, often counties or national regions, which the zones represent.

The *type I* flows at the aggregated country level are covered by the national trade statistics (Intrastat and Extrastat). Statistical estimates for the *type IV* domestic trade flows, i.e. between administrative regions within a country, and for *type II* foreign trade flows, i.e. between a specific administrative region within the country and other countries, have been developed to some extent, e.g. at the county level in Norway and for the regions in Denmark.

Statistical estimates for the GDP of specific administrative regions within a country are available as well.

As to trade flows between zones located in different countries, e.g. the *type III* trade flows between regions separated by the borders of two neighbouring countries, the data problem has not yet been solved. One of the major statistical challenges in relation to freight transport modelling is to provide some reasonably reliable estimates of the type III flows (OD information).

Zoning principles are well described in various textbooks. As to the practical application of the zoning guiding principles, see the case description in the following Chapter II of the Norway – Jutland – continental Europe transport corridor.

[2] NUTS is the nomenclature system of territorial units used by Eurostat for management and presentation of statistics.

Origin-Destination Data for Transport Demand

A generic issue is the question of data needs and compilation of data. Limitations concerning data availability require the introduction of some rough simplifications of the different steps of the demand side of modelling, notably regarding the establishment of OD-matrices, e.g. based on production and consumption figures and the GDP for each zone.

An equation similar to the following could be applied as a basis for calculation of traffic attraction between two zones i and j, in the form of the total trade $T^m{}_{ij}$ (either in one or both directions) between the two zones of a certain commodity group m or unitised goods category m:

$$T^m{}_{ij} = T^m * F(\text{distance}) * (G_i)^{\alpha 1} * (A_j)^{\alpha 2}$$

$T^m = \sum T^m{}_{ij}$ is the total overall external trade flow of the country (e.g. Norway) or defined area in question for goods category m. F(distance) is the simplified distribution function to be applied in the model, where "distance" is measured as general costs. G_i is the flow generation factor for zone No i, e.g. expressed as the GDP of the zone or the zone's share of foreign trade/export. A_j is the flow attraction factor of zone No j (in the corridor or its catchment area but outside the country in question), e.g. expressed as the GDP or income level of the zone or the zone's share of foreign trade/import. $\alpha 1$ and $\alpha 2$ are parameters to be identified by regression analysis and calibration, for example based on known or estimated type III trade flow figures in Figure I.2.

The matrix could alternatively be constructed directly based on estimates of the type III trade flow figures.

One serious drawback to be mentioned is the lack of information about the logistics chain of the cargo unit from the initial consignor to the final consignee including their locations, i.e. there is basically a lack of OD information below a highly aggregated (e.g. national) level. The ferry operators may have such information to a certain degree, but in this case the information is often commercially restricted.

Forecasting and Unit Load Market Partitioning

The forecasting will have to be consistent with the formulation and description of alternative development scenarios, ref. the SUTRANET report 'Unitised Goods Transport Scenarios in the North Sea Region'.

The methodology involves a quantitative forecasting e.g. from 2005 up to 2020/25 in the case descriptions of container traffic development in the Port of Rotterdam and of Ro-Ro traffic development in the southern Norway – Jutland - continental Europe corridor. The modelling is confined to unitised goods flows – or even confined to a segment of unitised goods flows such as Ro-Ro flows or container flows only.

Thus the methodology is facing a challenge concerning market partitioning. The general cargo and bulk segments are excluded, and at the same time containerisation is ongoing as a parallel process which implies the transfer of an increasing part of these freight segments to containerisation. As to Ro-Ro traffic, a similar trend might apply although to a much lesser extend compared with container traffic. As a consequence, only part of the growth of container traffic can be explained by economic growth and increased international trade flows.

The modelling has to reflect – besides the overall growth in demand for freight transport - an ongoing change of the distribution on various cargo handling types. Another aspect is to which extend non-unit loaded goods carried by rail wagons and by lorries without accompanying trailers can be characterised as “unitised” goods.

Based on the above mentioned considerations, the question could be raised whether it is possible or appropriate to base a freight transport modelling process on the unitised goods flows segment only. On the other hand, unitised goods traffic constitutes an increasing share - particularly in value terms - of the international trade flows being handled. Base-year OD matrices for unitised goods flows will offer a useful tool for the assessment of changes introduced – or planned to be introduced - at the supply side of the transport system. Such changes could consist of infrastructure improvements and new route services, and of policy measures affecting the transport market such as road pricing.

As already mentioned, separate OD estimation and forecasting may have to be done for Ro-Ro transport (including RoPax ferry transport) and container transport.

II Case: The Southern Norway – Jutland - Continental Europe Corridor

The aim of this case study is to describe the unitised goods flows in the corridor encompassing southern Norway, Jutland/Funen, Schleswig-Holstein, Hamburg, and including linkages with western Sweden and with the western part of the European continent.

The case description will particularly address the competitiveness and complementarities between direct maritime transit routes linking Norway and continental Europe, and ferry routes connecting Norway with North Jutland. The question is how these flows could be modelled to present an overall picture to policy decision-makers and infrastructure providers.

The modelling guidelines also considers the general data requirements and methodologies for establishing a complete unitised freight transport modelling framework covering the corridor and its continental catchment areas.

1 PRESENTATION OF THE CORRIDOR

The corridor area for unitised and intermodal freight transport includes the following geographical area and North Sea Ports:

Figure II.1: Ports in the Norway – Jutland – continental Europe corridor

The ports only constitute nodes in the overall transport networks which serve the unitised goods flows in the corridor. The specific maritime routes and overland transport infrastructure have to be added, ref. Figure II.5 in this section.

Separate flow patterns should eventually be presented for RoPax/Ro-Ro ports and container ports. The following figure illustrates the annual container throughputs 2005 in major container ports in the North Sea Region (NSR), and the Ro-Ro flows in 2005 between selected countries in the NSR:

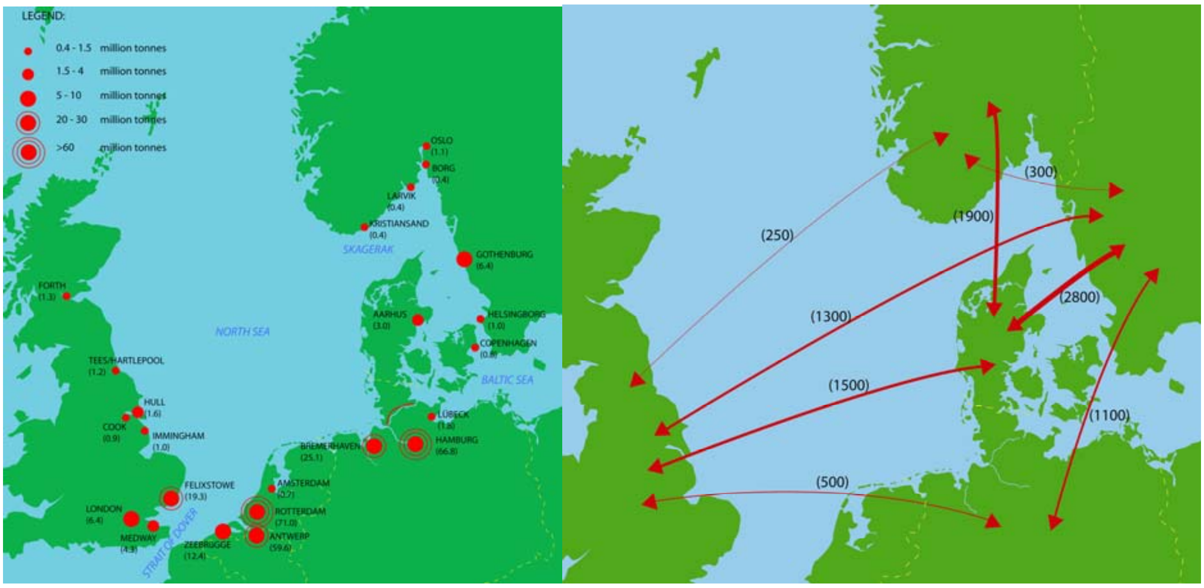


Figure II.2: Container throughput and Ro-Ro flows in the North Sea Region (2005)

The map that indicates Ro-Ro flows does not include Ro-Ro traffic between Norway and Germany and Ro-Ro traffic between Benelux and UK.

Modelling Steps and Components

Modelling within the scope of the Norway – Jutland - continental Europe corridor has to specifically include the steps indicated in the following diagram. These steps involve both the demand side and the supply side of modelling.

Following the zoning step, the generation and attraction of unitised goods transport in each zone has to be estimated. A preliminary flow distribution between zones in the form of OD matrices (and based on traffic generation and attraction for each zone) may have to be estimated preceding the definition of networks. In principle, however, these networks would influence the transport distance and generalised cost between zones and thus affect the distribution between zones.

Definition of geographical scope

Zoning

Generation and attraction of goods flows

Separation on main categories of goods (bulk etc., containers etc., and Ro-Ro)

Definition of networks and services for containers, swap bodies and Ro-Ro

Modal distribution ↔ **Distribution on routes (assignment)**

The last of the demand side steps is a market partitioning i.e. separate estimates of unitised goods categories. This has to be done before definition of the supply side such as infrastructure networks and freight transport services. The results of this step could be presented in the form of separate base-year matrices for e.g. Ro-Ro goods and container goods.

In any case the modal distribution and the assignment of flows will follow after the definition of networks and services. Ideally the distribution on modes and on routes should be done interactively, and the selection criterion should be the least "general cost" principle. Also in practice the modal distribution and definition of alternative routes could be combined to some extent.

The corridor modelling on the demand side will not present a complete freight transport modelling exercise in general terms, because some main steps and components will have to be simplified or even excluded. As a consequence, focus of the forecasting and scenario description will be on simplified demand modelling components.

The supply side of the modelling and the implications related to infrastructure and policy initiatives and alternative route choices can de done in more depth. The tool presented in Chapter III on the use of GIS for modelling and visualisation concentrates the focus on network specification, and the definition and estimation of the "generalised cost" of each link and node in the network. The identification of the unitised goods flow pattern, forecasting, modal distribution and route assignment have to be added to this tool.

Optional Routes in the Corridor

The traffic could be divided into the following main categories:

- Regional goods flows between Norway and Jutland/Funen (by RoPax and Ro-Ro vessels).
- Transit flows between Norway and continental Europe (by RoPax and Ro-Ro vessels).
- Container feeder flows between Norway and continental Europe (by Lo-Lo vessels). Some of this traffic is destined for transhipment in the deep-sea container ports).

The alternative routes that could serve these flows in principle consist of:

1. Direct and relatively short RoPax and Ro-Ro routes between southern Norway and North Jutland.
2. Overland route through Sweden to Gothenburg/Varberg and RoPax ferry routes from there to Jutland.
3. Long RoPax and Ro-Ro ferry routes between southern Norway/Gothenburg and seaports on the German Baltic Sea coast. This group of routes also includes Norwegian transit traffic via the Gothenburg-Kiel route.
4. Overland routes through western Sweden via ferry ports in Malmoe, Trelleborg and Ystad to the Baltic Sea coasts of Germany and Poland; or through western Sweden and Scania/Zealand via the ferry ports in Gedser and Roedby to the Baltic Sea coast of Germany.
5. Long Ro-Ro ferry routes between southern Norway and seaports on the German, Dutch and Belgian North Sea coasts.
6. Container feeder routes between ports in southern Norway and deep-sea container ports at the German North Sea coast and on the North Sea coasts of the Netherlands and Belgium. Some of this container feeder traffic between Oslo/Gothenburg and the deep-sea ports at the North Sea coast may flow via the Kiel Canal.

Figure II.3 illustrates the routing in principle.

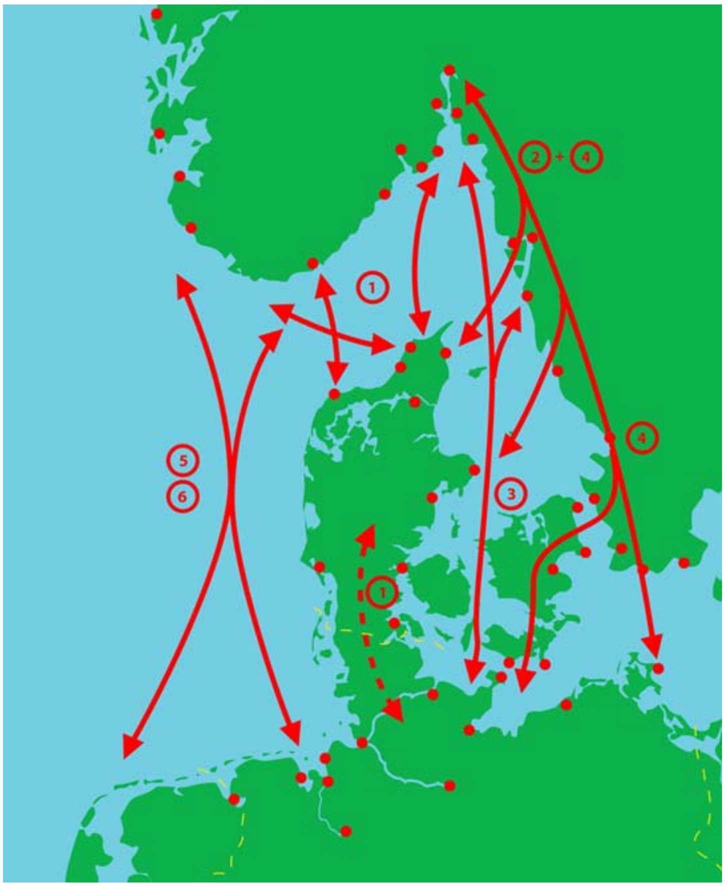


Figure II.3: Optional routes in the corridor in principle

Currently (2003-2006) only RoPax vessels serve lorry and trailer traffic between Norway and Denmark and between Norway and Germany. The only example in 2004-2005 of a Ro-Ro freight ferry service was between Brevik and Ghent in Belgium.

