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Literature Review:

Inland Navigation and Emissions

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Summary

The purpose of this paper was to carry out a short literature review on studies related to emissions from inland shipping. This paper provides background information to make position and policy decisions on the Trans-European Network for Transport programme, in particular Corridor VII (Danube River). The findings of this report show that emissions for inland navigation are less than air and road transport, but are not proven to have a distinct advantage over rail transport.

Conclusions

- Overall, rail and inland shipping have clear advantages over road and air transport in terms of emissions.
- Inland shipping does not have a distinct advantage over rail in terms of specific emissions.
- The characteristics of emissions within each mode of transport vary greatly due to differences in technology, infrastructure, and method of emission calculation, to name a few.
- NOX is one of the most significant emission compounds relevant to inland navigation. One study found NOX emissions are often underestimated.
- A detailed study should be carried out on how emissions could affect the sensitive ecological areas and cities along the Danube if more ship traffic is foreseen.
- Studies on emissions in the transport sector vary greatly in their finding. There is not an abundance of data available for inland navigation in comparison to other forms of transport.

Introduction

Transport is widely recognised to be a significant and increasing source of air pollution worldwide. Much discussion has been made on how to reduce this air pollution. One of the options to reduce emissions to the air is to use more environmentally friendly forms of transport.

The Trans-European Networks for Transport (TEN-T) is a program of the European Union (EU) to extend pan-European transportation corridors to connect the enlarged EU. Modification of the Danube River to handle more ship traffic is one of the most important components of this program.

The EU states in its White Paper on European Transport Policy for 2010 that inland waterway transport is energy-efficient, quiet and takes up little space[1]. This paper highlights river transport as "reliable and ideal for the carriage of heavy low-cost commodities over long distances". According to this paper, these factors make inland waterway transport a competitive alternative to road and rail transport, on those routes where suitable.

In spite of these advantages, emissions from inland navigation are still a concern. The purpose of this literature review is to discuss emissions form inland navigation in comparison to other forms of transport, such as rail, road, and air. It should also provide basic knowledge, in terms of emissions, to help make the decision to support, be neutral, or oppose plans to further transform the Danube into a transport waterway.

In other words, is inland navigation really more environmentally friendly in terms of emissions in comparison to other forms of transport? If not, does it make sense to modify the river even more when other forms of transport are more, or just as, environmentally friendly?

Methods

Information for this paper was obtained from various sources, including academic journal articles, official government publications, and studies even sponsored by the shipping industry.

The first step involved a search in an academic journal database on ship emissions in general. This search returned 50 articles. From these 50 papers, 11 were relevant to inland navigation. Furthermore, from these 11 papers, six articles contained relevant information on emissions useful for this literature review.

In addition to these journal articles, sources of information were obtained from governmental homepages (e.g. European Commission and the European

[1] White Paper – European transport policy for 2010: time to decide, EC 2001.

Environmental Agency, document downloads) as well as from a general internet search. A bibliography is included at the end of this report.

Energy consumption

One way to compare the efficiency of different forms of transport is through specific energy demand. The following table shows the specific energy consumption for different modes of transport.

Table 1: Relative energy use of different freight transport systems[2]. Energy (in kcal) to transport 1 kg of goods 1 km.

Transport mode	Energy	Ratio to most efficient
Water	0.10	1
Rail	0.32	3
Road	1.20	12
Air	6.36	64

According to data from the French Environment and Energy Management Agency, in terms of energy efficiency and the weight of goods that can be transport one kilometre by one litre of fuel, the figure for *road freight* is 50 tonnes, for *rail freight* 97 tonnes and for *inland waterways* 127 tonnes[3].

At first these statements seem like a good argument for inland navigation (i.e. assuming energy consumption is directly related to emissions emitted) in comparison to road and rail. However, this is not a safe assumption. A better comparison is to look at the specific emissions released to the environment. The following section discusses emissions in terms of various modes of transport, and for inland navigation alone.

