

The use of GIS for visualisation of competition between truck and RORO traffic

(Brugen af GIS til visualisering af
konkurrenceflader mellem lastbil og RORO trafik)

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Introduction

In recent years the use of GIS within different sectors, here among the transport sector, has increased. The popularity has however been limited by the relative high demand of knowledge associated with the adaptation of GIS and the users has therefore been predominated by research institutions whereas the associated businesses has been more reluctant in there use. This has lead to the following two aims for this project:

- The development of a fully functional prototype of a GIS-based tool to illustration and assessment of transport costs and competitive relations within freight transport.
- The developed prototype will demonstrate how a theoretic approach can be used in practice within the freight transport sector and thereby function as a catalyst for an increased cooperation between research at the University of Southern Denmark and the businesses within the transport sector in the south-western part of Jutland.

The SUC (Spatial Unfolding of Costs) model is a spatial GIS¹-based tool for visualisation and assessment of cost and competition within freight transport. The model in its present form focuses on road and sea transport but can easily as well include other modes like rail, air or inland waterways.

First of all it has to be made clear that the SUC model is not a traditional transport model – it is a strategic tool that can model and visualise the supply (or performance) of a multimodal 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 benefits to such an approach.

- The model is fairly low-cost to operate and computes fast. This means that it is easy to make large numbers of model runs and test different scenarios.
- The model can provide easily understandable information about the transport system and its performance – even for laymen. This can help broaden the decision making process.
- 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 SUC model consists of two more or less independent parts:

- A transport system modelling tool
- A visualisation tool

Both the transport system modelling tool and the visualisation tool are fully integrated within the geographical information system ARC/INFO.

The project has received most of its financial support from the SUC foundation in Esbjerg. The purpose of the SUC foundation is (after application) to support

¹ The SUC model is implemented using the geographical information system ArcGIS (ArcInfo Workstation 8.3).

educational and research projects on university level. It is provided that the supported activities is closely linked to the two universities in Esbjerg (University of Southern Denmark and Aalborg University) and promotes the development of "knowledge based" business in the south-western part of Jutland.

The project has also received support from the municipality of Esbjerg, Port of Esbjerg and InformiGIS ApS there as the official Danish distributor of the ESRI product line (ArcGIS, ArcInfo, ArcView ect.) has provided the necessary GIS licenses for this project.

The transport system modelling tool

The SUC model runs on a digital transport network that models the cost (or impedance) of using the transport system. The modelling tool can either run on an external network coming from e.g. a transport model or on its own internal network covering most of Europe.

The transport system modelling tool uses the digital network to calculate two major physical measurements of using the transport system:

- Transport distance
- Transport time

Most commonly the digital link represents different types of transport links e.g. roads or sea links. Besides keeping track of which link is connected to which link (topology) one of the basic functionalities in a GIS is to keep track of the length of each link. This means that the transport distances normally are automatically calculated and updated and can be found directly within the basic GIS data model although one still have to keep in mind the projection and scale of the digital network.

As goes for the transport time its first of all depends on the performance of the transport network. The transport time associated with traversing each link within the transport system depends on the physical length of the link and the speed that the link can be traversed with. The speed still being a physical measurement is however at bit more complicated to handle than the length. The speed depends of a variety of different parameters that even differs for the different types of transport modes².

In this project the focus has been on modelling the cost of freight transport on a European level and the modelling of the traverse speed has to reflect this purpose and level of aggregation. That 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 for the chosen aggregation level. Instead a more simple approach is chosen where all road links are classified according to a fairly simple functional classification based on 8 classes.

When transferring freight between links representing different modes (inter-modal changes) like e.g. from road to sea most of the transfers have a transport time associated with the modal shift.

² For road transport that would e.g. be gradients, numbers of lanes, traffic load, traffic composition etc.

The SUC model is build in such a way that it is possible to add a specific time delay to a specific node like e.g. a modal shift in a port or a mandatory rest within a drive-rest period.

The transport costs

Since freight transport to a large extent is regulated by the monetary cost an important step in the SUC model 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 the 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 Fares

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

$$DD_{cost} = (DD_{CC1} + DD_{CC2} + \dots + DD_{CCn}) \cdot TransportDist$$

Where DD_{cost} is the total Distance Dependent cost
 $DD_{CC1} \dots DD_{CCn}$ is the Cost Components
 TransportDist is the variable

The time dependent cost components are for road transport typically e.g. driver salaries or depreciation of the material (including e.g. financial costs). For sea transport a time dependent cost can, as well the distance dependent cost, also be used in cases of lack of information on fares for the specific seal link. The time dependent cost for each link is found as:

$$TD_{cost} = (TD_{CC1} + TD_{CC2} + \dots + TD_{CCn}) \cdot TransportTime$$

Where TD_{cost} is the total Distance Dependent cost
 $TD_{CC1} \dots TD_{CCn}$ is the Cost Components
 TransportTime is the variable

In the SUC model the distance and time dependent cost is modelled using a cost file describing the costs for different link types.

