SPATIAL AND ENVIRONMENTAL IMPACT OF PORT DEVELOPMENT

- Case study for the Port of Göteborg

Annex 3.2.3 to the Final Report

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PREFACE

This report has been written as part of the SUTRANET project (Work Package 3: Transport and Logistics Centres). SUTRANET (‘Sustainable Transport Research & Development Network in the North Sea Region’) is a project within the framework of the European Commission’s (EC’s) Interreg IIIB North Sea Programme.

The report presents a case study on the spatial and environmental impact of port development in Gothenburg (Göteborg), with the aim to identify barriers to port development and to extract some general methodological guidelines as regards environmental impact assessment of ports and logistics centres in the North Sea Region.

The report has been prepared by the Swedish Environmental Research Institute (Gothenburg branch), with Åke Sjödin and Erik Fridell as the main authors. Aalborg University’s Department of Development and Planning has contributed with some comments to draft versions of the report. The final version was presented in March 2007. A few editorial modifications have been added in June 2007.

SUTRANET, June 2007

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1 Introduction

As part of achieving the objective of Work Package 3, 'Transports and Logistics Centres', of the SUTRANET project – “to develop innovative intermodal transport systems and concepts through the use of transport and logistics centres” - a case study on the spatial and environmental impact of port/logistics centres development has been carried out, in order to identify environmental and spatial barriers to intermodal transport in the North Sea Region.

The case which has been selected for this study - the port of Göteborg - is suitable for a number of reasons:

- it constitutes one of the major ports in the North Sea Region, and is developing rapidly both in terms of overall turnover, and from a conventional port into a more holistic logistics centre.
- with its location inside a major city there are both environmental and spatial barriers to consider and try to resolve.
- the port has come a long way already as regards increasing environmental concern and improving environmental performance, and received the European Commission’s Clean Marine Award in 2004 for provision of shore-side electricity for regular RoRo ships, dramatically reducing their in-port emissions of noise and airborne pollutants.
- the port is presently in the process of applying for environmental permits from the government to increase both the port area and the port throughput substantially within the next decade.

The present case study has run in parallel to a national study on how the port of Göteborg and one of its major clients Volvo are affected by the new national EU-enforced legislation on air quality standards (Swedish: MKN) for nitrogen dioxide (Fridell et al., 2006). Since transport - in particular road transport - is a major source to nitrogen dioxide as well as several other health and environmentally hazardous air pollutants in densely populated areas such as Göteborg, and since many ports rely heavily on hinterland road transport, the new air quality standard for nitrogen dioxide is actually one example of an environmental barrier for port expansion and development which is stipulated by law. However, there are also other environmental and spatial barriers for port/logistics centres development that are highlighted and analysed further in the present study and in the study by Fridell et al. (2006).
2 General Issues Related to Spatial and Environmental Impact of Port Development

Due to historical reasons, most ports co-exist with urban settlements. The exploitation of good natural port locations has triggered the establishment of communities both for civilian trade and as strategic strongholds for national states.

The ports needed numerous services like for instance supplies, workforce and administration, while creating values such as trade and employment. The presence of an efficient port has always been a strong catalyst for societal development.

Today, the interaction between ports and cities does not require the closeness of earlier centuries. Synergies still exist, of course, but ports no longer need large workforces, and the availability of modern transportation and communication makes it possible to distribute many other functions.

However, the historical record of large ports growing from small as well as large cities stemming from smaller settlements, means that major ports and large cities still occupy common or adjacent locations. This naturally has lead to collisions of interests with continued growth in both sectors. Today the presence of an active port inside a city is often considered a nuisance. Many older centrally located port surroundings are being redeveloped for other uses.

What’s more, ports and cities frequently share the same land infrastructure. There are of course efficiency gains in this double usage but also considerable scope for conflicts and controversy.

As a port expands it tends to move out from the central position in a city to peripheral locations. So far most ports have been able to relocate major activities outside the city centres, sometimes in more than one step.

However, the increasing area needs of port and terminal operations have now reached a level where conflicts with recreational and environmental interests are becoming common. The importance of shoreline and shallow water organisms to the whole environment has only recently been fully appreciated.

The preservation of an adequate amount of wetlands, sands, reefs, etc., is vital to assure a fully functioning ecosystem. At the same time the value of the coast for recreation is obvious and this puts additional pressure on port development near major population centres.

The typical pattern of port expansion and possible areas of conflict are demonstrated in Figure 1.
Landfills are often used to increase the available areas for port operations. The ecological effects of landfills, however, have not been fully understood until recently. Most effects of landfills are of a local nature but wide scale intrusion into ecologically sensitive areas may lead to more global effects through the damage of key links in the overall ecosystem.

The presence of a port also leads to a concentration of land transport with trucks and trains. This frequently leads to overload of the land infrastructure and disturbances to nearby urban and residential areas.