The container traffic directly between Norway and Denmark is insignificant. Container feeder traffic between Norway and continental Europe mainly passes through the North Sea to Germany (Hamburg and Bremerhaven), the Netherlands (Rotterdam and Amsterdam) and Belgium (Antwerp and Ghent). Most likely, a considerable share of this traffic is for transhipment to overseas destinations. Due to the geographical location it is assumed that there is relatively little Norwegian container feeder traffic passing through the Kiel Canal.

The case description concentrates on the route options where the traffic flows can be estimated based on available statistics. There are no reliable data sources available as yet that could indicate the share of Norwegian transit traffic on routes 2) and 4). However, the Norwegian part of the freight flows via the route Gothenburg-Frederikshavn will be "guesstimated", because this route is an important option for the regional traffic between Norway and Jutland. The Norwegian goods transit traffic via Varberg-Grenaa is assumed to be modest. The route via western Sweden and Roedby-Puttgarten could also be considered as an optional route for Norwegian traffic to Schleswig-Holstein, Hamburg and beyond, although there is no available estimate of the Norwegian transit part of the traffic on this route either.

Goods transported to/from Norway on rail wagons are mainly confined to route 4), i.e. by rail through western Sweden and via the ferry ports in Trelleborg (to Germany) and Ystad (to Poland). There is no information available about the share of unitised goods carried on rail wagons as compared to general cargo and bulk. No goods transport on rail wagons has been reported via the port in Oslo.

One source of demand data as described above could be the newly estimated export/import part of the Norwegian National Freight Model. Similar modelling development as to the Danish part of the corridor (western Denmark: Jutland and Funen) has not as yet been attempted.

Corridor Zoning

The zoning applies the Eurostat's NUTS levels wherever possible (ref. Appendix B). The particular zoning will depend on the geographical scope of the corridor to be analysed and the aggregation level of the modelling.

The Norway – Jutland – continental Europe corridor, considering the limitations mentioned, involves the zoning indicated on Figure II.4. Please notice that the zone boundaries are only marked in principle, and not following the exact NUTS or county boundaries.

Figure II.4: Corridor zones

The selected zones and some zone data are presented in more detail in Appendix B as an illustrative example. However, the zone data in Appendix B are incomplete; further data compilation and elaboration is required.

It might be needed to accept using even more aggregated and thus fewer zones for some particular corridor model development and applications.

Specific Model Variables

The identification of adequate variables is influenced by the data availability (see the following section on data and statistics). Possible variables to be potentially retrieved form national statistical sources are as follows (preliminary listing):

- Population and population density of each zone;
- GDP of each zone;

- Total foreign trade (tonnes, values) split into import/export – OD etc.;
- Percentage of seaborne trade in total trade;
- Freight volumes on RoPax and Ro-Ro routes; and on container routes.

The following supply data have to be retrieved from other sources (ref. the SUTRANET reports on statistics):

- Distance and frequency of freight routes (time; combination of distance and frequency; general costs principle);
- Level of service for overland infrastructure links (standard and capacity of motorways/highways and railways).

Corridor Model Networks

The intention is to do a modelling confined to Ro-Ro and Lo-Lo freight flows, including overland links by road and rail through Jutland and Schleswig-Holstein.

The figure below presents on the map to the left the existing RoPax routes to be included in the model network. On the map to the right are added some potential future RoRo links through the North Sea and major road links in the corridor.

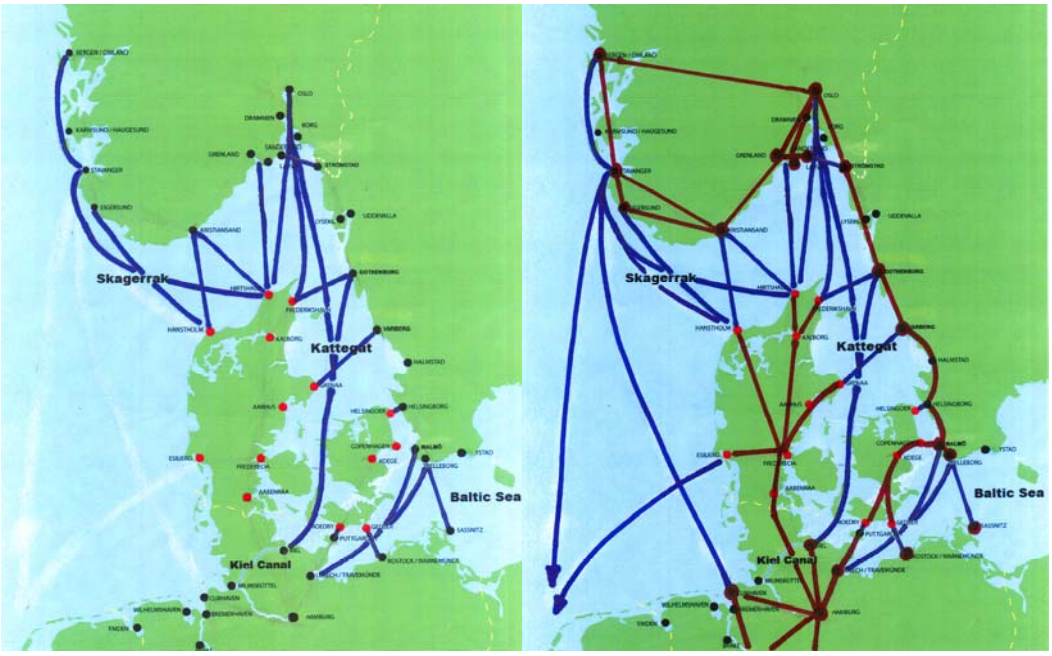


Figure II.5: Transport model network links

The existing and potential future railway networks in southern Norway, western Sweden, Denmark, and Schleswig-Holstein – and the continental highway links - are not indicated. A preliminary listing of existing and potential network links and nodes/terminals is presented in Appendix C.

2 DATA AND STATISTICS

The national statistical sources present the traffic flow data indicated in tonnes and units, and not in values. However, unit load value/weight ratios tend to be significantly higher for unitised goods than the value/weight ratios for bulk and non-unitised general cargo.

The extraction of trade value figures at port level from Intrastat and Extrastat sources has not been realistic within the limited scope and resources of the SUTRANET project.

Some Norwegian export/import freight flow data might also include cargo value. On the Danish side, no estimation of value flows via the ferry ports in North Jutland to/from Norway and Sweden has been attempted since a regional study carried out in 1989/90 (the "TRANE" project at Aalborg University). In principle it is possible to get data on trade flow values between Denmark and Norway (via the Extrastat foreign trade statistics sources). In any case, the unit values have to be estimated separately and based on detailed foreign trade statistics to be extracted on specific request and at cost, because such data are not publicised by the national statistical services. However, this requires a quite expensive ordering of data extracts and implies a very comprehensive data processing.

Estimates of GDP figures for each zone are to some extent available below the national level. If this is not the case, it is suggested that the zone's share of the national GDP could be estimated as the population proportion. Another option would be to take the income level in the zone into consideration because higher income implies higher import figures. However, exports may often be relatively higher from regions with relatively low income levels. As an example, in the case of Denmark export figures from western Denmark (Jutland and Funen) are higher than import figures, whilst the opposite is the case for eastern Denmark including Copenhagen.

The GDP figures at the zone level can be used as a basis for economic growth forecasting.

To the extent that foreign trade figures – and even the percentage of seaborne trade - are available, these could be used to establish some rough figures in OD-matrices for Ro-Ro flows and container flows respectively.

Development of Foreign Trade between Norway and Denmark

The following graph illustrates the development since 1989 of the annual trade in value terms (current prices) between Norway and Denmark.

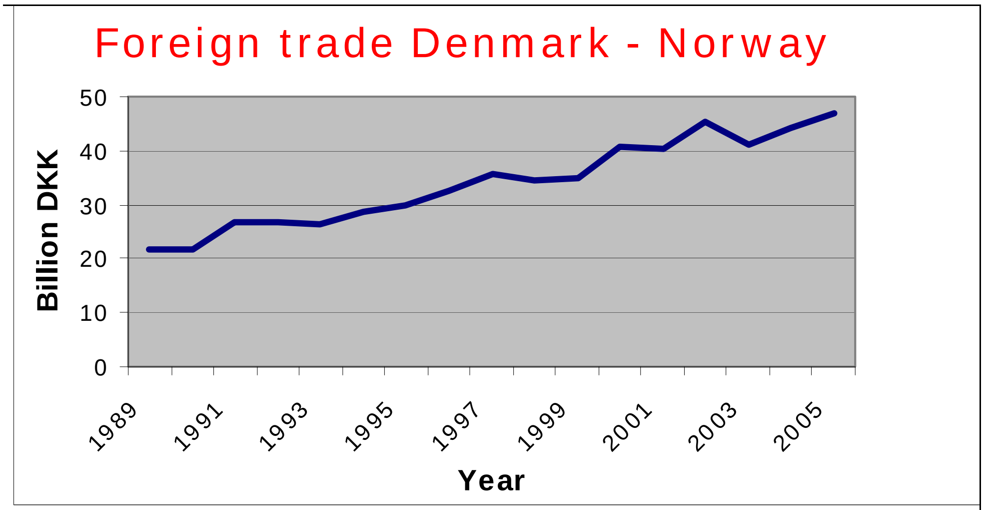


Figure II.6: Foreign trade development Norway-Denmark
(Source: SUTRANET based on Statistics Denmark)

It would be needed to base the forecasting of regionalised trade figures (e.g. between Norway and Jutland/Funen) on the envisaged GDP growth in Norway and Denmark.

Historical Freight Flow Data for Ro-Ro Traffic

Direct North Sea Ro-Ro Routes between Norway and the Continent:

In 2003-2005, there were no unitised goods flows reported on direct routes serving Ro-Ro traffic between Norway and the North Sea coasts of Germany and Netherlands/Belgium. However, potential 'Motorways of the North Sea' routes could be considered between Norwegian ports (Bergen, Stavanger/Risavika, Kristiansand, Grenland) and Cuxhaven (in Germany), IJmuiden (in the Netherlands) and/or Zeebrügge (in Belgium).

Direct Ferry (RoPax) Routes between Norway and Jutland:

Statistics Denmark presents time series 1990-2005/2006 of data (in tonnes and units) for annual flows via the direct ferry (RoPax) routes between Norway and Denmark (ref. SUTANET: 'Statistics Report Denmark', 2007). Except for the Copenhagen-Oslo route, the ferry ports in Denmark serving these routes are confined to Frederikshavn, Hirtshals and Hanstholm, and all these three ports are located in North Jutland.

The development in unitised goods flows on the direct ferry (RoPax) routes between Norway and Denmark in total, and on the Oslo-Copenhagen route, is shown in the following Figure II.7 (prepared and presented by Statistics Denmark):

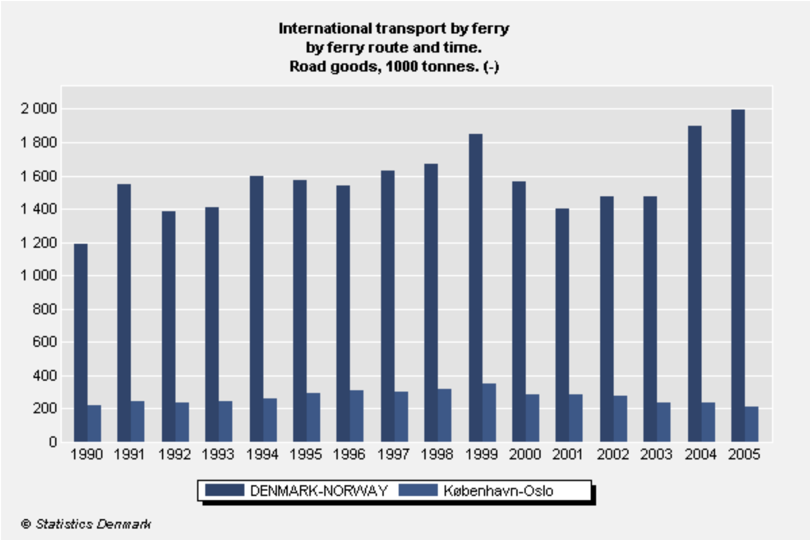


Figure II.7: Ro-Ro traffic between Denmark-Norway and Copenhagen-Oslo
(Source: Statistics Denmark)

Figure II.8 presents a graph of the development since 1989 in annual Ro-Ro traffic on RoPax ferry routes between Norway and Jutland (via the ferry ports in Hanstholm, Hirtshals and Frederikshavn). The annual figures of this graph are derived as the difference between the Norway-Denmark and Oslo-Copenhagen figures. Figure II.8 also includes a graph of the regional Ro-Ro traffic between Norway and Jutland – defined as traffic with origin and destination in Norway and in western Denmark (Jutland and Funen). The regional traffic figures are estimated, ref. Table A1 in Appendix A.