The toll and fare costs are normally linked to either a modal shift or the passage of a physical location like e.g. a bridge, a tunnel, a toll ring or using a sea link. As for the time and distance dependent costs the toll and fare cost calculations are controlled by a cost file.

The visualisation tools

One of the main purposes of the SUC model is to visualise the cost structure for freight transport on an international level – thereby providing useful and accessible information about the performance of the transport system. Not every aspect of the performance of the transport system can be shown in a

single map. Instead the SUC model is based on a number of visualisation possibilities the can be used in a variety of different ways.

The model has the following visualisation possibilities:

- Isocost maps
- Difference maps
- Scenario maps/Competitive areas
- Port/sea link hinterland areas
- Route sheaf
- Route competition

In order to give more practical exemplifications of the possibilities and functionalities of the SUC model visualisation tools some explorative examples are introduced in this section. It is not the purpose of the explorative example to perform an in-deep analysis and therefore the chosen model input and the calculation output will not necessarily reflect the current situation.

Isocost maps

Isocost maps are maps showing the cost of transport from (or to) a given location using the shortest possible (in most case the least expensive) route. The transport costs are often illustrated as uniform bands of isocost.

The SUC model is capable of handling point based events as e.g. drive-time restrictions. The model works in such a way that when a specific event occurs like e.g. passing a border or the transport time for a truck exceeds 9 hours, the model adds a penalty either as a cost or an additional travel time to the calculation. This should give a more realistic modelling of the transport cost on a European level.

An example of an isocost map where the calculations include drive-rest restrictions for road transport can be seen in Figure 1.

Figure 1. Isocost map of the transport cost from Esbjerg in Denmark to Germany, Benelux and France with drive-rest regulations and delays at border crossings.

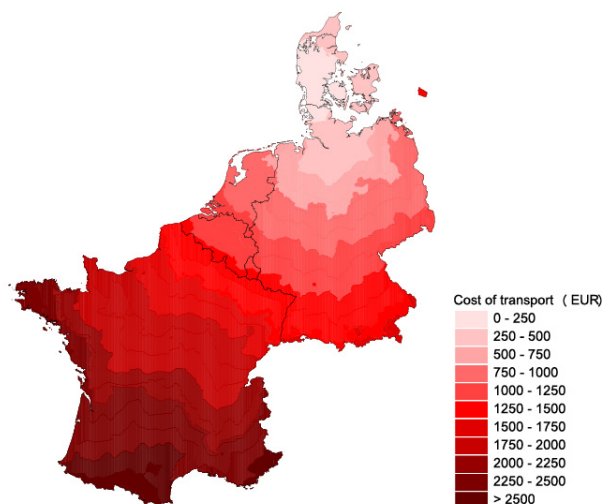


Figure 1 show an example of the cost of road transport from Esbjerg in Denmark to Germany, the Benelux and France³. It can be seen on the map how the isocost bands spreads out in more or less concentric circles from Esbjerg indicating a more or less spatially even performance of the transport system. At a closer look it is however possible to see how the better performance (due

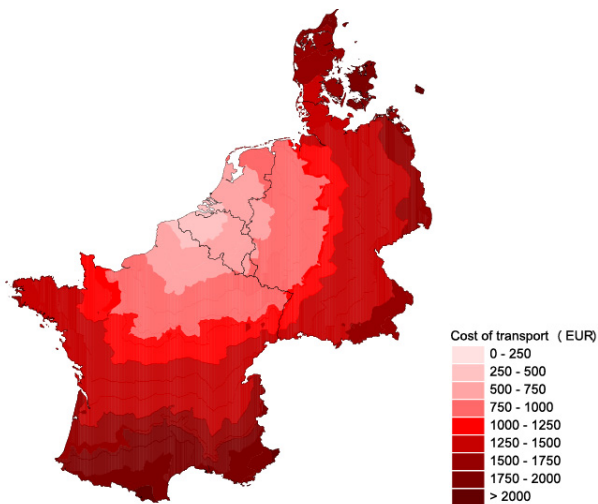
³ Please note that the figure is made for illustrational purposes and therefore can differ from a final calculation.

to higher speed) of the highway system "drags out" the isocosts along the highways.

