Sustainable inland transportation

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Abstract
Inland navigation is often mentioned as a 'green' alternative for the two other main inland transport modes: rail and road transport. In order to investigate the opportunities for inland navigation we first analyze the competitive position of inland navigation vis-à-vis the other main inland transport modes. For that, we perform a comparative study on the current sustainability performance of the three modes. Second, through a case study, we analyze a recent initiative for sustainable innovation of inland navigation in order to assess the barriers and opportunities for improving the competitive position of sustainable inland navigation.

Keywords: sustainability, inland transportation, case study

1. Introduction

Sustainable supply chain management is receiving increasing awareness from society, government, and businesses. Sustainable supply chain management refers to all forward processes in the chain: procurement of materials, production and distribution, as well as the reverse processes to collect and process returned used or unused products and/or parts of products in order to ensure socio-economically and ecologically sustainable recovery (Bloemhof and Van Nunen, 2005).
Sustainability of transportation modes is an upcoming issue nowadays. It looks like the implementation of sustainability started in the production of foods (Baldwin, 2009), also due to health issues and animal welfare. Then, reuse, recycling and remanufacturing became very popular ways to improve the sustainability of mainly long lasting consumer products like copiers, cars, computers (Quariguasi et al, 2008). With the increasing interest in carbon footprints, the focus in sustainability moved from a product towards a company, a chain or a transportation mode (ship, airplane, truck) as an entity.
The impact of transportation can play an important role in the overall sustainability performance of a product. This holds especially for foods, feeds and other bulk products

(IPTS, 2006). Transportation has a large contribution to pollution, resource depletion, congestion and greenhouse gas emission (Wu and Dunn, 1995). The impact of transportation on the environment and society is increasing because of the increase of freight transport. The goods transport in the European Union (EU) grew by 28% during the period 1995-2004. In that same period road transport grew by 35%, rail transport by 6% and inland navigation by 3% (European Commission, 2006).

Sustainability of a particular transportation mode does imply improvements of a combination of different and sometimes conflicting factors. Sustainability cannot be measured with a one dimensional indicator. Instead, we need to combine economic, social and environmental indicators (Triple Bottom Line).

According to the European Commission (2006) innovative inland navigation could be a considerable contribution to Triple Bottom Line performance. The specific goals set by the European Union are threefold: contributing to a modal shift, reducing the demand for transport and reducing the environmental impact of transport.

In order to investigate the opportunities for inland navigation we first analyze the competitive position of inland navigation in the Netherlands vis-à-vis the other main inland transport modes: road transport and rail transport. For that, we perform a comparative study on the current sustainability performance of the three inland transport modes. Second, through a case study, we analyze a recent Dutch initiative for sustainable innovation of inland navigation in order to assess the barriers and opportunities for improving the competitive position of sustainable inland navigation. The contribution to theory is mainly of an explorative nature: trying to understand the competitive position of inland transport modes and identifying opportunities and barriers for modal shift. Literature on sustainable modal choice is virtually nonexistent.

This paper is further organized as follows. Section 2 reviews the relevant literature on sustainable logistics and transport modes. Section 3 introduces the research methodology. In Section 4 we assess the economical, social and environmental performance of the three inland modalities, while Section 5 analyses a new concept in inland navigation. Finally, Section 6 discusses the main results.

2. Relevant literature

The field of sustainable logistics is quite broad. However, the majority of the literature focuses on trade-offs between *Planet* and *Profit*. Quariguasi et al. (2008) state that balancing environmental impacts and costs is already quite complex. They find that adopting cleaner solutions is generally bounded by increasing costs. However, expanded market share through environmental friendly innovations could result in net profits (Wu and Dunn, 1995). Murphy and Poist (2002) conjecture that logistics can only reach ts full potential through the proper trade-off between *People* and *Profit*. Carter and Jennings (2002) introduced the concept of Logistics Social Responsibility and developed a framework that ties together previously unrelated fields of logistics that are perceived as socially responsible.

Carter and Rogers (2008) were one of the first to coin the term 'sustainability' which integrates People, Planet *and* Profit (also known as 'Triple Bottom Line', see Section 2.1). Evaluating the sustainability of transport modes (Section 2.3) requires the evaluation of relevant indicators (Section 2.2).