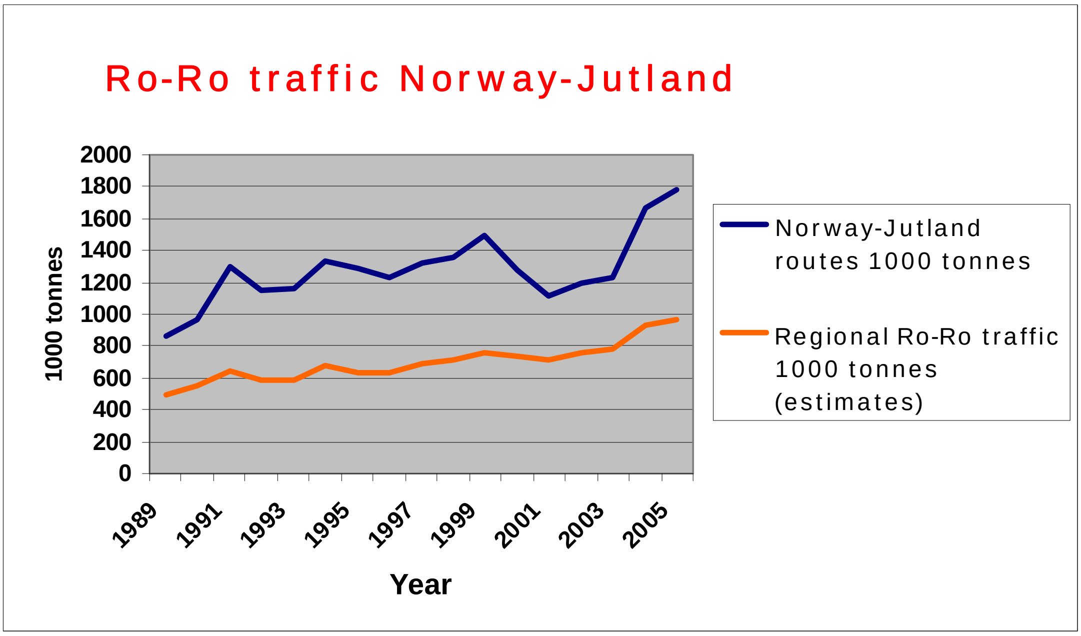


Figure II.8: Development of Ro-Ro between Norway and North Jutland

The opening of the Great Belt link (railway link in 1997 and motorway link in 1998) seems not to have affected the traffic via the ferry routes significantly, whilst the opening of the fixed link across the Oeresund (the "Sound") in July 2000 apparently has had some effect; probably some transit traffic between Norway and continental Europe has shifted from the routes via Jutland to the routes via western Sweden and Zealand.

The traffic of unitised goods via the ferry routes Jutland-Norway has grown by remarkable 45% from 2003 to 2005.

The time series presented in Appendix A (Table A2) for Ro-Ro traffic since 1990 on the Oslo-Kiel and Gothenburg-Kiel routes indicate a very fluctuating development pattern. In the beginning of the 1990's traffic was growing, but since the mid-1990's freight traffic on these routes has stagnated or even declined.

Development of Container Traffic

The development regarding container traffic in the corridor has shown a different pattern during the last 15 years compared to RoPax and Ro-Ro freight traffic. In this case only containers by Lo-Lo vessels are considered, excluding containers on Ro-Ro vessels e.g. via Grenland in Norway.

There is considerable container traffic ongoing by Lo-Lo vessels between Norway and the deep-sea container ports in Hamburg, Bremerhaven and Rotterdam. Information can be obtained from German, Dutch and Belgium statistics (ref. the SUTRANET statistics reports on Germany and Benelux).

The figures in Table II.1 (in 1000 tonnes and 1000 TEU) indicates the geographical distribution of Norwegian container traffic and applies to the year 2004:

Table II.1: Distribution of Norwegian container traffic on other North Sea countries

Country	1000 tonnes	1000 TEU units
Denmark	8	2
Sweden	48	
UK	131	12
Germany North Sea Hamburg	?	173
Germany North Sea Bremen	?	120
The Netherlands	991	109
Belgium	249	

(Sources: various national statistics, ref. SUTRANET statistics reports for Denmark, Sweden, UK, Benelux and Germany)

The tonnes figure in Table II.1 for Belgium includes tare weight of containers, whilst tare weight is excluded for the tonnes figures of the other countries.

As reflected in the table, the container traffic between Norway and Denmark is negligible.

The main part of container traffic between Norway and the Netherlands in 2004 flowed via Rotterdam (902x1000 tonnes) and the remaining part via Amsterdam (89x1000 tonnes). The container traffic between Norway and Belgium in 2004 flowed via Antwerp (181x1000 tonnes) and Ghent (68x1000 tonnes).

More detailed information about the geographical distribution of international container traffic to/from each of the Norway ports served by Lo-Lo vessels are presented in the SUTRANET database Annex 3 to 'Statistics Report Norway' (for the years 2003-2005).

Time Series of Container Traffic Development

The Table below illustrates the significant difference in growth rates in comparison between Ro-Ro traffic and container traffic.

Table II.2: Time series for Ro-Ro traffic Jutland-Norway and container traffic through Port of Hamburg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
RoPax/Ro-Ro traffic Jutland-Norway 1000 tonnes	965	1304	1145	1164	1331	1283	1233	1322	1356	1492	1274	1117	1191	1232	1661	1784
Index (1990 = 100)	**100**	**135**	**119**	**121**	**138**	**133**	**128**	**137**	**141**	**155**	**132**	**116**	**123**	**128**	**172**	**185**
Container throughput Port of Hamburg 1 million tonnes	20.31	22.21	23.31	26.13	28.91	30.29	31.99	35.22	36.11	40.01	45.29	49.76	57.19	64.28	74.03	83.08
Index (1990 = 100)	**100**	**109**	**115**	**129**	**142**	**149**	**158**	**173**	**178**	**197**	**223**	**245**	**282**	**316**	**365**	**409**

(Sources: Statistics Denmark Table SKIB32; Port of Hamburg, ref. the SUTRANET 'Statistics Report Germany')

Ro-Ro figures are excluding tare weight. Container figures are including tare weight (weight of containers without cargo)

The following presents some time series concerning the development of annual container throughput in selected ports during the latest 10-15 years.

Container traffic via Oslo Port:

The annual container Lo-Lo traffic (in 1000 tonnes, excluding tare weight) during 2001-2005 was:

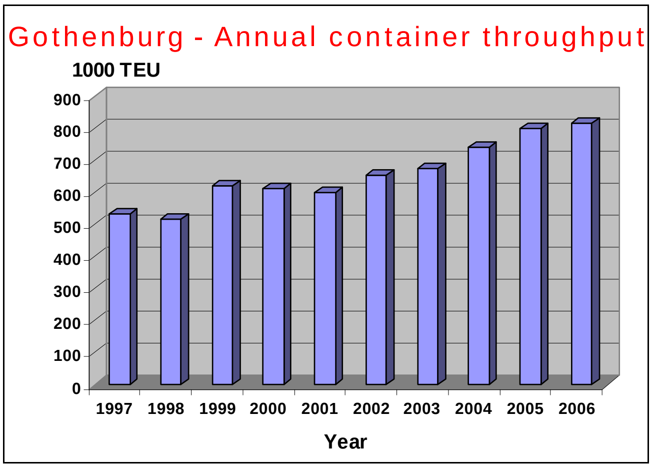
2001	1,019
2002	1,086
2003	1,166
2004	1,222
2005	1,090

(Source: SUTRANET working paper by TØI, 2006)

The annual throughput figures for Oslo illustrate the stagnating tendency in relatively small container ports handling feeder traffic.

Comparison of Gothenburg and Hamburg container ports:

The graphs in the following figure show the development of the annual container throughput (in TEU) for Gothenburg 1997-2006 and for Hamburg 1990-2005:



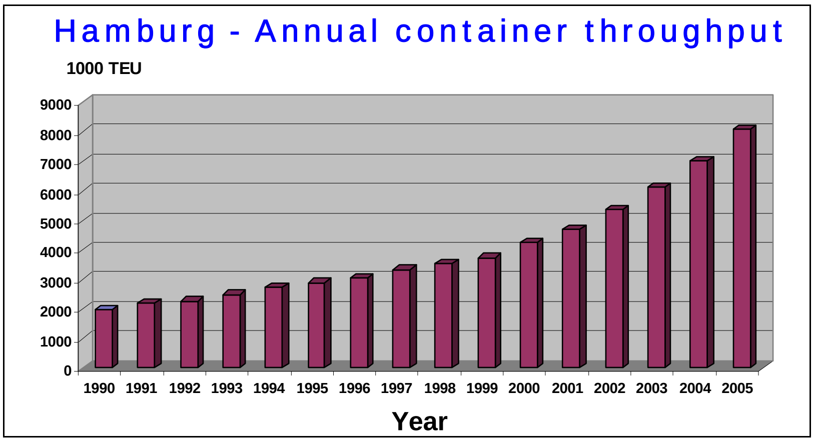
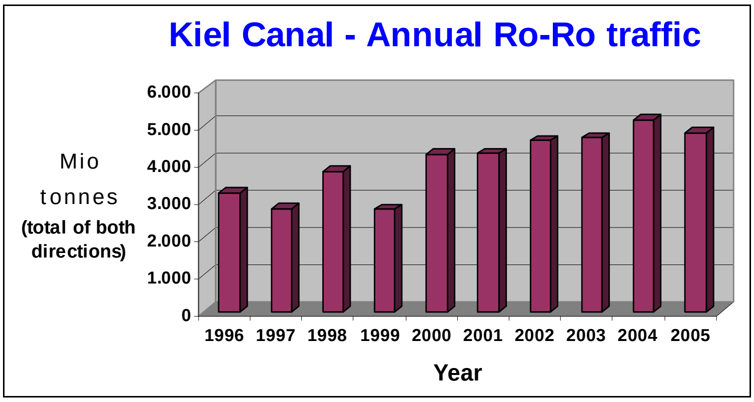


Figure II.9: Development of container traffic via Gothenburg and Hamburg
(Sources: Port of Göteborg; Port of Hamburg)

The graphs confirm that an exponential growth of container traffic takes place in the large deep-sea container ports. The medium sized container port in Gothenburg, where the main segment is the handling of feeder traffic, also experiences some growth but this growth is less stable; the port in Gothenburg also serves a few overseas container lines.

Traffic through the Kiel Canal:

The graphs in Figure II.10 show the development during 1996-2005 in annual Ro-Ro traffic and annual container traffic through the Kiel Canal:



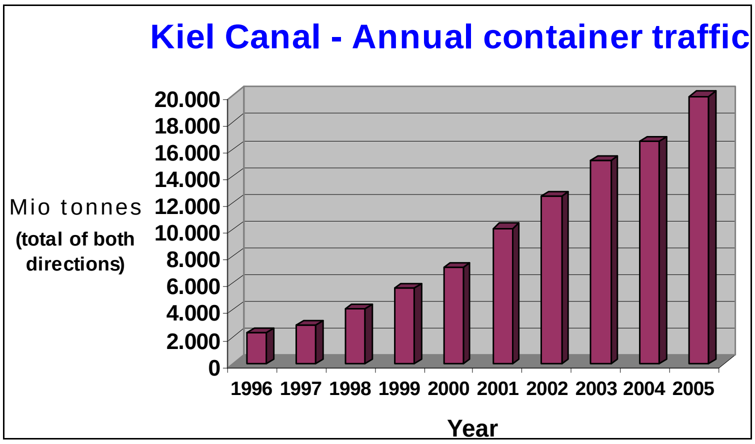


Figure II.10: Development of Ro-Ro-traffic and container traffic through the Kiel Canal
(Source: SUTRANET 'Statistics Report Germany')

The graphs illustrate the significant difference between the stagnating growth pattern of Ro-Ro traffic through the Kiel Canal compared with the exponential growth of container feeder traffic through the Canal to and from countries in the Baltic Sea Region. Already in 1999/2000, the annual container traffic volume exceeded the level of Ro-Ro traffic (in million tonnes).

Transhipment and Ro-Ro containers:

There is no information available about the transhipment share of the container traffic, i.e. the part of the traffic that has origin or destination overseas[3]. Transhipment may constitute the main share of the container feeder traffic between Norway and the North Sea deep-sea container ports, which implies that the statistics about container flow figures cannot be used directly for any forecasting of unitised goods traffic between Norway and continental Europe.

Another question is whether there is a competitive overlapping between unitised goods carried on Ro-Ro vessels (including containers on Ro-Ro trailer equipment) and unitised goods carried by Lo-Lo feeder vessels.

[3] The UK national statistical services carried out (in 2006) some surveys in UK container ports to establish the transhipment quantities. Similar surveys have not (to Authors' knowledge) been planned in other NSR countries.

3 ESTABLISHING OD-MATRICES

The base year is currently 2005/2006. Historical data involves the period 1985/1990/1995 – 2005/2006. Quantitative forecasting has been done up to 2020/25 for alternative sets of development variables as defined in the scenarios (ref. the SUTRANET report 'Unitised Goods Transport Scenarios in the North Sea Region'). This is to ensure that the period covered by the time series matches the length of the quantitative forecasting horizon i.e. a 15-20 years period.