Difference maps

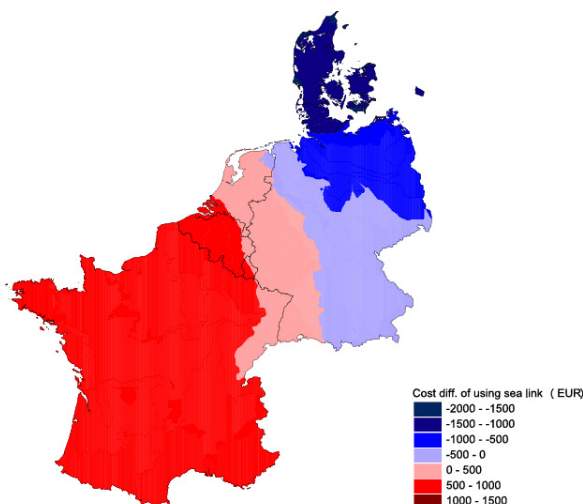
A difference map is basically two isocost maps that are subtracted. Figure 2 shows (as Figure 1) the cost of transport from Esbjerg in Denmark to Germany, the Benelux and France but this time by use of the Esbjerg – Zeebrugge sea link.

Figure 2. Cost of transport from Esbjerg in Denmark to Germany, Benelux and France by use of the Esbjerg-Zeebrugge sea link.



In this case the drive-rest effect is quite clear as the 1000-1250 EUR band is narrowed in due to the truck "resting". When crating a difference map Figure 1 and Figure 2 is "subtracted" and the result of such a subtraction is the difference map shown in Figure 3.

Figure 3. Difference map comparing road transport with combined sea-road transport.



The SUC model not only indicates the areas where the Esbjerg-Zeebrugge sea link is competitive but also gives an indication on how competitive the sea link is.

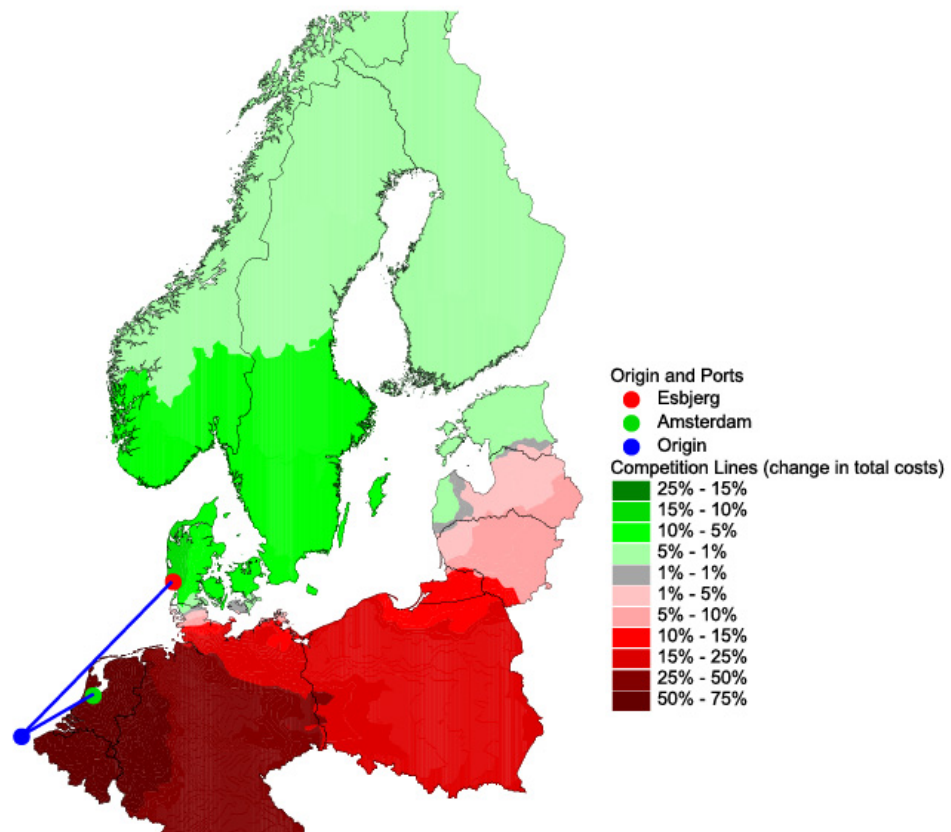
Basically Figure 3 shows that the Esbjerg-Zeebrugge sea link is competitive to road transport between Esbjerg and Germany, Benelux and France in the red

areas and not in the blue areas. How competitive (or not) the sea link is visualised by the intensity of the colours.