Emissions for various modes of transport

The most relevant emissions for the transport sector include:

- CO_2 – contributes to the forced greenhouse effect
- NO_X – acidification and eutrophication, adverse health effects, smog)
- SO_X – acidification, adverse health effects
- Particle matter, PM – adverse health effects
- Volatile organic compounds, VOC – ozone precursor

The following table shows the ratio of different modes of transport in terms of climate-relevant emissions from different studies. The higher the number is, the more damaging emissions are emitted.

[2] Pimentel D. & M., 1996.
[3] ADEME.

Table 2: Transport mode climate-relevant emissions ratios[4] (based on tonne-km values).

Source	Inland navigation	Rail	Road
BM für Verkehr, Technologie und Innovation. 2003, Austria	3.55	1	8.77
BM für Land- und Forstwirtschaft, Umwelt und Wasser, Umweltbundesamt, VCÖ.2004, Austria	6	1	23.5
Hoffmann I., Lauber I., Gütertransporte, ENRO 2/2001. 2001, Global	0.85	1	3.4
TU Graz, Hausberger S., Globale Modellbildung für Emissions- und Verbrauchs-Szenarien im Verkehrssektor. 1998, Austria	0.95	1	5.6
Umweltbundesamt, Umweltbilanz Verkehr. 1995, Austria	1.04	1	6.1
PLANCO. 1990, Germany	1	1	5
DIW, TÜV Rheinland. 1988, Germany	1.02	1	5.5

According to Table 2, road transport has the most emissions in each study. However, rail and inland navigation switch between first and second place for having the least amount of emissions depending on the study. This highlights an overall trend discovered during this literature study: the difference between emissions from road and inland navigation is foggy. This will be discussed in more detail later in the paper.

Although not shown in Table 2, inland navigation contributes less to air pollution per unit mass carried per unit distance than air transport[5]. Aviation is by far the most polluting freight transport mode, expect for specific PM emissions[6].

In order to compare emissions from various modes of transport in more detail, ideally the difference in distance and travel routes are taken into account. This is usually expressed in grams of pollutant emitted per tonne and km of goods transported.

Table 3: Average emissions by mode of transport based on one Dutch study[7].

Transport mode	CO_2 (g/t-km)	NO_X (g/t-km)	PM (g/t-km)	SO_2 (g/t-km)
Barges	48.50	0.72	0.038	0.05
Electric train	27.91	0.05	0.009	0.14
Diesel train	39.58	0.61	0.025	0.05
Pipeline	8.4	0.015	0.003	0.041

The table above for barges should be compared to Table 4 (emissions from different types of ships); emissions values for barges should not be assumed for all types of inland navigation vessels.

In terms of CO_2 emissions alone, Figure 1 below shows that over the past 15 years in the EU-15, inland navigation emissions have been slightly above rail emissions, and well below road emissions.

[4] WWF Austria, April 2005.
[5] Colvil et al., 2001.
[6] European Environment Agency, 2001.
[7] Van Essen et al., 2003.