Establishing OD matrices for a base year is the most problematic step, as there is normally no adequate OD information publicly available. Individual ferry and line operators may have some relevant information but – as mentioned previously - this is in most cases restricted by commercial sensibility and property rights.

Instead the distribution of flows have to rely on "synthetic" or "artificial" data, or on a distribution key based on actually reported quantities, often on country basis. A rough and relative distribution at zone level could be done according to the regionalised Gross Domestic Product (GDP) and regionalised foreign trade figures within each country.

As to the Norway – Jutland – continental Europe corridor, the OD matrices could apply a zoning in accordance with the zones presented in Appendix B. Within the geographical scope of this corridor case description, the following zones in Norway could be applied for the breakdown of traffic to and from Norway (ref. Figure II.4): NO1-2; NO3; NO4; NO5-6; and rest of Norway. In this context the other zones in the corridor could be: DK1; DK2; DK3; DE1; DE2; DE3; DE4-6; NE1; NE2; and BE1. The external zones at a more aggregated geographical level could be (if central European countries are excluded): the rest of Germany; France; Spain/Portugal; Switzerland; and Italy.

In the case that only data on the national GDP is available, the regional GDP figures at zone level have to be estimated e.g. based on other zone data as explained previously.

Periodic OD surveys (e.g. every four years) have to be carried out to provide the minimum level of appropriate OD information for the modelling.

The Norwegian National Freight Model has elaborated some OD information. As to western Denmark, there are no matching modelling initiatives or OD information.

4 THE DISTANCE CONCEPT IN SUPPLY MODELLING

The "distance" or generalised cost of each link and node - and of alternative routes - is a measure of resistance on the particular link and route. It can be used for the assignment of goods flows on alternative routes (consisting often of two or more links).

The general cost of a particular link or route could be a combination of the transport fare charged per Ro-Ro unit or TEU, and the total transport time and/or frequency in case the maritime link section constitutes the main part of the route.

It is suggested (ref. Kronbak, 2005) that the generalised costs for each link of the route are composed of three cost contributions: distance dependant costs; time dependent costs; and toll and fares. Each of these components is described in the following Chapter III: 'The Use of GIS for Modelling and Visualisation'.

To enable the calculation of alternative route costs for each container unit (TEU) and Ro-Ro unit (accompanied trailer or semi-trailer; and swap bodies in case railway transport is involved), information is needed about:

- the vehicle operating costs (VOCs) for overland road links,
- the handling costs and/or fares in the port, and
- the fares or a calculated distance dependent cost for the various types of vessels (RoPax, Ro-Ro and Lo-Lo feeder vessels).

Future infrastructure investment, port fares, the introduction of fuel taxes and road pricing would affect the competitiveness between alternative routes. For instance the "Maut" in Germany and a future road pricing scheme for transport of heavy vehicles through Jutland and Sweden will affect the distribution and competition between direct maritime routes and overland routes combined with short ferry routes. The introduction of a particular road pricing for heavy vehicles will make the distance on the overland route "longer" in term of costs. This is one of the potential and effective policy tools available to provide a "level playing field" between alternative transport modes.

Unitised goods services by railways (swap bodies, containers, trailers) are not currently offered in the part of the corridor through Jutland and Schleswig-Holstein. However, such rail services could be introduced in the future. In this case the cost elements for the future railway links and terminal costs will have to be estimated to be included in the model network as well, ref. the model description in the following Chapter III.

III The Use of GIS for Modelling and Visualisation in the Norway – Continental Europe Corridor

Introduction

During recent years the awareness of how geographical information systems (GIS) can be used within different sectors, including the transport sector, has increased. The nature of transport makes it obvious to apply spatial modelling. The implementation has, however, been somehow limited due to the relative high demand for specialisation associated with the adaptation of GIS. As a result of this, the use of GIS within the transport sector has to some extent been predominated by research institutions, whereas the associated businesses have been more reluctant to apply GIS-based tools.

On this background, the SUC Foundation ("SUC-Fonden")[4] in Denmark decided to fund a project that should demonstrate how a theoretical spatial modelling approach can be used among different players (businesses, decision makers, government etc.) within the freight transport sector. The aim of the project was to develop a fully functional prototype of a GIS-based tool to provide modelling, assessment and illustration of transport costs and competitive relations between modes within freight transport.

The GIS-based tool was given the acronym SUC after the Foundation although in this context it is an acronym for "Spatial Unfolding of Costs". SUC is a spatial GIS-based tool for visualisation and assessment of cost and competition within freight transport. The tool in its present form focuses on road and short sea transport, but it can easily as well include other modes like rail, air or inland waterways.

The presented tool is not a traditional transport model – it is a strategic tool that can model and visualise the supply (or performance) of an intermodal transport system. In contrast to a traditional transport model it does not include any modelling of the demand for transport or assignment of transport flows. There are a number of advantages to such an approach:

- The tool is fairly low-cost to operate and it computes fast. This means that it is easy to make a large number of model runs and to test different scenarios.
- The tool can provide easily understandable information about the transport system and its performance e.g. as thematic maps. This can help broaden the decision-making process.

[4] "SUC-Fonden" is a foundation that is locally based in south-western Jutland with the aim to support research and higher education initiatives in this geographical area.

- Any user can combine the output of the model (the supply of the transport system) with their individual demand model. There is no need to share confidential and sensitive business information.

The base of the tool is a transport system modelling tool. The transport system modelling tool maintains a digital transport network covering most of Europe, and it is possible to model the generalised cost of transport for the entire network. The network model can handle both link-based costs and node (point) -based costs, which makes it possible also to model all kinds of modal shifts etc.

On top of this the SUC tool includes a number of visualisation possibilities designed to help analysing different aspects of the performance of the transport system. These possibilities for visualisation include e.g. "isocost" maps (see below). Both the transport system modelling tool and the visualisation tool are fully integrated within the geographical information system ArcInfo Workstation.

This chapter describes the application of the SUC tool to the SUTRANET project. It is organised as follows: The following Section 1 describes the tool, and Section 2 shows an example of how the tool can be implemented within a project like the unitised goods transport network in the Norway – Jutland - continental Europe corridor.

1 MODELLING THE PERFORMANCE OF THE TRANSPORT SYSTEM

The modelling of the cost of traversing an intermodal transport system can be divided into two steps: first a modelling of the physical performance of the transport system, and secondly a calculation of the cost associated with the use of the transport system.

The modelling of the physical performance of the transport system is closely linked to the implementation within the GIS and provides the distance and transport time for traversing space using the intermodal network. Calculation of the cost associated with the use of the intermodal transport system is based on the physical performance of the transport system as the costs are divided into distance and time dependent costs, and toll and fares costs.

The modelling of the physical measurements and calculations of costs are further dealt with in the following sub-sections.

1.1 The Digital Network and Modelling of Distances and Transport Time

There exist a number of different conceptual models for implementing intermodal transport systems within GIS. The conceptual models differ to some extent depending on the specific GIS software chosen for the modelling, but basically most transport systems are modelled as digital networks represented by vectors and therefore based on the geometrical primitives: links (or arcs) and nodes.

Vector representation for modelling and handling of digital networks is very commonly used, and examples can be found in e.g. car navigations systems and route finding tools on the internet (MapQuest 2006). It is, however, not within the scope of this chapter to give a thorough description of the functionalities of geographical information systems or the handling of digital intermodal networks as such description can be found elsewhere in the literature (Jourquin and Beuthe 1996; Kronbak et al. 1996; Jourquin and Limbourg 2003; Kronbak 2005).

1.2 The Transport Costs

As the purpose of the SUC tool is to model the cost of unitised freight transport, an important step in the modelling is the transformation of the physical measurements (transport distances and time) into monetary values. This is done by calculating a generalised cost for traversing each link in the digital network and a cost of passing through specific nodes.

The generalised cost for each link is composed of an addition of three cost contributions:

- Distance dependent costs;
- Time dependent costs;
- Toll and fare costs.

The distance and time dependent costs normally apply to road transport whereas sea transport normally operates with fares.

The distance dependent cost components for road transport are typically vehicle operating costs (VOCs) covering e.g. fuel consumption, maintenance, tires etc. For sea transport a distance dependent cost can also be used e.g. in cases with lack of information on fares. The distance dependent cost for each link within the network can be found as:

$$DD_{\cos t} = (DD_{CC1} + DD_{CC2} + ... + DD_{CCn}) * TransportDist \qquad (1)$$

where DD_{cost} is the total Distance Dependent cost for the link;
DD_{CC1} … DD_{CCn} are the Cost Components;
TransportDist is the length of the link.

The time dependent cost components for road transport are typically wages and depreciation of the equipment and material (including e.g. financial costs). The time dependent cost for each road link is found as:

$$TD_{\cos t} = (TD_{CC1} + TD_{CC2} + \ldots + TD_{CCn}) * TransportTime \qquad (2)$$

where TD_{cost} is the total Time Dependent cost;
$TD_{CC1} \ldots TD_{CCn}$ are the Cost Components;
TransportTime is the time used to traverse the link.

In the SUC tool the distance and time dependent costs are modelled using a look-up table describing the cost for different link types or specific links. In the same way as for the calculation of the traverse time, the calculation of the different cost elements can be made on an arbitrary classification of the transport network based on e.g. country, region, road type, truck type, wages etc.

The fare and toll costs are normally linked to either the use of a sea link, modal shift or the passage of a physical location like e.g. a toll bridge, a toll tunnel or a toll ring. The fare and toll costs for specific links are found as:

$$Fare \,\&\, Toll_{\cos ts} = FTC_1 + FTC_2 + \ldots + FTC_n \qquad (3)$$

As it was the case for the time and distance dependent costs, the fare and toll cost calculations are controlled by look-up tables. The fare and toll cost file includes more information than the distance and time cost files but the principle is the same.

1.3 Advantages of the SUC Tool

Besides mapping of the present performance of the transport system, one of the main purposes of the SUC tool is to illustrate the consequences of changes in the transport system. In order to do that it must be possible to change as many parameters as possible. This calls for a simple but at the same time flexible model for handling the cost of transport.

The way that this paradox has been solved in the SUC tool has been to develop a cost model based on a fairly simple functional classification of links and nodes within the digital network and then to use a SQL[5] like approach to calculate the costs of traversing the transport system. This means that the demands in terms of information requirements for the digital network are very limited, and at the same time the possibilities for defining and using different costs are quite flexible. This gives the possibility to use the tool for modelling a large variety of different scenarios.

[5] SQL = Structured Query Language is an interactive computer programming language for getting information from and updating a database, i.e. it is designed for retrieval of data in a database management system.

There are basically two types of changes that can be made within the SUC modelling tool and which will affect the performance of the transport system, i.e. either changes to the network or changes to the costs. Examples of possible changes to the network could be:

- Introduction of new infrastructure. This could be in the form of new roads, ports, fixed links, new railways etc. In this context new sea links like e.g. Motorways of the Sea (MoS) are also to be looked upon as infrastructure.
- Major changes in the existing infrastructure. In this case that could be e.g. limitations on road links used by trucks, upgrading of existing sea links to MoS routes, or upgrading of railway links.
- Changes in the performance of the infrastructure. Examples of this could be increased congestion on roads but also decreased congestion due to e.g. information technology. For the sea links it could be improved performance due to more effective port operations etc.

Examples of possible changes to the costs could be:

- Any type of changes in the cost of operating. This could be changes in fuel prices, salaries, financial costs etc.
- Any form of road pricing. This could be a road pricing scheme that depends upon distance, time or location, or it could be a common European road pricing scheme.
- Changes in pricing and performance at transfer points. This could be changes in the cost and time use at modal transfer in ports, terminals, at borders etc.

The SUC tool can handle the modelling of any of the above mentioned changes, either one at a time or in any arbitrary combination.

2 VISUALISATION

It is not possible to show every aspect of the performance of an intermodal transport system on a single map. Instead the SUC tool is based on a number of visualisation possibilities that can be used in a variety of different ways. In its current form the tool has the following visualisation possibilities:

- Isocost maps;
- Differential maps;
- Scenario maps;
- Port hinterland area maps.

In relation to the SUTRANET project's Norway – Jutland – continental Europe transport corridor description, only isocost maps are used and presented. In this chapter, the SUC tool has been used for modelling the cost of transporting one trailer from respectively Hamburg, Oslo and Stavanger. These locations have been chosen as they represent major terminals or nodes in the transport system.

2.1 Variables and Assumptions

In the context of the Norway - Jutland – continental Europe corridor the focus has been on modelling the cost of freight transport at a European level, and the modelling of the traverse speed for roads has to reflect this purpose and level of aggregation. This means that a model for calculating e.g. the road traverse speed that uses parameters like the number of lanes, the gradient of the road etc. will be too advanced (and expensive) for the chosen aggregation level. Instead a more simple approach is chosen where all road links are classified according to a fairly simple classification, and a country specific look-up table determines the speed for each of the link types. This way of handling road speed still provides the possibility to introduce and use country specific congestion factors.

The cost of traversing each link depends, as previously described, upon the valuation of the time use and the valuation of the distance.

In this implementation the value of time (VOT) is modelled as a composite cost composed of several components. As the transport is international the costs are based on the ITD (International Transport Denmark) cost calculator. The same VOT has been used for all countries in order to make the calculations more understandable, although the model can handle almost any arbitrary differentiation of the cost.