The most important environmental effects related to ports may be summarised as:

- Effects on sensitive near-shore ecosystems (ex shallow water fish breeding areas).
- Influence from dredging and earthworks on currents and circulation.
- Influence on water runoff and ground water.
- Reduction of wetlands as nitrogen traps.
- Soil contamination.
- Release of pollutants deposited in sediments.
- Emissions to air from port and transport activities.
- Emissions to water from port and transport activities.
- Accidental spills from cargo, of bunker oil and other fluids from ships.
- Noise.
- Visual “pollution” (scenery, night lighting).

A more comprehensive summary of the environmental impact of port activities can be found in Trozzi and Vaccaro (2000). Most of the effects are local in character but the size and concentration of some European ports may lead to effects also on a regional magnitude.
One of the findings of the SUTRANET project (Work Package 2, Motorways of the North Sea, Task 1.1, report on “Major Intermodal Ports in the North Sea Region”), is that just three geographical areas account for 90% of the North Sea Region intermodal/unitised (container and RoRo) traffic (Haven/Humber, Rhine/Scheldt and Elbe/Weser), and may dominate intermodal maritime traffic flows in the region even more in the future, which “raises questions regarding the sustainability of current and future transport provision and in particular the very high degree of concentration within relatively few sensitive estuarial areas in northern Europe”.

At the same time the European Commission has identified waterborne transportation as an important element to enable continued growth of the European economy simultaneously promoting sustainability of European freight transport. For instance, everything else put equal, maritime freight transport is roughly between two and three times more energy efficient than road freight transport, thus emitting half to one third of CO₂ per weight unit cargo and unit distance transported compared to road transport. The port infrastructure is the key to the expansion of waterborne transportation, but also the likeliest bottleneck.

A challenge for the future is to find solutions that may accommodate increased activity in the land/sea transfer while at the same time minimizing the environmental and societal impacts.

Examples of activities:

- Optimisation of port/terminal location and distribution.
- Innovations that increase throughput while reducing intermediate storage.
- Innovative solutions that reduce port/terminal land use.
- Advanced planning of land infrastructure.
- Simulations of effects on ecosystems.
3 Description of the Case - Port of Göteborg

3.1 Historic and Present Situation

The City of Göteborg was founded in 1621 on direct orders from the Swedish king Gustav II Adolf. Apart from being a strategic military defense location, there were also strictly commercial reasons to settle a new town at the mouth of the River Göta, the river which connects the largest lake in Sweden, Lake Vänern, with the North Sea. By that time, water transport was almost the only means of exporting the classic Swedish iron and timber, which were - and still are - extensively produced on the lands surrounding Lake Vänern. The new city was ideal to serve as a transhipment point between river craft and deep-sea vessels, and hence the Port of Göteborg was established simultaneously.

The creation of modern-day Port of Göteborg goes back as far as the 1840's, when the first berths along River Göta were built. The rest of the 19th century saw the southern river bank along the city being exploited for port purposes. Along with the expansion the port needed more space, and in the middle of the 20th century most of the port facilities moved out of the city centre to the north river bank. By this time the port also hosted several large shipyards.

The port went through a rapid development in the 1960's and 1970's. The Skandia Container Terminal was built to take care of the new container traffic. Deep-sea RoRo traffic was developed by Scandinavian ship-owners and shipyards, and a new RoRo-terminal, the Älvsborg Harbour, was built. To allow large oil tankers to berth, a crude oil jetty was built. The two harbours Rya and Skarvik, were the refined oil is handled, were improved.

Today, there are four main terminals, all located on the north shore of the Göta River mouth, as seen by Figure 2 below: the oil terminal located in the Tors (1), Skarvik (2) and Rya (3) harbours, the RoRo terminal located in the Älvsborg and Arendal harbours (4), and the container terminal and the car terminal, both located in the Skandia harbour (5). The Tors harbour is the jetty where crude oil is discharged and pumped to the oil refineries of Göteborg, whereas Skarvik and Rya handles imports and domestic distribution as well as exports and storage of oil and oil products. Paper and steel are the main cargoes handled in the RoRo terminal, which serves daily traffic to the UK and Belgium. The container terminal serves exclusively liner traffic moving in inter-continental trade, either directly from Göteborg or by feeder vessel via a continental port.

![Figure 2](image-url) Map overview of the Port of Göteborg with the geographical distribution of terminals and harbours.
Other minor terminals of the port are: (6) Frihamnen, the oldest part of the existing port, used for trains and trucks to/from Denmark and passenger traffic to England and Norway; (7) the Majnabbe harbour, dominated by ferry traffic to/from Kiel; (8) the Stigbergs quay, once used for the transatlantic traffic between Göteborg and North America; (9) the Masthuggs quay, used for the ferry traffic to/from Denmark; (10) the Arendal area, a former ship building yard, now a centre for many transport companies and particularly for transport of automotive components and spare parts; and (11) the harbour railway track, the most densely trafficked in all of Sweden, and with a total track length of more than 100 km.