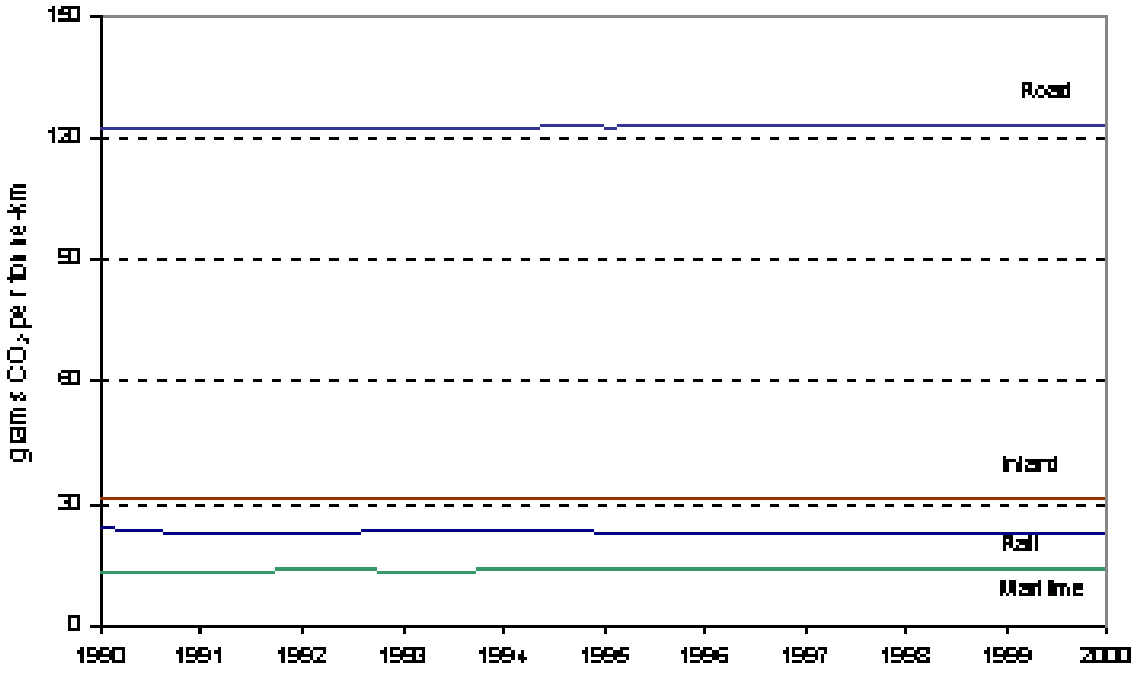

Figure 1: Specific emissions of CO_2 per tonne-km and per mode of transport in EU-15, 1990-2000[8].

Based on the information so far, one has read that inland navigation emits slightly more emissions than rail transport. But there are studies that show that is not completely.

Such a study by Kolb and Wacker takes 'total trips' into consideration. Total trips refer to different distances for the single means of transport, as well as pre-trips, post-trips (e.g. taking goods to and from the train station/port), and different weight load factors. The study also suggests that the use of flat-rate average factors to compare different types of freight transport is not permissible (which is the method usually used for simple estimation of freight transport emissions). In most 'total trip' transport tasks investigated in this study, railway was the most favourable mode of transport, although inland shipping was the most favourable for some types of transport in terms of specific energy consumption and CO_2 emissions [9]. In this case, there was still not an overwhelming advantage of inland shipping over rail.

Figure 2 gives a general overview of the specific emissions in the EU-15 between 1990 and 2000. The x-axis refers to index values for this time period. For example, specific emissions from inland transportation are not higher than those from road transport. The graphs show that emissions for road and rail have generally reduced, emissions from inland navigation have stabilised, and emissions from sea transport have slightly increased during the 10-year period.

[8] Trends, 2003.
[9] Kolb, A. and Wacker M., 1995.