In the same way as for the VOT, the vehicle operating cost (VOC) is a composite cost composed of several components. Again the cost components and the costs are based on the ITD cost calculator. The applied VOT and VOC costs are shown in the following Table III.1.

Table III.1: The VOT and VOC cost applied in the SUC tool

Component	Road transport cost per trailer
VOT	10 EUR/h
VOC	1 EUR/km

Source: The ITD (International Transport Denmark) cost calculator

When making interpretations of the isocost maps it has to be kept in mind that the calculation of costs for road transport heavily depends on the assumed flow speed on each network link. In order to illustrate the potential of the transport system, free flow conditions has been assumed on all parts of the Trans-European Transport Network (TEN-T). Ideally the average speed on the congested European road network would be an output from a transport model.

The sea transport system is somehow much simpler than the road transport system. Each sea link simply has its own cost (or fare). Due to the opaque pricing structure for sea transport, the operators' trailers list prices have been used for all sea links. A map of the intermodal network can be seen in Figure III.1.

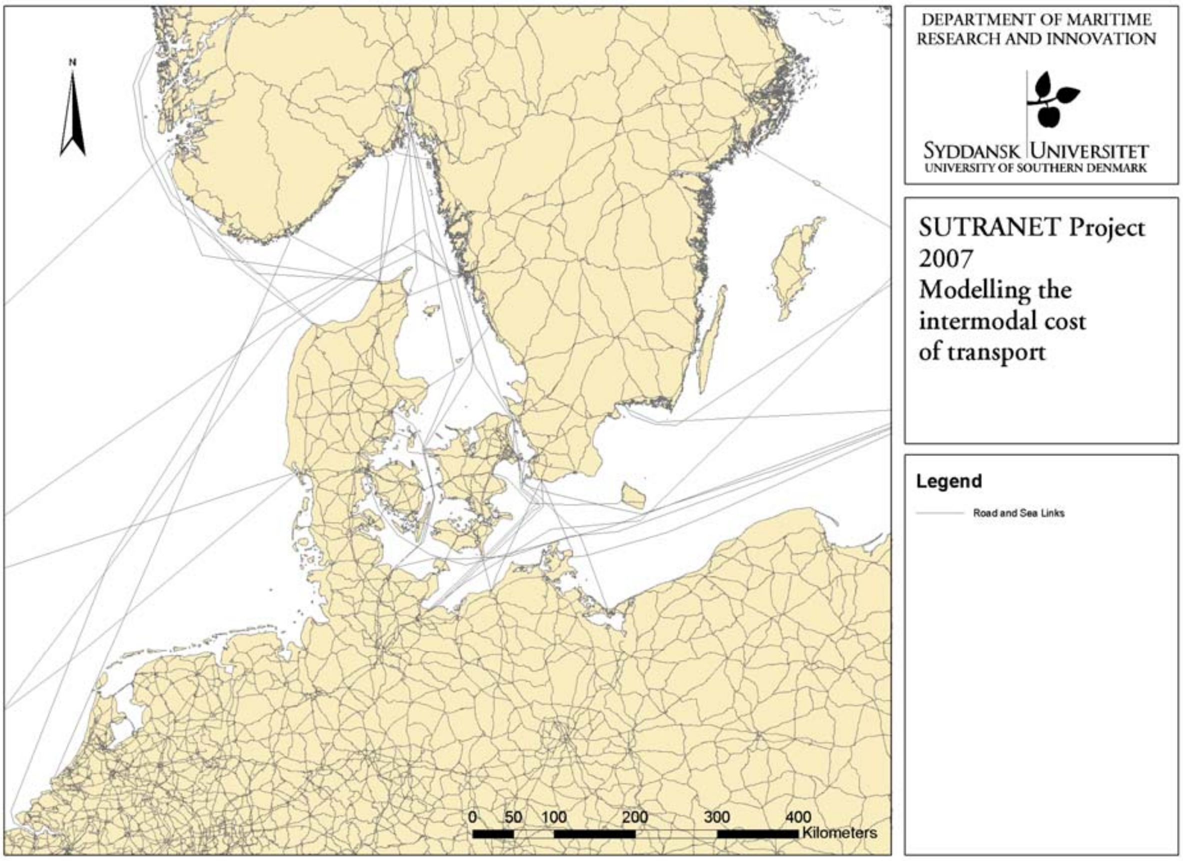


Figure III.1: The intermodal transport system used for the calculations

As the purpose of the modelling is to evaluate the performance of the road-sea intermodal transport system, a threshold limit of approximately 3 departures a week has been used for the sea links. This is of course a simplification of the sea link transport system within the North Sea area as there are a number of liner services within the area with lower frequencies. Also a number of east-west going sea links into the Baltic Sea have been omitted.

2.2 Isocost Maps

Isocost maps are showing different cost levels for the accumulated cost of transport from a given location by using the shortest possible route (in this case the least expensive route according to the general cost criterion). The transport costs are illustrated as uniform bands of isocosts.

The calculated isocost map for an intermodal transport originating in Hamburg can be seen on Figure III.2.

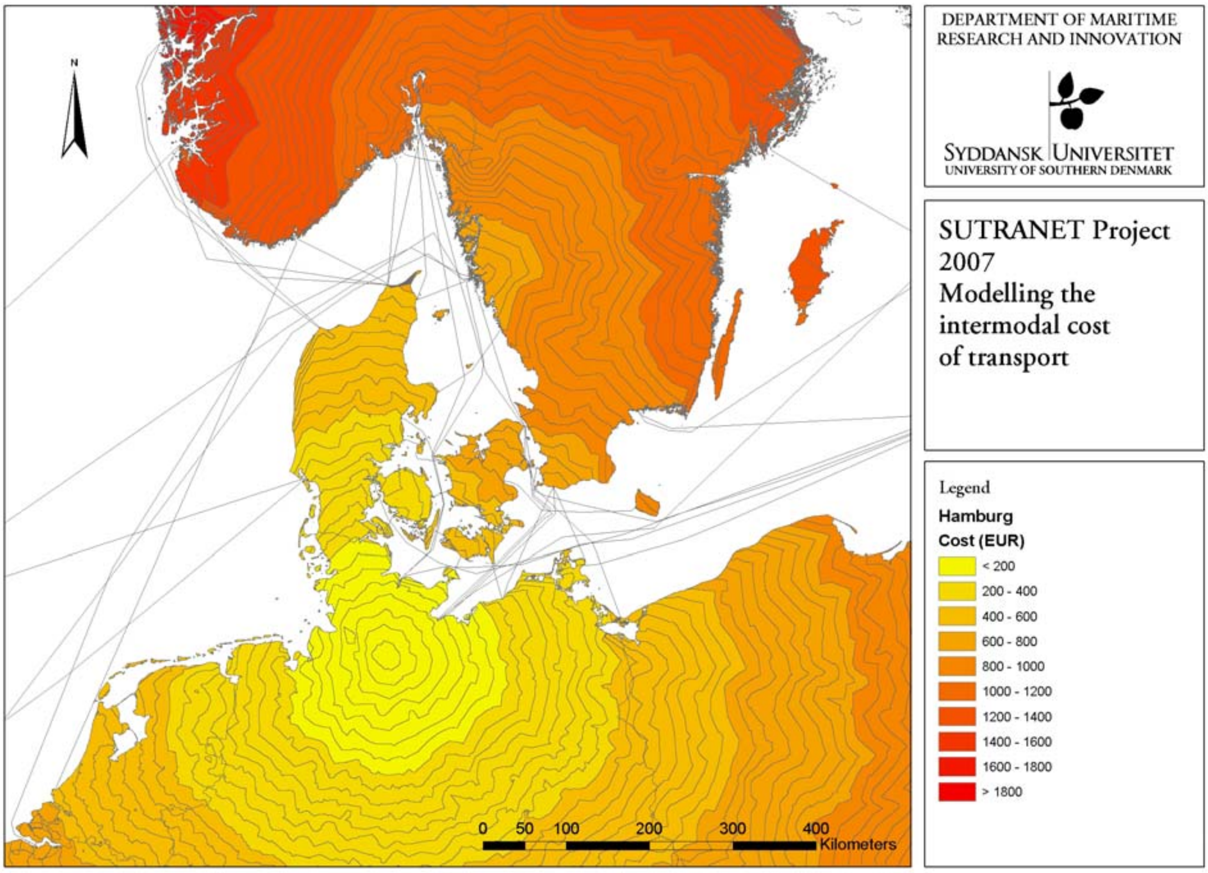


Figure III.2: Isocost map for intermodal transport originating in Hamburg

At first glance the isocost bands seam to spread out in more or less concentric circles with Hamburg in Germany as origin. This would indicate an almost equally spatial distributed cost of using the transport system. There are, however, plenty of variations within the cost structure that influences the pattern on the isocost map.

The different speed on the road network links and especially on the motorways affects the shape of the isocost bands. Towards the central part of Jutland, the motorway (E45/A7) stretches the isocost band along the line routing of the motorway.

Also the sea lines influence the isocost bands. When interpreting the maps it is, however, important to keep in mind that the frequency of the sea lines has not explicitly been taken into account. This means that the sea lines either perform at there best being available just when there are needs or that the truck transport can be organised to fit the sea line schedule.

The Trelleborg-Travemünde sea link (served by Scandline) “beachheads” the isocost bands at Trelleborg in Scania, indicating that this is the least expensive route between Hamburg and the southern part of Sweden. The same type of “beachhead” can be seen at Gothenburg. It might look as this “beachhead” is due to the Frederikshavn-Gothenburg sea link (served by Stena Line) but in this case it is the Gothenburg-Kiel/Travemünde sea link that is the least expensive.

In the Oslo area - although it is nearly impossible to see on the above map - the cost of using the route through Gothenburg is almost the same as using the route through northern Jutland. This is not very surprising because the pricing of the different alternative routes to a large extent are correlated. This tight competition between the two routes can much easier be seen on the isocost map for an intermodal transport originating in Oslo, which is shown on Figure III.3.

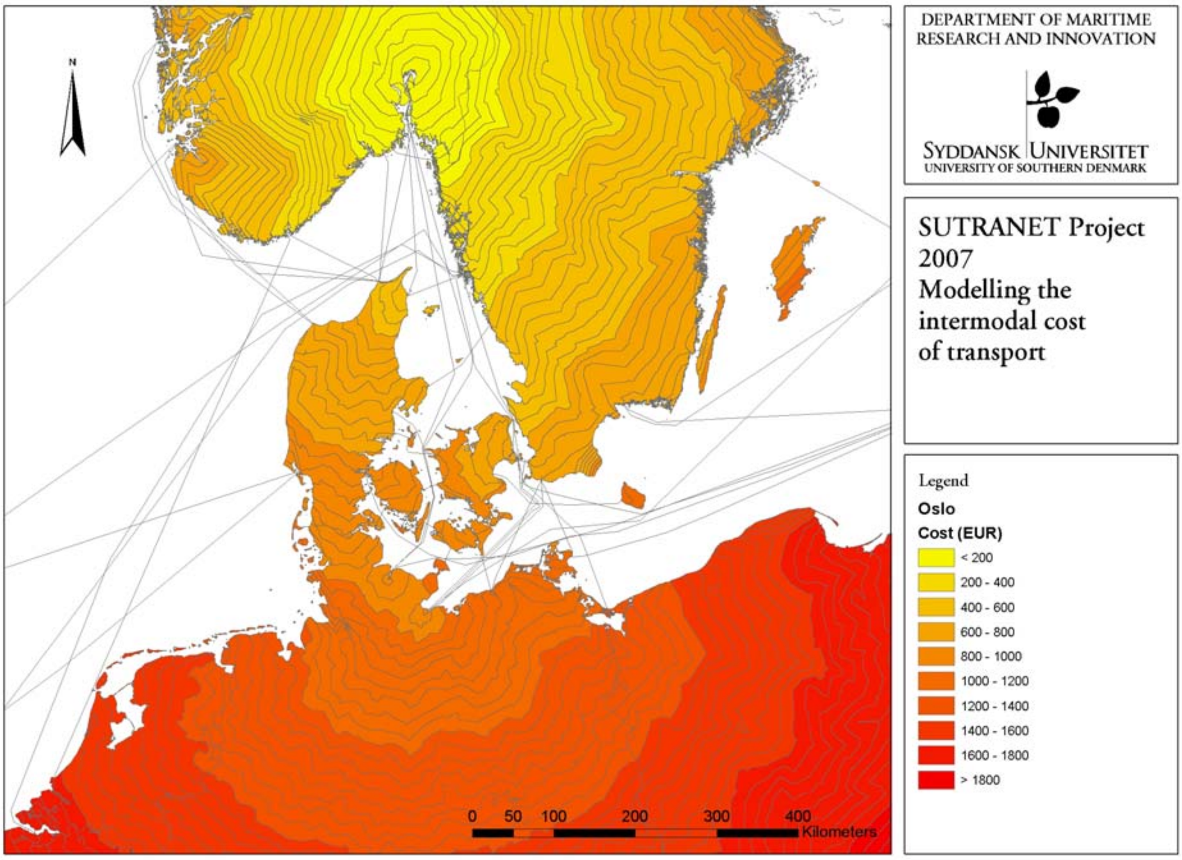


Figure III.3: Isocost map for intermodal transport originating in Oslo

Again the isocost bands seams to spread out in more or less concentric circles, in this case with Oslo in Norway as origin. The influence of the major road transport system can be seen on this map as well, as the E18 stretches the isocost band along the line routing between Oslo and Stockholm in Sweden.