The Port of Göteborg is today the largest port in Scandinavia, and one of the ten largest in the North Sea Region. In terms of RoRo throughput it is the fifth largest in the NSR. Below are some capacity and throughput figures from 2005 (www.portgot.se):

- 788,000 containers TEU
- 574,000 RoRo units
- 304,000 cars
- 19.5 million tonnes of oil
- 37.2 million tonnes of goods
- Total port land area: 3.6 million square metres
- Total number of berths: 151
- Total length of berths: 12 kilometres

The port's cargo turnover comprises almost 60% oil and almost 40% general cargo (95% of which is unitized). The remainder - dry bulk cargo - is very small. The yearly increase in overall throughput is 8%, which means a doubling approximately every ten years.

The port is certified according to the environmental standard ISO 14001. In general, environmental issues constitute an important foundation for the activities of the port. The following is a list of good examples put into practise during recent years:

- **Vapour recovery**: Several units have been installed at the oil depot of the port, reducing air emissions of volatile organic compounds from about 450 tonnes to about 25 tonnes per year.
- **Shoreside electricity**: In year 2000 the port introduced the first shore-connected electricity supply in the world designed for RoRo vessels, recognized by the European Commission’s 2004 Clean Marine Award. The shore-side electricity option has been used by three to six RoRo vessels in regular (weekly) traffic, reducing emissions in port of NO\(_x\), SO\(_x\), particulate matter and noise significantly. Furthermore, part of the electricity used for shore-side connection is "green", as being supplied from wind power stations located in the Göteborg archipelago.
- **Railway transport**: In 2004 the railways carrying cargo to and from the port were electrified. Today about 20% of all cargo units transported to and from the port are by rail. The long-term goal is to reach a 50% share for rail transport.
- **Emission control on working machinery and non-road vehicles**: The port has taken a policy decision on that all new working machinery and non-road vehicles shall be equipped with oxidation catalysts and particle traps. At present (2005), 121 out of the port's own fleet of 143 vehicles are equipped with catalysts and particle traps.
- **Heavy eco-driving**: In 2005, 100 drivers of non-road vehicles were trained in eco-driving (calm driving) as a means of saving diesel fuel and reducing air emissions. Improvements in fuel economy of up to 30% have been recorded.
3.2 Future Situation

The yearly increase in the total number of units handled in the Port of Göteborg over the last couple of years (cf Figure 3), predicts roughly a doubling of the overall port throughput within the next ten years period. This forms the basic condition for the Port of Göteborg’s application - with the accompanying environmental impact assessment - for new legal permits submitted to the responsible authorities in 2002 (Port of Göteborg, 2002). In the environmental impact assessment study the present situation, represented by year 2001, forms the base scenario. The future scenario, to which the base scenario is compared, is the doubling of the port throughput (compared to 2001) to occur by the year 2012.

In short, the future port expansion scenario, of which the environmental consequences are analysed and highlighted in the environmental impact assessment study, is mainly characterised by:

- A doubling of the harbour traffic in 2012 compared to 2001, involving expansion of the RoRo- and container harbour areas (terminals, quays) and associated activities.
- Subsequent increases in road transport and associated needed changes in road traffic infrastructure.
- Increase in rail transport and subsequent changes in railway infrastructure.
- Increase of depth of fairways leading into ports.

By promoting more efficient flows of cargo and a more efficient use of existing terminal, quay and associated areas, there will be no need to expand the container and car terminals beyond the existing port area and adjacent industrial areas in order to host the port expansion foreseen to 2012, cf. Figure 4. Increased efficiency of cargo flow and area use can be reached by e.g. increasing container stacking height and width, and by using quay cranes with longer working radius. However, the projected doubling of goods through the RoRo-terminal until 2012 cannot be handled within the existing facilities (quay berths and terminal areas). To fulfil this, a doubling of the number of quay berths from the present six to twelve, and an associated increase in terminal area are required, cf. Figure 5.
Figure 4. Map of present terminal and quay areas for the container, car and RoRo-terminals (within the blue line) and area required for the expansion of the container and car terminals, excluding the RoRo-terminal (within the green line). Red lines demarque the physical borders for the environmental impact assessment of the port expansion scenario (Port of Göteborg, 2002).
Figure 5. Map of the new quay and terminal areas (light-blue dashed lines) required for the expansion of the RoRo terminal (City of Göteborg, 2005; Port of Göteborg, 1999).
4 Environmental Impact Assessment of the Port Expansion Scenario

The Port of Göteborg prepared an environmental impact assessment (EIA) study in 2002, as part of the port's application of new permits for the port operation, including the planned and projected expansion until 2012 (Port of Göteborg, 2002). The aim of the EIA is to identify and describe the effects of the present and projected activities associated with the port on human health and the environment. The most important effects to consider for a port expansion scenario are highlighted in the scheme on national environmental objectives established for Sweden, and presented in Figure 6. See further the SUTRANET report within WP 1, “Environmental Impact of Sea Transportation in the North Sea Region”.

![Figure 6. National environmental quality objectives for Sweden (Swedish Environmental Objectives Council, 2006). The most important environmental objectives to consider in an environmental impact assessment for a port expansion scenario are marked with red borders.](image)

The environmental effects described in the EIA are from direct and indirect emissions. Direct emissions are those related to activities which the port are directly in control of, such as emissions to air and noise from non-road vehicles and working machinery within the port area, whereas indirect emissions are those related to transport to and from the port, whether by road, rail or sea, in which case the port has very limited (legal) possibilities to influence.