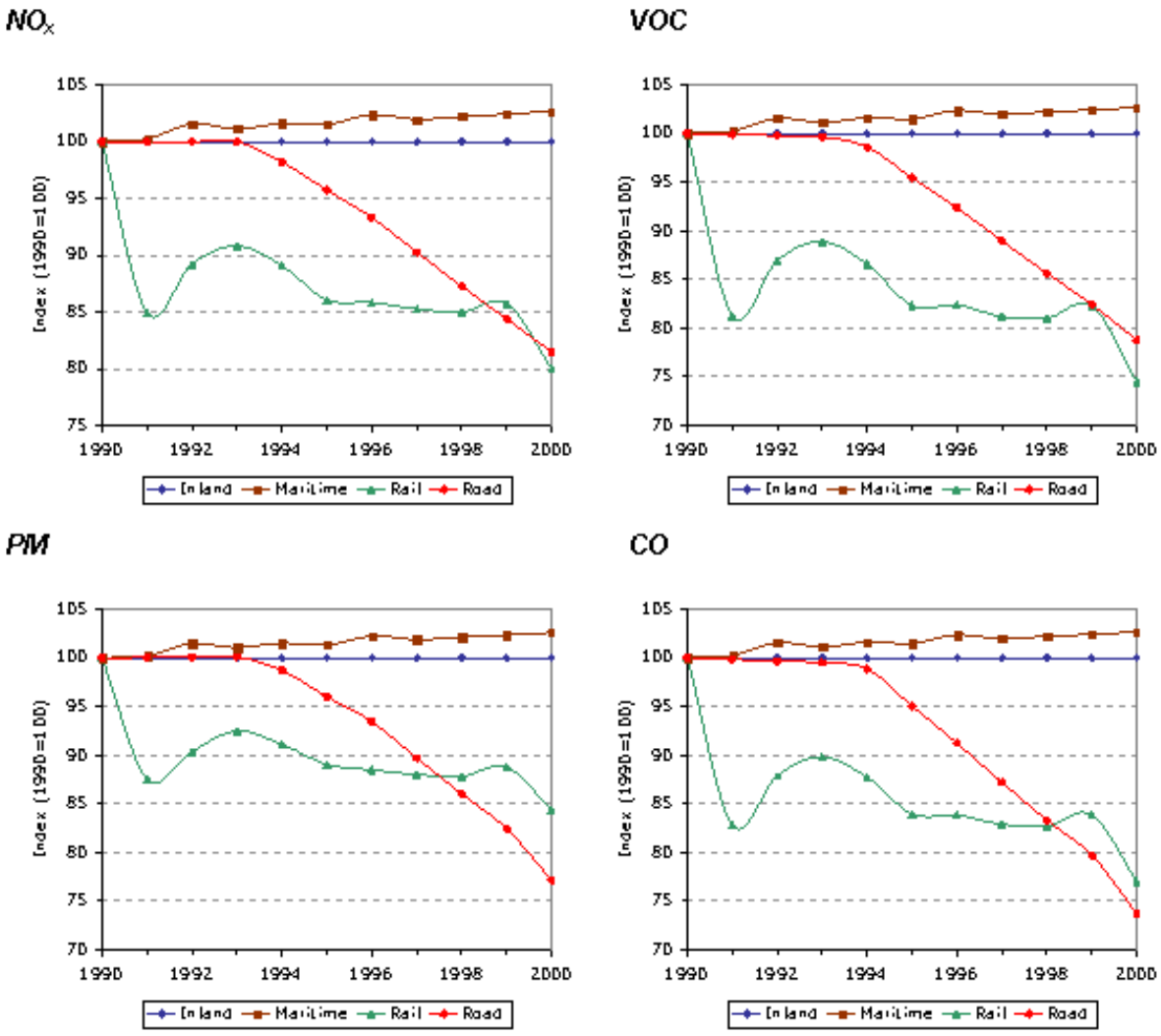

Figure 2: Modelled specific emissions of NO_X, VOC, PM and CO per tonne-km and per mode of transport in EU-15, 1990-2000[10].

In some countries, emissions from inland navigation have reduced. For example, the Emission Protocol in the Netherlands reports a slight improvement in inland shipping emission factors between 1990 and 2000 as more modern engines were incorporated into the fleet[11].

Emissions for waterborne transport

This section highlights emissions from ships. Specific emission data for ships alone are still poor, and are usually reported as fuel or energy-specific emission factors, in unite of kilograms per tonne of fuel or grams per kilowatt-hour, respectively[12]. These data cannot be compared with data from other modes.

[10] Trends, 2003.
[11] Adviesdienst Verkeer en Vervoer, 2003.
[12] European Environment Agency, 2001.

The fuel consumption rates and emissions from ships are different for different types of general cargo and container ships[13]. Wet and dry bulk carriers, which are larger and generally slower, perform better than general cargo and container ships.

For Ro-Ro ships ('roll-on, roll-off' ships with ramps to directly un-/load lorries for transport along the waterway) the specific energy consumption and exhaust emissions (measured per transported tonne-cargo/km) can be higher than for corresponding road transport[14] (see
Table 4).