Scenario maps/Competitive areas

Scenario (or competitive areas) maps sum up and illustrate information from a series of calculations. In this case the calculated example is from the Baltic Sea Area. Due to the complexity of the multimodal road and sea transport system in the Baltic Sea area the calculations have been simplified in order to better illustrate how scenario maps are generated. Figure 4 shows a calculation of the competitive areas between two freight routes serving the Baltic Sea Area using either the Port of Esbjerg or the Port of Amsterdam. In order to simplify the calculations only transport time has been used as competitive parameter.

Figure 4. The competitive areas (hinterlands) for two routes using either Port of Esbjerg or Port of Amsterdam.



The calculation has been made under the assumption that freight will be transported by sea to either Port of Esbjerg or Port of Amsterdam and transferred to road. From each of the two ports the freight transport will use the fastest route either only by road or in combination with the sea links within the Baltic Sea.

The grey band on Figure 4 shows the area where the difference in transport cost (in this case only transport time) between the two routes is less than 1%. This line can also be referred to as the competitive border between the two routes. In the green areas the route using Port of Esbjerg is the fastest and in the red areas

the route using Port of Amsterdam is the fastest (the two colours also represents the respective hinterlands for the two routes).

The calculation is then repeated for a number of different scenarios each decreasing the transport time for each route by 5%. The different intervals within the two coloured areas show how far the competitive border will move due to the decrease in transport time in the scenarios. This means that if the transport time for the route using Port of Amsterdam decreases with 5 % the hinterland for the route using Port of Esbjerg diminishes to covering Denmark, the southern part of Norway and half of Sweden. On the other hand if the transport time for the route using Port of Esbjerg decreases by 5% the hinterland area will expand to most of Latvia and the western most part of Lithuania.

The example indicates that if the route using port of Esbjerg wishes to increase its competitiveness with the route using port of Amsterdam transport time might not be the best parameter to compete on. Instead other parameters like e.g. price, regularity or frequency might be better.

These types of maps can be made for any kind of changes or comparisons within the transport system like e.g.

- The impact of increased congestions on the TEN-T
- Changes in transfer pricing in ports
- The impact of environmental taxes on sea transport
- The introduction of a common European toll on road transport

Or more specific changes like e.g.

- The competitive borders between a MoS going from Trelleborg in Sweden to Rostock and the route using the Øresund Bron and a possible future Fehmarn fixed link.

Port/sea link hinterland areas

Maps for port/sea link hinterland areas are closely connected with the competitive area maps. Instead of showing the hinterlands for just two routes these kind of maps can show the hinterlands for all ports within an area for different types of sea transport. An example of such a map is shown in Figure 5.

Figure 5. A map of port/sea link hinterland areas.

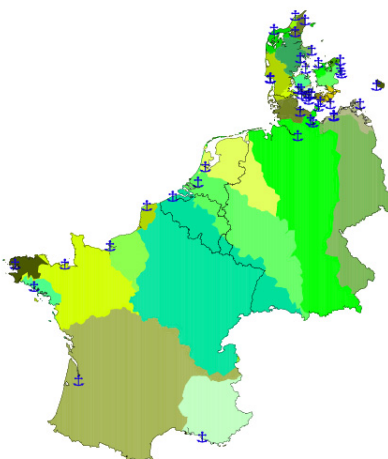


Figure 5 shows the "least cost" hinterlands for a number of different ports. The calculations are made by first of all selecting the ports that can serve the type of sea transport under investigation e.g. RORO etc. Next a "sea penalty" is added to each port. The "sea penalty" first of all covers the differences in the cost of getting into the ports by sea but can also include e.g. the different cost in each port of

transferring the freight from sea to land. When the "sea penalty" is assigned to

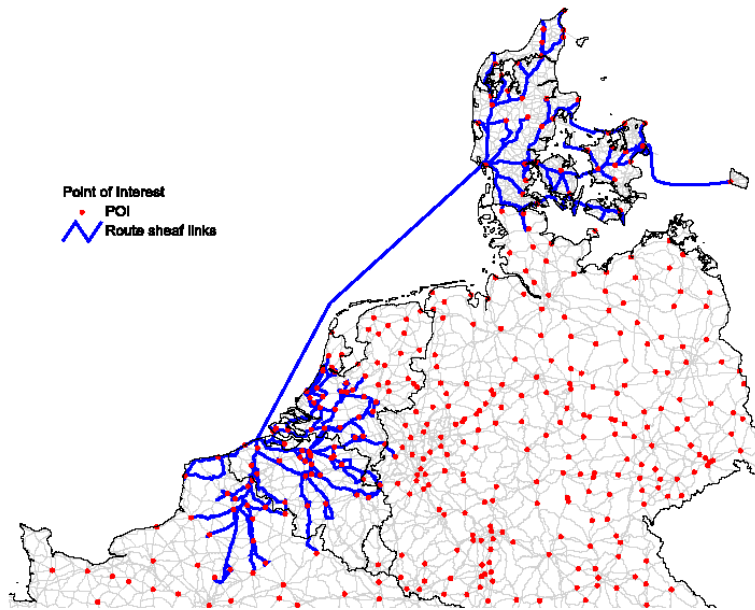
each port the SUC model calculates the total transport cost using the road network and based on that generates the “least cost” hinterland map.