The physical area contained by the EIA, involving both the direct and indirect emissions, is marked out by the red lines in Figure 4. Outside these borders, the road transport associated with the port makes up less than 1% of the overall road traffic.
4.1 Direct Emissions

4.1.1 Emissions to air

Emissions to air within the port area mainly arise from non-road vehicles and working machinery, internal transport and fossil fuel plants for heat production. Non-road vehicles/working machinery is the predominant source, accounting for 90% of the overall NO\textsubscript{x}, CO and EXHAUST PM emissions, and 75% of the CO\textsubscript{2} and VOC emissions. In the port expansion scenario by 2012, the overall emissions of VOC, CO and EXHAUST PM will be reduced markedly compared to in 2001, NO\textsubscript{x} emissions will be slightly reduced, SO\textsubscript{2} emissions remain unchanged, whereas CO\textsubscript{2} emissions will double. This is mainly the combined result of the increased operation time for non-road vehicles and working machinery with improved VOC, CO, EXHAUST PM and NO\textsubscript{x} emission performance compared to the 2001 fleet, but with more or less the same fuel economy as the 2001 fleet.

4.1.2 Emissions to water

Emissions to water within the port area arise from surface water released directly to the harbour basin and waste water which passes the municipal water treatment works before it is released into the recipient. To reduce the risk for discharge of oil pollutants into the recipient with the surface water, oil filters and oil deflectors are used. Surveys conducted in 2001 demonstrate that the content of oil, expressed as non-polar aliphatic hydrocarbons, in the surface water on average is slightly above the detection limit, and on the same level as in surface water from ordinary roads/streets and industrial areas. Effluents from the port’s vehicle wash halls, the truck repair shop and office and staff buildings are connected to the waste water network. Oil deflectors are used mainly to reduce the risk for oil release into the waste water during various incidents. The waste water from the major wash hall was surveyed with regard to various pollutants in 2001, and only the content of unpolar aliphatic hydrocarbons\textsuperscript{1} and Zn exceeded the guidelines provided by the municipal water treatment works.

Compared to the situation in 2001, the amount of pollutants released to the recipient via the surface water and to the waste water will increase somewhat in 2012 in the expansion scenario.

4.1.3 Dredging

Since the port is located at the mouth of the Göta river, carrying sediments that are continuously being settled on the bottom of the harbour basin, regular dredging is necessary to maintain the depth of the harbour basin. During the dredging a temporary turbidity and dispersion of pollutants occur. These pollutants may be of a local origin or transported from remote locations and accumulated over a long period of time. Sediments near the Älvsborg and Skandia harbour have been analysed frequently. A few exceedances of recommended concentrations with regard to the content of Hg, Cd and PCB have been observed. However, the extent of dredging to maintain the required depths of the harbour basin will not be affected by the expansion of the port.

\textsuperscript{1} the main content of oils (residual, diesel, lubricating oils, etc.) is unpolar aliphatic hydrocarbons, consisting solely of carbon (C) and hydrogen atoms (H) in single bounds (C-H-chains, general chemical formula (C\textsubscript{n}H\textsubscript{2n+2}).
4.1.4 Noise emissions

Noise from the port area arises mainly from non-road vehicles and working machinery handling the goods or goods carriers, i.e. containers, trailers, cars, etc., on the terminal surfaces and at the unloading/loading ramps of the ships. The situation in 2012 after the expansion, compared to the situation in 2001, will be that the majority of the non-road vehicles and working machinery will have been replaced with newer less noisy units, leading in the direction of lower noise emissions. At the same time the overall number units and the overall number of operation hours of these units will increase, leading in the direction of higher noise emissions. Noise stemming from containers, trailers, etc., will tend to increase in 2012 compared to 2001, due to the increased activity in the port expansion scenario.

A holistic survey of the present and future noise situation in the Skandia and Älvsborg harbour has been undertaken to study the impact of the port expansion scenario. In this study, noise associated with the direct operation of the port has not been separated from the noise associated with ship, road and rail traffic, and the general background of noise in the area, see further sub-section 4.2.4.

4.2 Indirect Emissions

4.2.1 Emissions to air

Ship traffic accounts for more than 90% of the overall indirect air emissions - not including CO₂ which was not calculated for ships in the EIA - associated with the port within the physical borders of the EIA (see Figure 4). Road transport accounts for less than 10%, and emissions from railway traffic is negligible, especially since the main railway track carrying goods to and from the port has been electrified.

The calculated ship emissions in 2001 and 2012 operating at berth and on the fairway, respectively, in the Älvsborg, Arendal and Skandia harbour, are presented in Figure 7. The calculations for 2012 assume an increase of transported goods of 100%. Despite this, - since both the size (width) of the ships and the load factor are expected to increase - the number of ships calling on Port of Göteborg is expected to increase by only 10% between 2001 and 2012. Furthermore, the calculations assume a sulphur content of 1% in 2012 compared to 2.5-3% in 2001, and that dedicated measures on the ships have reduced emissions of NOₓ and exhaust PM by 20% on average per ship. As can be seen by Figure 7, there are only marginal changes in emissions from 2001 to 2012, apart from SO₂ emissions, which are significantly reduced.