Most interesting on this map is, however, the area around and to the north of Hamburg. It can quite clearly be seen how the isocost bands stretched by the E45 motorway from Jutland meets with the isocost band “beach headed” in both Kiel and Lübeck/Travemünde. This indicates a very tight competition between the routes going via northern Jutland and via Sweden.

Finally an isocost map for an intermodal transport originating in Stavanger in Norway is shown on Figure III.4.

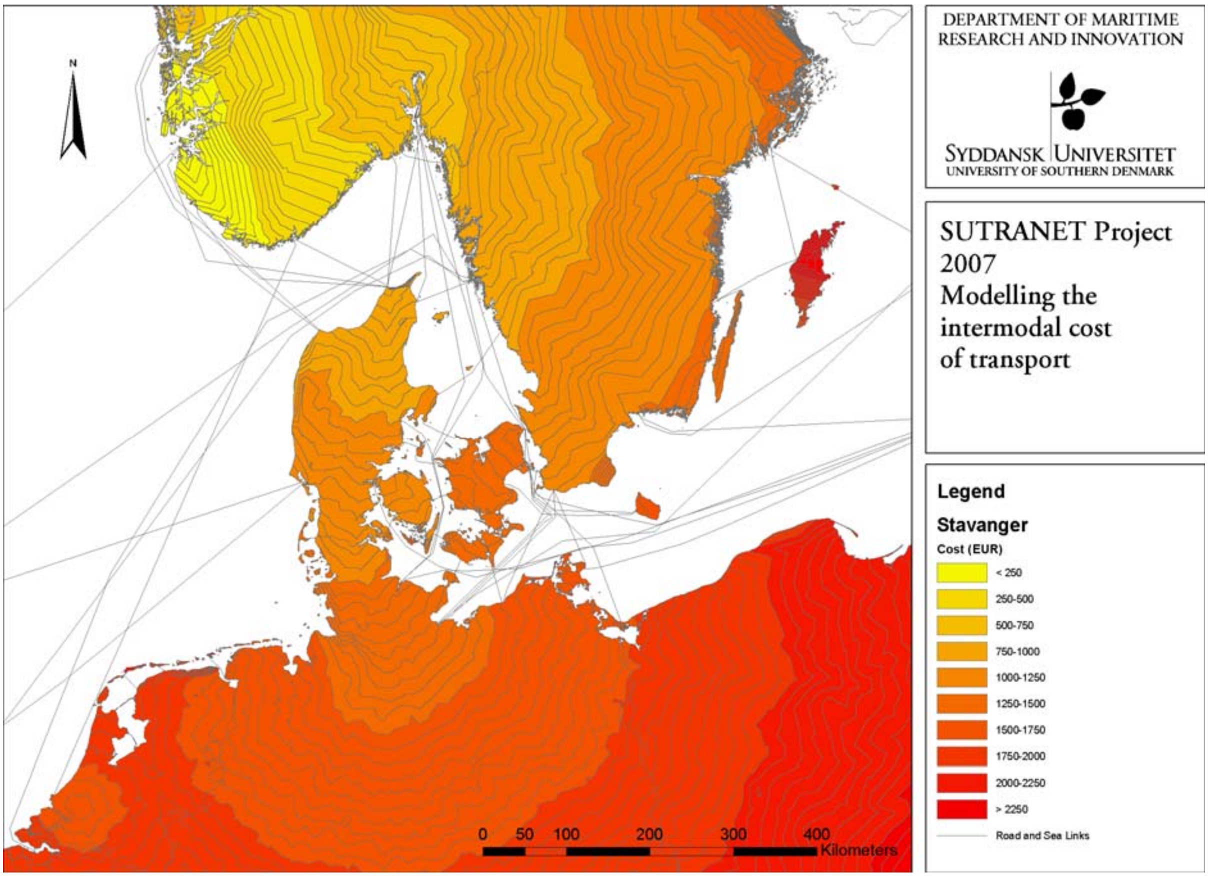


Figure III.4: Isocost map for intermodal transport originating in Stavanger

The map in Figure III.4 has some similarities with the Oslo map in Figure III.3 as goes for the isocost lines in Sweden. In this case, however, the least costly route to the northern part of Germany goes via Jutland. Moreover, it is worth noticing that the route from Kristiansand to Rotterdam is competitive for destinations in Belgium, the Netherlands and the southern part of Germany. This can be seen as the route “beachhead” in the lower left corner of the map.

REFERENCES AND LITERATURE

General Literature:

Danish Transport Council, 2002: Goods Transport Modelling vol. I – Data and Methodologies (Note No. 02-02, March 2002)

Hensher, D.A. and Button, K.J. (ed.), 2000: Handbook of Transport Modelling (Elsevier Science Ltd, 2000)

Kristiansen, J., 2002 (in Danish): Færgeruternes Godstransport (Unpublished report by the “TRANE” project. Department of Development and Planning, Aalborg University February 1992)

Kristiansen, J. et al, 2001: Goods Transport Models – Data and Methods (Paper presented at “Trafikdage”, Aalborg University, August 2001)

Kronbak, J., 2005: The use of GIS for visualisation of competition between truck and RoRo traffic (Paper presented at “Trafikdage”, Aalborg University, August 2005)

Matrex Oy, 2003: FRISBEE: Freight Transport Model in Europe and Russia (Slide presentation dated 9 January 2003)

Northern Maritime Corridor, 2003: Data delivery for the Northern Maritime Corridor (Report No 2-01 of the NMC project under Interreg IIIB, April 2003)

Northern Maritime Corridor, 2003: Further Breakdown of Transport Flow Information for the Northern Maritime Corridor (Transnational Report of the NMC project under Interreg IIIB. Report No 2-02, July 2003)

SINTEF, 1998: STEMM WP4 and WP7 Report for the Nordic Freight Study (Report submitted to the European Commission, DG VII. SINTEF Civil and Environmental Engineering, Norway 11-09-1998)

Tavasszy, L.A., 2006: Freight Modelling – An overview of international experiences (Paper prepared for the TRB Conference on Freight Demand Modelling. Washington DC, 25-27 September 2006)

TØI, 2002: PINGO. A model for prediction of regional and interregional freight transport. Version 1 (TØI rapport 578/2002. Institute of Transport Economics, Norway April 2002)

TØI, 2005 (in Norwegian): Forslag til ny og mer detaljert soneinndeling i Nemo (Working document TØ/1780/2005. Institute of Transport Economics, Norway)

TØI, 2006: Establishing marginals for Norwegian freight flows in 2003 (Report TØ/1837/2006. Institute of Transport Economics, Norway)

Virth, Inge, 2004: Applications, weaknesses and development issues of the Swedish National Freight Transport Model System Samgods (SIKA Document 2004:1)

VTI and Inregia AB, 2001: A Conceptual Framework for Analysis and Model Support for Swedish Studies of Freight Transport and Transport Policy (Swedish National Road and Transport Research Institute, November 2001)

Literature Referring to the SUC Modelling Tool:

ATL, 2004: Transport Agreements between ATL – The Employers' Association for Transport and Logistics and SiD – The General Workers' Trade Union in Denmark, March 1st 2004 – March 1st 2007 (Obtained 1 February 2006, http://www.atl.dk/graphics/Downloads/overenskomster/Overenskomst_2004_engelsk.doc)

Danish Ministry of Transport, 2003: Danish Manual for Economic Evaluation of Transport Investments (in Danish). ISBN 87-91013-36-4

Jourquin, B. and Beuthe, M., 1996: Transportation policy analysis with a geographic information system: the virtual network of freight transportation in Europe (Transportation Research C 4 6, pp. 359–371)

Jourquin B. and Limbourg S., 2003: Assignment techniques on Virtual Networks: Performance considerations on large multi-modal networks (Paper presented at the NECTAR conference, Umea, Sweden, 13-15 June 2003)

Kronbak, J. and Riff-Brems, C., 1996: Modelling of multimodal transport networks in GIS (in Danish) (Notat 1996-4, Department of Planning, Technical University of Denmark)

Kronbak, J., 2005: The SUC Model - A spatial GIS-based tool for visualisation and assessment of cost and competition within freight transport (Final Report, Department of Environmental and Business Economics, University of Southern Denmark. Esbjerg 2006)

Krumme, G., 2006: Economic Geography Glossary (viewed 1 February 2006, http://faculty.washington.edu/krumme/gloss/i.html)

LEGO, 2006: Corporate information and company profile (viewed 1 February 2006, http://www.lego.com/info/pdf/LEGO_company_profile_UK.pdf)

Luo, M. and Grigalunas, T.A., 2003: A Spatial-Economic Multimodal Transportation Simulation Model for US Coastal Container Ports (*Maritime Economics & Logistics* 5: 158–178)

MapQuest, 2006: (viewed 1 February 2006, http://www.mapquest.com/)

Port of Esbjerg, 2005: (viewed 1 February 2006, http://www.esbjerghavn.dk/default_uk.asp)

Appendix A:
TIME SERIES FOR RO-RO TRAFFIC

Table A1 presents the estimated time series 1989-2005 for different segments of Norwegian Ro-Ro traffic in the Norway – Jutland – continental Europe corridor. Only tonnes figures are included, as it has not been possible to retrieve unit (number of trailers etc.) figures.

Table A1: Annual figures of Ro-Ro traffic via Jutland (sum of both directions)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Norway-Denmark 1000 tonnes		1187	1550	1384	1406	1594	1575	1542	1626	1673	1845	1560	1398	1470	1471	1894	1993
Copenhagen-Oslo 1000 tonnes		222	246	239	242	263	292	309	304	317	353	286	281	279	239	233	209
Norway-Jutland 1000 tonnes	863	965	1304	1145	1164	1331	1283	1233	1322	1356	1492	1274	1117	1191	1232	1661	1784
Estimated transit share %	55	55	60	60	60	60	60	60	60	60	60	55	50	50	50	55	55
Estimated transit 1000 tonnes	475	531	783	687	698	799	770	740	793	814	895	701	559	596	616	914	981
Estimated regional 1000 tonnes	388	434	521	450	460	532	513	493	529	542	597	573	558	595	616	747	803
Gothenburg-Fr.havn total 1000 tonnes	1380	1585	1582	1648	1565	1896	1653	1918	2092	2197	2156	2130	2126	2255	2210	2399	2243
Estimated Norwegian Transit share %	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Estimated Norwegian Transit share 1000 tonnes	152	174	174	181	172	209	182	211	230	242	237	234	234	248	243	264	247
Estimated Norwegian regional share %	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Estimated Norwegian regional share 1000 tonnes	104	119	119	124	117	142	124	144	157	165	162	160	159	169	166	180	168
Estimated total Norwegian transit 1000 tonnes	627	705	957	868	870	1008	952	951	1023	1056	1132	935	793	844	859	1178	1228
Transit Ro-Ro index	89	100	136	123	123	143	135	135	145	150	161	133	112	120	122	167	174
Estimated total Norwegian regional 1000 tonnes	492	553	640	582	583	674	637	637	686	707	759	733	717	764	782	927	971
Regional Ro-Ro index	89	100	116	105	105	122	115	115	124	128	137	133	130	138	141	168	176
Foreign trade Denmark-Norway Value index		100	109	106	104	110	112	121	130	123	121	138	133	146	130	137	144

Sources: Statistics Denmark Table SKIB32 (1990-2005 figures); TRANE project (1989 figures)
Figures are excluding tare weight. The value index for foreign traded Denmark-Norway is in fixed prices.

The shares of transit traffic for the Norway Jutland ferry routes and the Gothenburg-Frederikshavn ferry route are estimated as percentage figures in Table A1, see as follows.

Assumptions/estimates of Norwegian traffic via Sweden and Gothenburg

In 1989 it was estimated (the "TRANE" project: 'Færgeruternes Godstransport', Aalborg University February 1992) that 200-300 x 1000 tonnes of the total of 1380 x 1000 tonnes was traffic to/from Norway via Svinesund (border between Norway and Sweden). If around 60% of this share is transit through Jutland, it gives 9-13% (11% in average) Norwegian transit traffic share. If the share of regional traffic is assumed to be 40%, this gives 6-9% (7.5% in average) Norwegian regional traffic share. These estimates are highly unreliable because there are no recent origin-destination surveys on which to base the estimates.

There are no data available on the share of Swedish transit traffic (to/from Germany and beyond) on the ferry route Gothenburg-Frederikshavn, but according to rough estimates this share was around 50% in 1990 and has probably declined to 25-30% in 2005. This implies that the growth in Norwegian regional traffic (defined as traffic with origin or destination in western Denmark) is higher than reflected by the 7.5% figure in Table A1.

Direct Kattegat routes between Norway and the Germany Baltic Sea coast

This group involves the ferry (RoPax) routes between Oslo and Kiel and between Gothenburg and Kiel. There are no statistics available regarding the share of Norwegian transit traffic via Gothenburg-Kiel.