Another type of hinterland map could e.g. be “least time” hinterlands.

Route sheaf

Maps showing a route sheaf are a bit different from the previous mentioned maps. The idea is to focus on a specific key link e.g. a sea link, a port or a bridge and show the different routes that uses the link as part of the least cost (or shortest) path. An example of a route sheaf map for the Esbjerg-Zeebrugge sea link is shown in Figure 6.

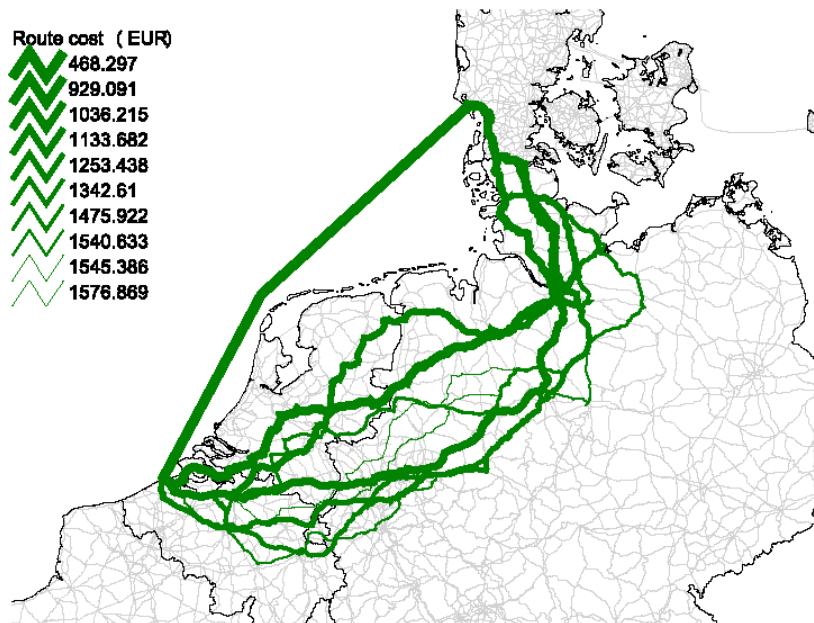
Figure 6. Route sheaf map for the Esbjerg-Zeebrugge sea link.



As mentioned above the map in Figure 6 shows a sheaf of all the routes where the Esbjerg-Zeebrugge sea link is part of the least cost path. The map has some similarities to the port hinterland maps and all the routes forming both ends of the sheaf indicates the hinterland – not for the ports but for that specific sea link. Each route can be selected and analysed individually.

Route competition

The final type of maps included in the SUC model within this project is route competition maps. Most pairs of origin and destinations within a transport system can be served by different routes. Whereas the previous maps shows the situation using the optimal (or least cost) route – route competition maps shows the competition between different routes serving the same origin and destination. An example of a route competition map for the Esbjerg-Zeebrugge link is shown in Figure 7.

Figure 7. Example of a route competition map for the Esbjerg-Zeebrugge sea link.

The route competition map in Figure 7 is calculated by first finding the optimal least cost route between Esbjerg and Zeebrugge and the excluding some of the used links from the network. Which type of links that are excluded depends on the type of routes that are to be compared. In this example the used motorways and sea links has been excluded after each calculation but any type of exclusion selection can be made.

The map in Figure 7 shows, not surprisingly, that the Esbjerg-Zeebrugge sea link is the optimal connection between Esbjerg and Zeebrugge and the most competitive road route goes thru Belgium over Hamburg and, with the used cost structure, is approximately twice as expensive.

Literature

Port of Esbjerg (2005); Text and information from www.port-of-esbjerg.dk obtained at the 6/7-2005.

Danish Ministry of Transport (2003); Manual for samfundsøkonomisk analyse – anvendt metode og praksis på transportområdet (in Danish). ISBN 87-91013-36-4.

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