![Figure 7](image-url)  
Figure 7. Emissions from ships - associated with transport of goods to and from the Port of Göteborg - in 2001 and 2012 operating at berth (left) and on the fairway (right) respectively, within the physical borders of the EIA, cf Figure 4.
The number of trucks carrying goods to and from the port terminals amounted to 1400 per day in 2001, increasing to 2150 per day in 2012 as a result of the port expansion. The fraction of the traffic associated with the port within the physical borders of the EIA is significant, resulting in emission fractions of up to 30% of the overall traffic emissions depending on parameter. At the border junctions the port traffic fraction is in the order of 10%, whereas outside of the EIA borders it is only about 1%. Compared to in 2001, the port expansion scenario results in a large reduction of emissions of NO\textsubscript{x}, VOC and exhaust PM in 2012, due to the penetration of new trucks meeting more stringent emissions standards, whereas CO\textsubscript{2} emissions increase somewhat (inside the EIA study area).

### 4.2.2 Emissions to water

Indirect emissions to water mainly stem from ships - by leakage of toxic compounds from systems, release of ballast water during ship loadings, and spill during bunker operations. Along with the increase in ship traffic in the port expansion scenario, it is likely that both toxic leakages from antifouling agents as well as release of unwanted organisms with ballast water will increase in the recipients near the city of Göteborg and the Göteborg archipelago. However, both the use of toxic antifouling agents and the control and handling of ballast water are on the agenda of international conventions, for instance within IMO all use of antifouling agents containing tin organic compounds were forbidden from 2003, and must be removed or be completely covered with some other non-penetrable surface coating before the end of 2008. Therefore, the problem with release of tin organic compounds from shipping may have ceased by 2012. Furthermore, IMO aim to introduce new guidelines for the handling of ballast water in the near future.

Regarding reducing the risk of spill during bunker operation in the Göteborg harbour, the Port of Göteborg, the coast guard, the provincial government of the county of Västra Götaland and the bunker companies have collaboratively increased security and improved environmental protection during bunkering in a project entitled "Green bunkering".

### 4.2.3 Noise emissions

Indirect noise emissions arise mainly from ships in fairway operation and at berth. The road and rail transport associated with the port activities accounts for a small and negligible fraction, respectively, of the overall noise emissions inside the port and in the port surroundings. Noise emissions from ships arise during manoeuvring in the port, and from the auxiliary engines and ventilating systems when at berth. The ship engines contribute mainly to the low frequency noise, which can be transported over long distances and is difficult to quench, whereas load and unload activities contribute mainly to higher equivalent and maximum noise levels expressed as dBA (see further sub-section 4.3.3).
4.3 Environmental Impact and Consequences

4.3.1 Air quality

A dispersion model has been used to calculate the ambient air concentrations of NO\textsubscript{2} inside the port area, in residential areas in the port vicinity, and in the Göteborg urban air basin in general, for the base year 2001 and for the port expansion scenario in 2012 (City of Göteborg, 2002). The results from the dispersion calculations have then been compared with the national air quality standards for NO\textsubscript{2}, reflecting the common air quality guidelines for NO\textsubscript{2} within the European Union as laid down in the EU Air Quality Directive and the associated Daughter Directive for NO\textsubscript{2}, in order to identify and analyse eventual exceedances of the standard.

The results from the dispersion calculations and the subsequent analysis, show that the air quality standard for daily and hourly averages of NO\textsubscript{2} tend to be exceeded in one of the model receptor points close to a major arterial roadway through a residential area on the northern side of the Göta River (Biskopsgården, see Figure 8). In this point, the traffic carrying goods to and from the Arendal, Älvsborg and Skandia harbour account for a little more than 5% of the yearly average of the ambient NO\textsubscript{2} concentration in 2001, and a little more than 2% in 2012. In fact, the NO\textsubscript{2} air quality standards would still be exceeded, even if the harbour traffic was excluded in the calculations.

Figure 8. Calculated daily averages of ambient NO\textsubscript{2} concentrations (as 98-percentiles) in the port and the port surroundings in 2012 (port expansion scenario). Red areas indicate exceedances of the air quality standard (Swedish "Miljökvalitetsnorm") for the daily average of NO\textsubscript{2} (60 g/m\textsuperscript{3} as 98-percentile).
4.3.2 Impact on water quality, soils and sediments

In the case of impact on water quality and soils, the environmental impact assessment of the port expansion scenario by 2012 can be summarised as follows:

- **Surface water:** The concentrations of oil pollutants in surface water from the port are low and considered typical for waste water from ordinary traffic or industrial surfaces. The contribution of mineral oil to the recipient from the port and port activities is considered to be very small and the environmental consequences of the surface water release to be marginal.