2.1 Triple Bottom Line

Elkington (1997) first introduced the term 'Triple Bottom Line' (TBL) to acknowledge that companies have an extended responsibility that include environmental and social aspects as well. TBL is used as a framework for measuring and reporting corporate performance against economic, social and environmental parameters. The TBL concept holds two main principles: i) companies fully abide the law and meet all obligations imposed by legislation and ii) companies that are socially and environmentally responsible accept a higher level of obligation and moral responsibility than demanded by mere compliance with the law (Robins, 2006). Through TBL one measures both quantitatively and qualitatively the degree in which a company is creating value for shareholders and society (Savitz, 2006).

The economic component extends beyond financial accounting as it includes issues like competitiveness, job and market creation and long-term profitability (Jamali, 2006). Jamali describes the social component as an organization's impact on social systems in which it operates, including issues like human rights, safety and public health. Environmental sustainability focuses on living and non-living natural systems including ecosystems, land, air and water (Nykvist and Whitmarsh, 2008). The intention of TBL is not the description of each dimension separately, but their integration (Vanclay, 2004). A measurement framework is needed to integrate these pillars (Fawcett et al, 2007).

2.2 Sustainability assessment indicators

Literature provides several frameworks for measuring sustainability in logistics, but a standard framework does not exist. Jeon and Amekudzi (2005) categorizes possible frameworks as i) linkages-based frameworks, ii) impacts-based frameworks, and (iii) influence-oriented frameworks.

A popular *linkages-based framework* is the Pressure-State Response (Gilbert and Tanguay, 2000). Human activities affect life and natural resources. The response from society is taken by economic, social, environmental and general policies and by awareness and social behavior. Indicators are constructed by examining the influences and interconnectedness of various factors so that suitable responses can be developed.

A common *impacts-based* framework is a three-dimensional list of economical, social and environmental impacts (Litman and Burwell, 2006). These indicators cover passenger and freight transport and are measured both quantitatively and qualitatively. A similar list is provided by Jeon et al. (2008). For each dimension, a number of goals and associated performance measures are defined (Table 1).

Insert Table 1 here

The *influence-oriented framework* uses performance indicators that reflect the relative level of influence and control an agency has with respect to making progress toward sustainability (Jeon and Amedudzi, 2005). The indicators are categorized by state, behavioral and operational level.

The literature on performance indicators for sustainable logistics shows no consensus. Some authors describe indicators as separate entities, whereas others acknowledge that factors related to sustainable logistics can influence more than one dimension and create several impacts.

MacRae et al. (1989) proposed a three-tier classification system for sustainability indicators, which we summarize as follows.

- First-tier indicators focus largely on minimizing the impacts of existing methods, activities or processes (efficiency measures)
- Second-tier indicators measure the extent to which older methods, technologies, or processes with high negative impacts are being replaced by newer ones with less negative impact (substitution)
- Third-tier indicators help to measure the extent in which rules and procedures are reconsidered with sustainability as a foundation (redesign)

First-tier performance improvements generally result in early successes (e.g. energy reduction, fuel efficiency). Possible second-tier improvements are conversion from fossil fuel to biodiesel or electricity, whereas a third-tier improvement may be to shift to an innovative transport mode.

2.3 Transportation mode choice

Cost minimization is the traditional driver for transport mode choice, although congestion, safety and environmental impacts have been identified as relevant factors by scholars (e.g. McGinnis, 1989). Saleh (1972) put forward that cost is an important factor in carrier choice but service is of greater importance to the shipper. Burdg and Daley (1985) found that carriers find service factors more important than low freight charges. Gibson et al. (1993) rank transportation modes on five criteria: customer service, rates and discounts, equipment availability, quality and performance history. One of the few recent studies (Vannieuwenhuyse et al, 2003) indicates that transportation costs are equally important as reliability, flexibility and safety. We did not find empirical evidence in literature for an increased awareness of sustainability issues in practice.

3. Research Methodology

The literature study of Section 2 suggests that transportation mode choice may have considerable impacts on sustainability performance. At the same time however there is little evidence that sustainability concerns actually affect transportation mode choice. In that light, we set out to 1) validate the proposition that modality choice is currently based on economic tradeoffs only (costs versus service), and 2) to analyze the opportunities and barriers for sustainable inland barge transport vis-à-vis road and rail transport. To do so, we first analyze and compare the sustainability performance of the three transportation modes in the Netherlands. Then we present and analyze the case of Schipco, a Dutch company that recently developed the concept of small push barges equipped with electricity generators. This concept is more fuel efficient and has the potential to generate less noise in more populated areas. We chose case study methodology as it is an appropriate approach when trying to gather understanding of complex phenomena (Yin, 2003). During a four month’s internship in the first semester of 2009 at Schipco by one of the co-authors, semi/structured, open-ended interviews with a freighter, two inland shipping companies, Rail Cargo Netherlands, Expertise and Innovation Centre Inland shipping, a barge operator, Connekt (an independent network of companies and authorities to promote sustainable mobility in the Netherlands), and the Maritime Research Institute the Netherlands were conducted.