Table 4: Summary of emission data for various types of ships[14].

Type of Ship	CO_2 (g/t-km)	NO_X (g/t-km)	SO_2 (g/t-km)	PM (g/t-km)
100 TEU container ship	18.9	0.60	0.38	0.049
1500 TEU container ship	12.9	0.41	0.26	0.033
6000 TEU container ship	11.1	0.35	0.22	0.029
2000 t bulk carrier	11.1	0.35	0.22	0.029
20000 t bulk carrier	5.6	0.18	0.11	0.015
80000 t bulk carrier	2.4	0.08	0.05	0.006
1000 lane metre Ro-Ro cargo ship	66.0	1.32	1.31	0.169
2000 lane metre Ro-Ro cargo ship	70.8	1.41	1.41	0.181
3000 lane metre Ro-Ro cargo ship	80.7	1.61	1.60	0.206
Euro 2 truck (20 t cargo)	50.4	0.52	0.0016	0.011
Euro 3 truck (20 t cargo)	50.4	0.42	0.0016	0.008

In the table above, Euro 2 and Euro 3 trucks refer to regulation for diesel truck engines. Euro 2 has been in operation since 1996, while the stricter Euro 3 standards were introduced in 2000.

Another source suggests that certain emissions for ships are often underestimated. A U.S. study by Corbett found that NOX emission inventories in the Northwestern United States were 2.6 times greater than a previous study by the same author in 2000[15]. This study also stated that 90% of ship emissions occurred in shipping canals outside of port regions either on rivers or within 322 km of shore, and that 65% of waterway NOX emissions were attributed to rivers. In one area, NO_X emissions compared to a major freeway segment.

Although sulphur compounds are parts of emissions from inland navigation, they are not as predominant as compared to seagoing ships, which use bunker fuels with high sulphur content[16].

[13] International Maritime Organization, 2000.
[14] Kristensen, H.O., 2002.
[15] Corbett, J., 2002.
[16] European Environment Agency, 2003.

Discussion

First, it should be stated that studies on inland navigation alone were somewhat limited, although many studies were found on seagoing ships. Even more difficult was finding emissions data for various forms of transport that were comparable. Most data was based on the entire transport sector, and not on specific forms of transport, without differentiations between passenger and freight transport.

Second, emissions vary greatly within each transport mode. This can be seen by the various levels of emissions from ships as described in Table 4. Similar differences also exist in emissions from trains. Specific emissions from trains depend greatly on the technical level and method of energy production used. Therefore, there can be significant differences in specific emissions from trains in different countries. In Austria for example, the train system has been electrified, where hydropower is partially a source of energy. Austrian data shows an emission reduction for heavy rail between 1950-1980[17]. For these reasons, it is difficult to generalise specific emissions from a certain mode of transport. Therefore, we cannot seaf3ely say that inland navigation has a significant advantage over rail transport in terms of emissions.

In the future, emissions from inland navigation could be reduced through improved fuel quality and engine technology. Yet, not all countries along the Danube have implemented the same standards in terms of ship maintenance and upkeep. Since ships travel along through many different countries, they are often not a local pollution problem, rather an international one[18].

There are other aspects of transport that have an effect on the entire system. For example, the higher emissions and specific energy demands of Ro-Ro ships could be compensated for by relieving congested roads, thereby reducing nose, accidents and traffic hams. Also, emissions in highly populated or ecologically sensitive areas can be more harmful than the same amount (or even more) emissions emitted in less sensitive or lowly populated areas[19]. This is a concern since there are many Natura 2000 sites along the Danube. These, and many more aspects, should also be considered on the overall scale of the transport system, but it was not within the scope of this literature review.

The environmental impacts of emissions, and other sources of pollution, from increased ship transportation along the Danube should be closely investigated.

[17] European Environment Agency, 2002.
[18] Corbett, J., 2003.
[19] European Environment Agency, 2001.

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