- **Waste water:** Pollutants released to the waste water are mainly mineral oils. Since oil deflectors are used within the port wherever there is a risk for oil contaminated effluents to reach the waste water network, only small amounts of mineral oils are released into it. These releases may affect the waste water cleaning process in the municipal waste water treatment works, however, the small amounts released from the port and port activities are considered to have a marginal impact on this process.

- **The river and ocean basins:** From ships at berth some leakage of toxics contained in antifouling agents and release of ballast water may have a negative impact on organisms living in the water. The port activities do not directly affect any physical area of interest for fisheries or leisure fishing. However, a certain impact may not be excluded through the port's contribution to the general pollution levels in the river and ocean basins in the area.

- **Dredging:** The environmental consequences of dredging to maintain fairway depths are considered overall to be small.

- **Soils:** From an environmental point of view, soils within the area where port activities are less sensitive, and since any new soil pollutants are not expected to occur any consequences on soil are not likely.

- **Swell and erosion:** Since ships speeds are normally low, swell and erosion of land areas surrounding the fairway are not considered as major issues for the port expansion scenario. However, erosion has been observed in some shallow bays in the Göteborg archipelago, that may be attributed to displacing ships.

4.3.3 Noise

Calculations of noise levels reveal that residential areas most exposed to noise from the port are located on the southern bank of the Göta River, opposite to and with a free view over the port terminals. Noise emissions occur preferably during the day and in the evening, which is the time period when loading and unloading of the ships normally occur. Loading and unloading activities, such as handling of containers with cranes and driving of working machines, have also been shown to contribute somewhat more to the noise than the ships. The calculated noise levels were compared with the guidelines according to the Swedish Environmental Protection Agency for external noise from existing industries. Exceedances of the guidelines occurred for **equivalent noise levels**\(^2\) (= the average noise for a given time period) during two hours (22-00) by 3 dBA in the most exposed receptor point, and for **max noise levels**\(^3\) (= the maximum noise level occurring during a given time period) by about 5 dBA in most receptor points. The calculations show that the noise will be at approximately the same levels in 2012 as in 2001, since in terms of noise emissions the expansion of port activities is counter balanced by the penetration of working machines in the port's fleet meeting more stringent noise emissions standards (cf Figure 9).

\(^{2}\) The guidelines for **equivalent noise levels** are 50 dBA during daytime on weekdays, 45 dBA during daytime on weekends and in the evenings, and 40 dBA during night time.

\(^{3}\) The guideline for **max noise levels** is 55 dBA.
4.3.4 Impact on cultural heritage and natural habitats by land intrusion

- Exploitation of the small island Lilla Aspholmen, part of the national historical interest the 17th century military fortress Älvsborgs Nya Fästning, for the expansion of the RoRo terminal between the Älvsborg and the Arendal harbour.
- Intrusion of the NATURA 2000-reservation area Torsviken by new road and rail infrastructure through the area, connecting to a new harbour with terminals for RoRo transport at the small island Stora Risholmen.
5 Extended Scenario Analysis and Impact Assessment for Port Development

5.1 Comparisons between Transport Modes

Conventional EIAs are limited by the fact that only local environmental consequences are considered, and that environmental effects on the regional and global scale are left aside. This is particularly a problem when transport and logistics systems are studied, since in particular freight transport to a large extent takes place across national borders and continents. Thus, to get the full picture of the consequences of the development or other changes in transport infrastructure systems in terms of the overall impact on the environment - whether beneficial or not for the environment - the value of conventional EIAs increase if they are complemented with scenario analysis involving impact assessments where also the environmental effects on the regional and global scale are taken into account. Furthermore, to be able to compare the overall environmental impact for various transport scenarios, ultimately one needs to make these comparisons on a monetary basis. An attempt to do so was made within a recent EU study, where transport impacts such as noise, air pollution, greenhouse gas emissions, and further also nuisance such as congestion and traffic accidents were analysed up- and downstream in monetary terms (European Commission, 2003). The results are summarised in Figure 10, and demonstrate for instance that, despite a major environmental impact from air pollutant emissions, sea transport may be more beneficial than road transport.

Figure 10. External costs - expressed as Euro per 100 TEU-km - caused by various modes of freight transport (European Commission, 2003).

In the scenario analysis by Fridell et al. (2006), further comparisons - in terms of environmental impact - between waterborne transport and road transport were made for specific cases in northern Europe. Figure 10 highlights the clear advantage for waterborne transport compared to road transport as regards climate impact (emissions of CO₂). In this case the emissions from a typical large ship of 6000 TEU capacity, a smaller ship (feeder) of 250 TEU capacity, and a road truck (3 TEU, fulfilling Euro IV emission standards) are compared for the same goods volume being transported from Hamburg to St Petersburg. The disadvantage of waterborne transport is also very clear from this figure, with several orders of magnitude higher emissions of SO₂ compared to road transport, and significantly higher emissions also of NOₓ and PM. The reasons for this unbalance is also clear: during the last ten years
significant pressure has been put on car manufacturers and road vehicle fuel producers from e.g. national governments and the EU to meet increasingly stricter exhaust emission and fuel quality standards, whereas comparably very little progress has been made in this field within the maritime sector. This also tells us that sea transport has a high potential to be much more competitive in environmental terms vs other transport modes, the challenge being to reduce air pollutant emissions substantially while retaining the high energy efficiency in freight transport.