The three modalities are assessed along the three dimensions of sustainability according to the measuring framework of Table 2, adapted from Litman and Burwell (2006), Litman (2008), Vanclay (2002) and Vanclay (2004). Here, extant sources provided the data for the quantitative measures; the qualitative measurements are a combination of both secondary sources and results from the interviews.

Insert Table 2 here

4. Sustainability of inland transport

Within the inland transport chain we may identify three main actors (van der Horst and de Langen 2008, see Figure 1): modality operators (barge operators, rail operators and trucking companies), terminal operators and shippers. The barge operators organize the transport on the inland waterways and may accommodate pre and post haulage. Terminal operators are responsible for storage and on on/off loading and may also offer services such as packaging and labeling. Ships are mostly owned by larger entrepreneurs, while privately owned ships are rare. Ships are often leased to the barge operators and operated by families (A&S Management, 2003). The freight forwarder is considered to be the most important link in the chain as it owns the cargo to be transported.

Insert Figure 1 here

The freight forwarder outsources a job or specific transport based on contracts to the barge operator, which in turn make all the necessary arrangements. Its responsibilities include choosing terminals to accommodate on and off loading (especially if pre or post haulage is required) and hiring shippers to arrange the physical transport of the cargo. Other important actors are financial institutions that play a decisive role in the acquisition process of new ships. Finally, governmental institutions monitor whether vessels satisfy port regulations and meet economic and environmental targets. We next discuss the sustainability performance of truck, train and barge regarding economic factors (Section 4.1), social factors (Section 4.2) and environmental factors (Section 4.3).

4.1 Economic sustainability performance

Quality& speed

Each modality has certain advantages with respect to delivery speed, flexibility and reliability. Inland navigation is considered to be both flexible and reliable as long as both inbound and outbound locations are situated at a waterway. Handling activities take time and therefore increase costs. Products that are time critical or shipped in small lots are more suitable for road transport. Trucks have the ability to reach most destinations, but are especially suitable for relatively short distances, especially when the final destination cannot be reached by waterway or rail. Rail transport, although not flexible, is a major competitor in international transport of containers. In addition, it provides a cheap way of transporting low value bulk goods. For certain routes inland navigation and rail transport are the faster option, especially when pre- or post transport is not required. Although slower in terms of absolute speed, these modes do not face the risk of congestion, as is typical for road transport. Summarizing, quality and speed depend on the type of cargo, travel distance and specific route. That is also why modalities are often combined.

Transport costs

It is difficult to point out specific freight rates per modality, as it depends on many factors. Rail and water transport have relatively high fixed costs compared to road transport and are therefore only competitive when volume and distance increase (Figure 2). Until recent, the transport sector had been booming and freight rates increased, for inland navigation this trend translated into the emergence of bigger vessels. However, the current crisis resulted in decreased demand and overcapacity, which in turn lowered the freight rates. Hence, all three modalities need to fight for their market share. In terms of infrastructural costs (construction and maintenance) and external costs (safety, nuisance emissions, etc.) per hundred ton-km (Table 3), inland navigation is by far the cheaper modality, while road and rail show similar performance.

Insert Figure 2 and Table 3 here

Quantity and modal split

Most ton-kilometers (ton-km) in the Netherlands are accounted for by road transport (Figure 2), which grew by 20% between 1998 and 2006. Rail grew rapidly also (40%), but quantities are relatively small. In terms of modal split, in the period 1998-2006 the share of road transport grew slightly from 53.7% to 56.0%, the share of inland navigation decreased from 41.7% to 38.3% and the share of rail transport increased from 4.6% to 5.8% (NEA, 2008).

Insert Figure 2 here

Energy consumption

In absolute terms the energy consumption of rail and water transport is significantly higher than that of road transport. However, the utilization rate of the latter is much smaller on average. Taking into account average utilization rates, it appears that road transport is a factor 2 to 3 less energy efficient than rail and inland navigation (Table 4).