Table A2: Annual figures of Ro-Ro traffic between Oslo/Gothenburg and Kiel (sum of both directions)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oslo-Kiel 1000 tonnes	789	812	757	895	1026	960	1065	1034	977	835	792	786	750	705	763	880
Oslo-Kiel Index (2005 = 100)	90	92	86	102	117	109	121	118	111	95	89	89	85	80	87	100
Gothenburg-Kiel 1000 tonnes	929	920	948	908	1011	1336	1213	1044	1023	942	1022	953	929	987	869	878
Gothenburg-Kiel index (2005 = 100)	106	105	108	103	115	152	138	119	117	107	116	109	106	112	99	100

Source: ISL based on Seehafen Kiel GmbH & Co, ref. the SUTRANET 'Statistics Report Germany'.

Tonnes figures in Table A2 include tare weight, and they cannot be compared directly with the figures in Table A1 for Ro-Ro traffic via Jutland.

The share of Norwegian Ro-Ro traffic via the Gothenburg-Kiel route is not known. A preliminary "guesstimate" could be 10%, and the derived data are only to be considered as synthetic model data.

Statistics Norway presents, in its Table 04225 (ref. the SUTRANET report 'Statistics Report Norway'), the goods flows on the Oslo-Kiel route, but only since 2003. These figures exclude tare weight and cannot be compared directly with the figures in Table A2.

Appendix B:
DETAILED ZONE DATA

Some socio-economic data for each of the selected zone is presented in the following tables. However, the data filling in the tables is incomplete, and the aim of presenting the tables is to demonstrate the data needs.

Zones suggested to be selected for the Southern Norway-Jutland corridor analysis (ref. Chapter II) are marked by grey colour. These zones might be even further aggregated.

Zones covering Denmark

The zones in Denmark follow the division into five administrative regions as from January 2007.

SUTRANET Zone id	NUTS Level (zones)	Zone area (Regions)	Population 1000 inh. 1.1.2005	Area km^2	Population Density people/km^2 1.1..2005	GDP Billion DKK 1990	GDP Billion DKK 2005	GDP Billion € 2005	Foreign trade Billion € 2005
DK1		North Jutland	577	7,875	73.3				
DK2		Mid-Jutland	1,213	13,042	93.0				
DK3		South Denmark	1,184	12,082	98.0				
DK1-3		West Denmark	2,974	32,999					
DK4		Zealand	806	7,237					
DK5		Copenhagen	1,632	2,514					
DK4-5		East Denmark	2,437	9,751	249.9				
DK1-5		Denmark, total	5,411	42,750				208.6	

Sources: Statistics Denmark.

The Copenhagen Region (zone DK5) includes Bornholm.

The following zones could be selected for the SUTRANET case study corridor (Norway – Jutland – continental Europe):

DK1: North Jutland
DK2: Mid-Jutland
DK3: South Denmark
DK4-5: East Denmark

The new regions in Denmark have not as yet (2007) been incorporated in the Eurostat's NUTS statistical zoning system. Each of the Danish counties (which expired to exist as from 1 January 2007) still represents a NUTS 3 zone.

Zones covering Norway

The boundaries of the zones in southern Norway follow the division into counties ("fylker"). They are not included in the Eurostat's NUTS system because Norway is not an EU member state.

Zone id	PINGO zones	SUTRANET zone	Zone area	Population 1000 inh. 1.1.2005	Area km^2	Population Density People/km^2 1.1.2005	GDP Billion € 1990	Price index factor 1990-2005	GDP Billion € 2005	Foreign trade Billion € 2005
NO01	1		Oestfold							
NO02	2		Akershus							
NO01-02	1+2	NO1	Oestfold and Akershus	745	9,099	81.9				
NO03	3	NO2	Oslo	454	522	869.7				
NO04	4		Hedmark							
NO05	5		Oppland							
NO04-05	4+5	NO7	Hedmark and Oppland							
NO06	6		Buskerud							
NO07	7		Vestfold							
NO08	8		Telemark							
NO06-08	6+7+8	NO3	Buskerud, Vestfold and Telemark	624	32,433	19.2				
NO09	9		Aust Agder							
NO10	10		Vest Agder							
NO09-10	9+10	NO4	Austagder and Vestagder	261	16,433	15.9				
NO11	11	NO5	Rogaland	381	9,378	40.6				
NO12	12	NO6	Hordaland	438	15,460	28.3				
NO14	14		Sogn&Fjordane							
NO15	15		Moere&Romsdal							
NO14-15	14+15	NO8	Sogn&Fjordane and Moere&Romsdal							
NO16	16		Soer-Troendelag							
NO17	17		Nord-Troende-lag							
NO18	18		Nordland							
NO19	19		Troms							
NO20	20		Finmark							
NO16-20	16-20	NO9	Northern Norway							
NO01-20			Norway, total	4,606					237.9	

Sources:
- Statistics Norway
- Transportstatistik 2005 NTN korridoren (Institut for Transportstudier, December 2005)

The zones suggested to be selected for the SUTRANET case study corridor are:

NO1: Oestfold and Akershus
NO2: Oslo
NO3: Buskerud, Vestfold and Telemark
NO4: Aust Agder and Vest Agder
NO5: Rogaland
NO6: Hordaland
NO7: Hedmark and Oppland
NO8: Sogn&Fjordane and Moere&Romsdal
NO9: Soer-Troendelag, Nord-Troendelag, Nordland, Troms and Finmark

Zones in Sweden

The zones in Sweden follow the division into regions (NUTS 2 zones) and counties ("län").

SUTRANET Zone id	NUTS Level (zones)	Zone area	Population 1000 inh. (1.1.2005)	Area km^2	Population Density 1.1.2005	GDP Billion €	Foreign trade
SE1	3 (SE0A1)	Västra Götaland	1,522	23,956			
SE2	3 (SE0A2)	Halland	284	5,462			
SE1-2	2 (SE0A)	West Sweden	1,806	29,418			
SE3	2 (SE04)	South Sweden	1,311	13,982			
SE4¤	2 (SE09)	Smaaland etc.	800	33,333			
SE5	2 ((SE02)	Östra Mellansverige	1,515	38,609			
SE6	2 (SE01)	Stockholm	1,873	6,519			
SE7	2 (SE06)	Norra Mellansverige	826	63,987			
SE8	(SE07-08)	Norrland	881	224,466			
SE1-8		Sweden, total	9,011				

Source: Statistics Sweden (www.ssd.scb.se)

No zones in Sweden are suggested to be selected for the SUTRANET case study corridor.

Zones in Germany

Each "Länder" constitutes a NUTS 2 zone, whilst "Kreise" are NUTS 3 zones.

SUTRANET Zone id	NUTS Level (zones)	Zone area	Population 1000 inh. 1.1.2005	Area 1000 km^2	Population Density 1.1.2005	GDP Billion €	Foreign trade Billion €
DE1	2 (DEF)	Schlesvig-Holstein	2,829	15,763			
DE2	2 (DE6)	Hamburg	1,735	755			
	2 (DE5)	Bremen					
	2 (DE9)	Nidersachsen					
DE3	(DE5+ DE9)	Bremen and Niedersachsen					
DE4	2 (DE8)	Mecklenburg-Vorpommern					
DE5	2 (DEA)	Nordrhein-Westfalen					
	2 (DE3)	Berlin					
	2 (DE4)	Brandenburg					
	2 (DED)	Sachsen					
	2 (DEE)	Sachsen-Anhalt					
	2 (DEG)	Türingen					
DE6	DE3+DE4+ DED+ DEE+ DEG						
	DE1	Baden-Württemberg					
	DE2	Bayern					
	DE7	Hessen					
	DEB	Rheinland-Pfalz					
	DEC	Saarland					
DE7	DE1+DE+ DE7+DEB +DEC						
		Germany, total	82,501			2,237.6	

The following zones could be selected for the SUTRANET case study corridor:

DE1: Schleswig-Holstein
DE2: Hamburg
DE3: Bremen and Niedersachsen
DE5: Nordrhein-Westfalen
DE7: Baden-Württemberg, Bayern, Hessen, Rheinland-Pfalz and Saarland

These zones might need to be further aggregated.

Zones covering Benelux

The Netherlands is divided into two NUTS 2 zones.

Zone id	NUTS Level (zones)	Zone area	Population 1000 inh. 1.1.2005	Area 1000 km^2	Population Density 1.1.2005	GDP Billion €	Foreign trade Billion €
NE1	2 (NE1)	North Netherlands					
NE2	2 (NE2)	West Netherlands					
NE1-2	(NE1+NE2)	The Netherlands, total	16,306			505.6	
BE1	1 (BE0)	Belgium	10,446			298.4	

The following zones could be selected for the SUTRANET case study corridor:
NE1-2: The North Netherlands and the West Netherlands
BE1: Belgium

External Zones, Short Sea

The following zones could be preliminarily selected for the SUTRANET case study corridor:

SUTRANET zone id	Zone area	Population 1000 inh.	Area 1000 km^2	Population density	GDP Billion €	Foreign trade
	Rest of Germany					
	France					
	Spain/Portugal					
	Switzerland					
	Italy					
	Mediterranean					

External Zones, Deep Sea

SUTRANET zone id	Zone area	Population 1000 inh.	Area 1000 km^2	Population density	GDP Billion €	Foreign trade

No external (deep sea) zones are envisaged to be selected for the case study corridor as long as the modelling is confined to Ro-Ro traffic.

Appendix C: NETWORK DETAILS – RO-RO

The Norway – Jutland – Continental Europe Corridor

The information presented in this appendix is to be considered as preliminary, and it requires further elaboration.

Abbreviations used:

H = Motorway/Highway
S = Ro-Ro or Ropax route
R = Railway link

Selected routes: Ro-Ro combined with Highways/Motorways

Bergen – Stavanger (H) – Zeebrügge (S) – Paris (H)
Bergen – Stavanger (S)
Zeebrügge – Lyon – Milano – Verona (H)
Stavanger – Cuxhaven (S) – Bremen - Duisburg – Paris (H)
Cuxhaven – Frankfurt (H) – Freiburg – Lyon (H)
Frankfurt – Switzerland (border) - Milano – Verona (H)
Cuxhaven – Bremen - Hannover – Innsbruck (Brenner) – Verona (H)
Cuxhaven – Hamburg (H)
Stavanger – Hanstholm (S) – Kolding – Padborg (border) – Hamburg (H)
Stavanger - Kristiansand (H) – Hanstholm (S)
Kristiansand – Hirtshals (S) – Kolding (H)
Kristiansand – Zeebrügge (S)
Kristiansand – Cuxhaven (S)
Kristiansand – Grenland (H)
Grenland – Zeebrügge (S)
Grenland – Cuxhaven (S)
Oslo - Grenland (H) – Hirtshals (S)
Oslo – Frederikshavn (S) – Kolding
Grenland – Sandefjord (H) – Strömstad (S) – Gothenburg (H)
Oslo – Svinesund (border) - Gothenburg (H)
Oslo- Kiel (S) – Hamburg (H)
Oslo – Cuxhaven (S)
Gothenburg – Kiel (S)
Gothenburg – Frederikshavn (S)
Gothenburg – Helsingborg (H) – Elsinore (S) – Roedby (H) – Puttgarden (S) – Hamburg (H)
Gothenburg – Malmoe – Oeresund (border) – Roedby
Gothenburg – Trelleborg – Lübeck (S) – Hamburg (H)

Puttgarden – Lübeck – Hannover (H)
Hamburg – Hannover - Frankfurt (H)
Frankfurt – Freiburg (border) – Lyon (H)
Frankfurt – Swiss border – Italian border – Milano (H)
Hannover – Innsbruck – Padova (H)
Lyon – Milano – Padova (H)

Motorway/Highway Links

Link No	Link	Link Type(s)	H km	Travel speed	Travel tme hurs/min		
	Bergen-Stavanger	H/S	215		3h 45m		
	Stavanger-Eigersund	H	80		1h 20m		
	Stavanger-Kristiansand	H/R	235		3h 55m		
	Eigersund-Kristiansand	H	175		3h 05m		
	Kristiansand-Grenland	H/R	170		2h 55m		
	Kristiansand-Larvik	H/R	197		3h 35m		
	Grenland-Larvik	H/R	35		45m		
	Grenland-Oslo	H/R	160		2h 25m		
	Larvik-Oslo	H/R	130		1h 55m		
	Larvik-Sandefjord	H	20		25		
	Oslo-Bergen	H/R	515		8h 20m		
	Oslo-Svinesund (border)	H/R	120		1h 55m		
	Svinesund-Gothenburg	H/R	185		2h 35m		
	Oslo-Gothenburg	H/R	295		4h 25m		
	Strömstad-Gothenburg	H	170		2h 20m		
	Gothenburg-Helsingborg	H/R	220		2h 40m		
	Gothenburg-Malmoe	H/R	280		3h 20m		
	Gothenburg-Trelleborg	H/R	300		3h 55m		
	Helsingborg-Malmoe	H/R	65		55m		
	Malmoe-Trelleborg	H/R	35		40m		
	Malmoe-Oeresund (border)	H/R	15		15m		
	Oeresund (border)-Trelleborg	H/R	35		35m		
	Oeresund-Hoeje Taastrup	H/R	42		40m		
	Oeresund (border)-Koege	H/R	60		55m		
	Koege-Roedby	H/R	125		1h 35m		
	Malmoe-Hoeje Taastrup	H/R	60		1h 05m		
	Malmoe-Ringsted	H/R	100		1h 35m		
	Malmoe-Koege	H/R	80		1h 20m		
	Malmoe-Roeby	H/R	195		2h 45m		
	Mamoe-Korsoer	H/R	146		2h 15m		
	Frederikshavn-Taulov	H/R	268		3h 30m		
	Frederikshavn-Kolding	H	272		3h 35m		
	Hirtshals-Taulov	H/R	273		3h 35m		
	Hirtshals-Kolding	H	278		3h 40m		
	Hanstholm-Taulov	H	263		4h 15m		
	Hanstholm-Kolding	H	268		4h 20m		
	Taulov-Esbjerg	H/R	88		1h 15m		
	Kolding-Esbjerg	H/R	76		1h 10m		
	Taulov-Padborg/border	H/R	100		1h 25m		
	Kolding-Padborg/border	H/R	80		1h 15m		