![Figure 11](image.png)

Figure 11. Comparison of the emissions from two sizes of ships (6000 TEU and 250 TEU, respectively) and from road trucks (capacity 3 TEU, fulfilling Euro IV emission standards) for goods transport from Hamburg to St Petersburg (Fridell et al., 2006). Resuspension is non-exhaust particulate matter, i.e. from resuspension of road dust from the road surface.

To take this analysis one step further, the emissions presented in Figure 11 were translated to monetary terms using the same methodology as in the EU Clean Air for Europe (CAFE) Program (CAFE, 2006). The external costs per mass unit of pollutant emitted are given in Table 1.

![Table 1](image.png)

Table 1. External costs per mass unit of pollutant emitted in various geographical areas of Europe (CAFÉ, 2006).

Figure 12 gives the environmental costs for the emissions to air from the same transport options as presented in Figure 11. Note that environmental costs (including health) are the only external costs represented in Figure 12. To achieve a more fair picture of the comparison, other external costs such as

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CAFÉ is a programme of technical analysis and policy development that underpinned the development of the Thematic Strategy on Air Pollution under the Sixth Environmental Action Programme.
accidents and congestions also need to be considered (c.f. Figure 10). However, it is clear from Figure 12 that air pollutant emissions from waterborne transport needs to be reduced substantially in order for sea transport to be competitive to road transport in terms of environmental impact. This is particularly true for transport by smaller ships.

Figure 12. The same comparison as in Figure 11, with air emissions translated into monetary terms (Fridell et al., 2006).

5.2 Comparisons between Transport Routes

The planned expansion of the Port of Göteborg - the doubling of the goods flow through the port in 2012 compared to in 2001 - will enable the port to act as a major and competitive hub for sea transport in northern Europe. The port will have better prerequisites to attract and host large trans-ocean ships, for which the final destination or origin of goods may be ports including hinterlands around the Baltic Sea. The environmental impact of such scenarios has been elaborated in the study by Fridell et al. (2006). Three alternative routes for a transatlantic ship calling on a north European port, carrying goods with final destination St Petersburg, were defined: A) reload to smaller ships in Port of Göteborg, B) reload to smaller ships in Port of Hamburg, and C) reload to road truck in Port of Hamburg (cf Figure 13). It is assumed that the port expansion enables the number of large container ships calling on the Port of Göteborg to increase from today’s one per week to four per week. The resulting extra emissions - split into local (in Göteborg and Hamburg) and global (outside of the two cities) emissions - for routes A and B are presented in Figure 14. Route A yields somewhat lower overall emissions than route B. Expressed in monetary terms, route A results in some 30 MEuro less costs yearly than route B (Figure 15).
Figure 13. Three alternative routes for a transatlantic ship calling on a north European port, carrying goods with final destination St Petersburg, were involved: A) reload to smaller ships in Port of Göteborg, B) reload to smaller ships in Port of Hamburg, and C) reload to road truck in Port of Hamburg (Fridell et al., 2006).

Figure 14. Increase in emissions - split into local emissions (in Göteborg and Hamburg) and global emissions (outside of the two cities) - in a port expansion scenario for routes A and B, respectively, as defined in Figure 12 (Fridell et al., 2006).
Figure 15. Comparison of environmental costs between route A and B (Fridell et al., 2006).

It should be noted that the route B alternative has not considered the option of a shortcut route via the Kiel Canal.
6 Measures to Reduce Spatial and Environmental Barriers to Port Development

In the following chapter a number of measures are listed that may make port development less sensitive with regard to spatial and environmental barriers. In view of the growing concern for climate change, being mainly a consequence of increasing CO₂ emissions from burning of fossil fuel, port development - as a promoter of modal shift from road to more energy efficient waterborne freight transport - may become a global key issue within the next decades to come. However, there are both other environmental as well as spatial barriers to overcome before this can be the case.

6.1 Emissions to Air

6.1.1 Non-road vehicles and working machinery

- Equipping new and possibly also existing vehicles/machinery with oxidation catalysts and particulate traps, which may reduce emissions of CO, HC and PM by up to 90%.
- Enhanced penetration of new vehicles/machinery and of vehicles/machinery meeting more stringent emission standards, particularly for NOₓ, then required by existing regulation.
- Initiate and establish programmes for calm driving (EcoDriving).
- Improve port logistics, reducing fuel consumption and pollutant emissions per goods unit handled.

6.1.2 Ships

Direct emissions (ports have large influence):
- Introduce and increase the supply and use of shore-side electricity.

Indirect emissions (ports have minor or no influence):
- Use of fuels with lower sulphur content (by regulations or voluntarily).
- Use of sulphur scrubbers (by regulations or voluntarily).
- Use of NOₓ reduction systems (by regulations or voluntarily).
- Use of particulate traps (by regulations or voluntarily).

Measures to deal with the indirect emissions deserve further attention. Dealing with the indirect emissions is crucial for waterborne transport to be competitive - from an environmental point of view - with other modes of transport. Fridell et al. (2006) studied the potential and cost-benefit of the listed measures in more detail. Substantial emission reductions may be achieved, cf Figure 16. Furthermore, all above measures are very cost effective - the environmental benefit of any of the measures expressed in monetary terms exceeds largely the abatement costs, cf. Figure 17. Introducing all listed measures combined will result in lower air pollutant emissions - except for sulphur - from waterborne transport compared to road transport, cf. Figure 18.
Figure 16. Emission reductions achieved for various measures/abatement techniques for ships. Calculations made for route A according to Section 5.2 (Fridell et al., 2006).

Figure 17. Cost-benefit analysis of the measures quantified in Figure 16 (Fridell et al., 2006).
6.1.3 Electricity and heat consumption

- Use of electricity produced by wind power plants.
- Use of natural gas for heating purposes.

6.2 Emissions to Water and Soil

- Education of involved staff on the surface water handling system, where the major risks are and where, when and how cleaning agents should be used, and how the surface water is secured when accidental spills occur.
- Equipping bunker vessels with appropriate tools to prevent and take care of bunker oil spills.
- Equipping surface and waste water wells with oil absorbing filters.
- Storage of diesel oil and oil contaminated waste within the port area in weather protected tanks and trays for collecting spill.
- Use of high quality materials in hydraul tubings to prevent breakages and accidental hydraulic oil spills.
- Make available cleaning-up equipment with associated instructions to handle spill and leakage.
- Promotion of the use of environmental friendly antifouling agents.
6.3 Noise

6.3.1 Handling of containers
It is hard to find practical solutions to reduce noise associated with the handling of containers, mainly because the design and construction of the containers are set by international standards. Thus, improvements in this field require redesign of the international container standards.

6.3.2 Non-road vehicles and working machinery
- Enhanced penetration of new vehicles/machinery and of vehicles/machinery meeting more stringent emission standards for noise then required by existing regulation.
- Initiate and establish programmes for calm driving (EcoDriving).
- Improved port logistics, reducing noise emissions per number of units handled.

6.3.3 Ship engines
- Introduce and promote use of shore-side electricity.

6.3.4 Loading and reloading of ships
There are similar barriers to find practical solutions to reduce noise from loading and reloading of ships as for reducing noise associated with the handling of containers, cf chapter 6.3.1.

6.4 Waste
- Establish waste receival stations within the port area equipped with roofs and spill protection.
- Introduce economical incentives for ship operators to reduce the water content in ship sludge.
7 Conclusions and Recommendations

Seaports play an important role for trade and societal development in the North Sea Region; this was true in the earlier days, and is even more so today with the increasing globalisation. Thus, ports develop in order to meet an increasing demand of goods transport. However, although this might have been the case in the past, port development today is no longer only synonymous with a raw expansion, mainly since the general concern in the society of health and environmental issues keeps growing. As promoters of sea transport and of modal shifts from road to sea, ports are important in this respect, since transport at sea is roughly three times more energy efficient than road transport, which means that the impact on global warming is equally smaller from sea transport compared to road transport per unit goods transported. On the other hand, ports and sea transport cause other emissions than CO₂ that are hazardous to both human health and the environment, in which case sea is less favourable than road transport (per unit goods transported). Thus, for port development and the increasing transport of goods by sea to move in a more sustainable direction, substantial measures need to be taken within the next decade to reduce emissions of primarily SO₂ and NOₓ from shipping. Also important is that, since many ports co-exist with major urban settlements, noise emissions from port activities are reduced. To reduce both congestion and population exposure to health hazardous air pollutants in these settlements, a modal shift for transport of goods to and from the port from road to rail needs to be promoted. Simultaneously, an increasing share of rail transport to and from the port should be operating on electricity rather than on diesel. Furthermore, in order to avoid conflicts from land use and deterioration of cultural heritage and natural habitats, the needs of ports’ physical expansion must to a much larger extent than before be met by more efficient use of existing port areas.

Recommendations:

• Reducing emissions of both SO₂ and NOₓ from shipping is very cost-effective compared to many other measures to reduce these emissions. Policies need to be developed that take advantage of this fact, so that maritime emissions within the next decade are more in line with corresponding emissions from road transport per unit goods transported. Here, both the European Commission, national governments as well as local governments, including ports and port authorities, can play a significant role. An interesting initiative is that by the Swedish Maritime Administration on environmental fairway dues (www.sjofartsverket.se).

• Research and standardisation work that aims at finding technical solutions on how noise emissions from port activities, e.g. loading and reloading of ships, can be reduced substantially, need to be strengthened. The European Commission is a key player.

• The railway network and associated railway transports connecting to ports should be improved by e.g. new infrastructure, improved transport efficiency and transfer of goods between transport modes, electrification of tracks, etc. Local governments together with railway and port operators can present good examples.

• Careful and advanced planning and protection of natural habitats and cultural heritage when ports expand spatially. Local governments, ports and NGO’s have to be involved in co-operation.
8 References