	Kolding-Flensborg	H/R	95		1h 25m		
	Kolding-Hamburg	H/R	240		3h 20m		
	Elsinore-Hoeje Taastrup	H/R	61		1h 10m		
	Elsinore-Ringsted	H/R	104		1h 30m		
	Elsinore-Roedby	H/R	196		2h 55m		
	Hoeje Taastrup-Roedby	H/R	147		2h 05m		
	Hoeje Taastrup-Korsoer	H/R	100		1h 30m		
	Koege-Roedby	H/R	125		1h 35m		
	Ringsted-Roedby	H/R	118		1h 20m		
	Ringsted-Taulov	H/R	157		2h 15m		
	Roedby-Puttgarten	S/(H/R)	(19)		(20m)		
	Korsoer-Nyborg	H/R	27		35m		
	Nyborg-Kolding	H/R	105		1h 35m		
	Nyborg-Taulov	H/R	85		1h 25m		
	Padborg (border)-Flensborg	H/R	10		15m		
	Flensborg-Hamburg	H/R	160		2h 25m		
	Padborg (border)-Hamburg	H/R	170		2h 40m		
	Kiel-Hamburg	H/R	100		1h 40m		
	Puttgarden-Hamburg	H/R	155		2h 25m		
	Puttgarden-Lübeck	H/R	92		1h 25m		
	Lübeck-Hamburg	H/R	70		1h 20m		
	Lübeck-Hannover	H/R	210		3h 00m		
	Lübeck-Duisburg	H/R	440		6h 00m		
	Lübeck-Frankfurt	H/R	555		7h 05m		
	Cuxhaven-Hamburg	H/R	215		3h 00m		
	Cuxhaven-Bremen	H/R	105		1h 35m		
	Cuxhaven-Bremerhaven	H/R	45		45m		
	Bremerhaven-Bremen	H/R	65		1h 05m		
	Bremerhaven-Hamburg	H/R	180		2h 40m		
	Hamburg-Bremen	H/R	125		2h 00m		
	Hamburg-Hannover	H/R	155		2h 25m		
	Hamburg-Duisburg	H/R	380		5h 15m		
	Hamburg-Frankfurt	H/R	500		6h 25m		
	Bremen-Hannover	H/R	126		1h 55m		
	Bremen-Frankfurt	H/R	445		5h 40m		
	Bremen-Duisburg	H/R	270		3h 45m		
	Wilhelmshaven-Duisburg	H/R	305		4h 20m		
	Wilhelmshaven-Frankfurt	H/R	485		6h 10m		
	Frankfurt-Freiburg (border)	H/R	270		3h 40m		
	Freiburg (border)-Lyon	H/R	440		6h 40m		
	Frankfurt-Switz border	H/R	315				
	Switz border-Italian border	H/R	295				
	Italian border-Milano	H/R	60				
	Duisburg-Paris	H/R	535		6h 55m		
	Frankfurt-Milano	H/R	670		8h 40m		
	Hannover-Innsbruck (Brenner)	H/R	805		10h 05m		
	Innsbruck-Verona (Brenner)	H/R	275		3h 35m		
	Zeebrügge-Paris	H/R	310		4h 20m		
	Zeebrügge-Lyon	H/R	780		10h 00m		
	Lyon-Milano	H/R	445		6h 05m		
	Milano-Verona	H/R	165		2h 25m		

SUTRANET

Ro-Ro and Ropax Links

Link No	Link	Link Type(s)	Distance S km	Distance S nm	Sailing time hours/min	Frequency (2005)	Time in port hours/days	Total time	Costs Acc. trailer Euro	Costs Semi-trailer Euro
	Bergen-Stavanger	H/S	190	102	3h 55m	1/d	12h		**700**	**600**
	Bergen-Hanstholm	S		260	16h 30m	1/d				
	Bergen-Hirtshals	S		290						
	Stavanger-Hanstholm	S	320	175	9h	1/d	12h		**850**	**700**
	Stavanger-Hirtshals	S	380	205	11h					**704**
	Stavanger-Cuxhaven	S	580	315	16h	3/w	1d		**-**	**950**
	Stavanger-Zeebrügge	S	940	510	26	1/w	2d		**-**	**1200**
	Eigersund-Hanstholm	S	250	135	7h					
	Eigersund-Hirtshals	S	310	165	8h 30m					
	Kristiansand-Hanstholm	S	123	70	3h 40m	3/d	3h		**660**	**590**
	Kristiansand-Hirtshals	S	125	71	4h	3-4/d	3h		**660**	**586**
	Kristiansand-Cuxhaven	S	500	270	13h 30m	3/w	1d		**-**	**900**
	Kristiansand-Zeebrügge	S	870	470	24h	1/w	2d		**-**	**1150**
	Grenland-Hirtshals	S	157	108	6h	1/d	6h		**750**	**650**
	Grenland-Cuxhaven	S	680	370	19h	3/w	1d		**-**	**1000**
	Grenland-Zeebrügge	S	1050	570	29h	1/w	2d		**-**	**1250**
	Larvik-Hirtshals	S	163	90	5h 30m	1/d				
	Larvik-Frederikshavn	S	191	105	5h	2/d				
	Sandefjord-Strömstad	S	68	37	2h 50m	5/d	2h		**180**	**-**
	Oslo-Hirtshals	S	260	143	8h 30m	1/d				
	Oslo-Frederikshavn	S	291	157	9h	1/d	6h		**700**	**600**
	Oslo-Copenhagen	S	504	272	16h	1/d				
	Oslo-Cuxhaven	S	840	455	23h	1/w	2d		**-**	**1150**
	Oslo-Kiel	S	666	366	19h	1/d	12h		**1050**	**900**
	Gothenburg-Frederikshavn	S	93	50	3h 15m	7/d	2h		**300**	**250**
	Gothenburg-Kiel	S	437	236	14h	1/d	12h		**950**	**800**
	Gothenburg-Travemünde	S		252	15h	1/d				

	Varberg-Grenaa	S		64	4h 30m	2/d				
	Helsingborg-Elsinore	S/(R)	5	3	20m	100/d	20m		**130**	**-**
	Malmö-Travemünde	S		141	9h	3/d				
	Trelleborg-Travemünde	S	220	120	7h 30m	6-7/d	2h			
	Trelleborg-Sassnitz	S		60	3h 45m	5/d				
	Roedby-Puttgarten	S/(H/R)	19	10	1h	48/d	40m		**290**	**-**
	Gedser-Rostock	S		26	1h 45m	9/d				
	Esbjerg-Zeebrügge	S	640	346						

Notes/assumptions:
Sailing time is estimated based on 20 knots (37 km/h), if no time table information is available.
Sailing distance is roughly estimated for the following routes:
Grenland-Cuxhaven; Grenland-Zeebrügge; Kristiansand-Cuxhaven; Kristiansand-Zeebrügge; Stavanger-Cuxhaven; Stavanger-Zeebrügge; Eigersund-Hirtshals/Hanstholm; Stavanger-Hirtshals/Hanstholm; Hirtshals-Bergen.
1 nautic mile (nm) = 1852 m.
1 knot = 1 nm per hour = 1.852 km/h.
Waiting time in ports before departure is an estimate based on sailing frequency, and includes handling of semi-trailers in both ends of the route.
Only trucks with accompanied trailers are served on the following short ferry links (no unaccompanied trailers):
Sandefjord-Strömstad; Helsingborg-Elsinore; Roedby-Puttgarden.
Unaccompanied trailers (semi-trailers) are served on the envisaged Ro-Ro routes between Norwegian ports and Cuxhaven/Zeebrügge.:

Costs/prices:
Estimated route prices/costs per accompanied trailer or semi-trailer include port taxes etc.
1 accompanied trailer = 20 lane meters
1 semi-trailer = 17 lane meters
Sources:
Cargo price lists published by Scandlines and Color Line. Costs on routes served by other operators are estimated (red colour).

Railway Links

Link No	Link	Link Type(s)	Distance R km	Travel speed km/h	Travel time hours +min	Link cost per semi-trailer year 2020 Euro	
	Stavanger-Kristiansand	H/R					
	Kristiansand-Grenland	H/R					
	Kristiansand-Larvik	H/R					
	Grenland-Larvik	H/R					
	Grenland-Oslo	H/R					
	Larvik-Oslo	H/R					
	Oslo-Gothenburg	H/R					
	Gothenburg-Helsingborg	H/R					
	Gothenburg-Malmoe	H/R					
	Helsingborg-Elsinore	S/(R)					
	Helsingborg-Malmoe	H/R					
	Malmoe-Trelleborg	H/R					
	Malmoe-Copenhagen	H/R					
	Frederikshavn-Taulov	H/R					
	Hirtshals-Taulov	H/R	280			**300**	
	Taulov-Esbjerg	R					
	Kolding-Esbjerg	H/R					
	Taulov-Padborg (border)	R	95			**100**	
	Kolding-Padborg	H/R					
	Elsinore-Copenhagen	H/R					
	Elsinore-Ringsted	R					
	Elsinore-Roedby	H/R					
	Ringsted-Roedby	R					
	Copenhagen-Roedby	H/R					
	Roedby-Puttgarten	S/(H/R)					
	Copenhagen-Korsoer	H/R					
	Korsoer-Nyborg	H/R					
	Nyborg-Taulov	R					
	Nyborg-Kolding	H/R					
	Padborg (border)-Hamburg/Maaschen	H/R	170			**200**	
	Kiel-Hamburg	H/R					
	Puttgarten-Hamburg	H/R					
	Lübeck-Hamburg	H/R					
	Cuxhaven-Hamburg	H/R	220			**250**	
	Cuxhaven-Bremerhaven	H/R					
	Bremerhaven-Bremen	H/R					
	Hamburg-Bremen	H/R					
	Hamburg-Hannover (?)	H/R					
	Bremen-Hannover (?)	H/R					
	Hamburg-Frankfurt	H/R	500			**500**	
	Frankfurt-Milano/Verona	H/R	700			**700**	
	Frankfurt-Lyon	H/R	710			**700**	
	Zeebrügge-Paris (?)	H/R					
	Zeebrügge-Stuttgart (?)	H/R					

Ferry Terminals

Node No	Ro-Ro Terminal	Time in terminal hours/days		Terminal cost semi-trailer Euro		
	Bergen			**50**		
	Stavanger/Risavika			**50**		
	Kristiansand			**50**		
	Grenland			**50**		
	Sandefjord			**-**		
	Oslo			**50**		
	Strömstad			**-**		
	Gothenburg			**50**		
	Hanstholm			**50**		
	Hirtshals			**50**		
	Frederikshavn			**50**		
	Zeebrügge			**50**		
	Cuxhaven			**50**		
	Helsingborg			**-**		
	Trelleborg			**50**		
	Elsinore			**-**		
	Roedby			**-**		
	Puttgarden			**-**		
	Lübeck/Travemünde			**50**		
	Kiel			**50**		

Notes/assumptions:
The estimated terminal charge is only on departure and not included in the ferry operator’s handling costs.

Intermodal Terminals (Road/Rail)

As per year 2020.

Node No	Road/Rail Terminal	Time in terminal hours/days		Terminal cost per semi-trailer Euro		
	Taulov	1d		**200**		
	Hamburg/Maschen	1d		**300**		
	Frankfurt	1d		**300**		
	Lyon	1d		**300**		
	Milano/Verona	1d		**200**		

Estimated Costs - 2005/2006 level

Accompanied trailer:

Max length 18.75m = xx lane meters

Time dependents costs (per hour or day):	
Driver (including administration etc.)	40 euro per hour
	360 euro per day
Engine (depreciation, maintenance, overheads, admin. etc.):	100 euro per day
Semi-trailer (depreciation, maintenance etc.):	35 euro per day
Distance dependent costs (road):	
Driver:	0.10 euro per km
Engine (fuel, maintenance):	0.50 euro per km
Semi-trailer (maintenance etc.):	0.05 euro per km
Road tax in Germany (the “Maut”) including misc. costs:	0.20 euro per km
Terminal costs:	
Handling in Ro-Ro terminal:	n.a.
Handling in Road/Rail terminal:	200 euro
Border crossing (toll, customs tax):	30 euro

Driving/rest regulations:

?

Unaccompanied trailer (semi-trailer):

Only on Ro-Ro routes.
1 semi-trailer = 2 TEU (approximately)
Xx lane meters

Time dependents costs:

Distance dependent costs:

Terminal costs:	
Handling in Ro-Ro terminal:	100 euro
Handling in Road/Rail terminal:	200 euro
Border crossing (toll, customs tax):	n.a.