Insert Table 4 here

Congestion

Delays resulting from congestion are typical for road transport, mainly due to the presence of secondary users. Secondary users of rail transport, passenger trains, also cause some delays, but this is decreasing due to changing priority rules. Secondary use of inland waterways is negligible. Impacts of accidents on delays are much higher for rail transport and inland navigation, but their occurrence rate is much smaller than that for road transport. Here, delays mainly originate in the process of on and off loading.

Employment

The transportation sector was hit hard by the crisis. Vessel owners even need to operate the ships themselves in order to save costs rather than hiring personnel. The period prior to the crisis showed a vast demand for jobs in both management and operations.

4.2 Social sustainability performance

Safety

Inland navigation and rail transport are considered to be very safe transport modalities, especially when compared to road transport (Table 5). The latter has such high accident rates due to the presence of secondary users and the larger volume transported by road. Accidents show a decreasing trend; truck accidents decreased about 33% between 2001 and 2006. Most injuries and fatalities in rail transport are due to secondary users.

Insert Table 5 here

Human health impacts & environment

These impacts are closely related to environmental performance and are discussed next.

4.3 Environmental performance

NO_x, CO_2, SO_2 and CO Emissions (Table 6)

The total emission of NO_x decreased with 10.6% in the period 1998-2006, which is almost completely due to developments in road transport (13.6% decrease). Taking into account transported volume and distance shows that inland navigation and rail transport have a better performance than road transport: while the share of road transport increased from 54% to 56%, the share in NO_x emission decreased from 77% to 75%.

The total emission of CO_2 increased with 23.6% in 1998-2006. Road transport is again the main contributor, with emissions growing 22% in this period (from 84% to 87% in terms of modal share). Inland navigation and rail transport show stable values.

Road transport's SO_2 emission share sharply decreased from 60% in 1998 to just 3.6% in 2006, while there were little developments in rail transport and inland navigation. Since 2006, inland navigation is the largest emitter of SO_2.

In 1998-2006 road transport's and inland navigation's CO emission share decreased from 85% to 79% and from 42% to 38% respectively. Rail transport's emission share increased from 4.6% to 5.8%, but in absolute terms it has by far the lowest gram/ton-km emission rate. Road transport has the highest rate, but shows rapid improvements.

Insert Table 6 here

Noise pollution

Inland navigation itself hardly produces any noise. There are even regulations that limit the noise of vessels to make sure that shippers get enough sleep. That is probably why we could not find any statistics on noise pollution of inland navigation. Road transport is one of the largest contributors to noise pollution, as one third of the Dutch population is affected (Table 7). However, rail transport has a significant contribution as well if the modal share is taken into account. It is the vibrations and rough surface of wheels and rails that cause the noise. More people are potentially affected by noise pollution because more and more housing is constructed near highways and railroads. Finally, road transport affects more people, but rail transport causes higher noise levels.

Insert Table 7 here

Water pollution

There is not much information available regarding groundwater and waterway pollution. Water pollution is caused by on and off loading and the use of lubricants, but it seems to be limited. Inland navigation vessels used to use waterways for waste dumping and cleaning, but waste dumping is not allowed anymore and cleaning is done nowadays by specialized parties.

4.4 Conclusion

At the moment the competitive position of inland navigation is still strong due to its competitive freight rates, reliability, high volume transport and safety. However, one of the most used marketing tools for inland navigation is its sustainable character. This is certainly true as inland navigation achieves good performances on economic, social and environmental aspects of sustainability. However, this is not due to the sector’s innovative capabilities, but rather due to its inherent ability to transport high volumes, which in turn economizes fuel consumption. Rail and especially road transport are accomplishing much more rapid developments on sustainability.

5. Case study Schipco BV

Schipco BV, a consultancy firm specialized in transport solutions, developed an innovative concept for small barges. Their motivation came from the limited availability of small inland navigation vessels (smaller than 86 meter and capacity below 1500 ton) and the recent call for more sustainable transport modes. The innovation is based on a combination of existing technologies that have not been used together before. In terms of the three-tier classification system of McCrae et al (1989) this could be classified as a second-tier adaption (substitution). An electric propulsor is installed on a tugboat together with a number of batteries and a small generator for emergencies. The push barges are equipped with a generator to generate and store energy. If the tugboat uses this energy, the combination of vessels will use the energy that is needed for that particular combination of tugboat and push barges and energy is saved. If each push barge has sufficient electric power capacity to move itself and the tugboat there will be no excess use of energy and the power capacity is used more efficiently. This allows one to travel emission free with reduced noise pollution through highly populated areas and with significant emission reduction through sparsely populated areas. In a later stage, liquid gas (LNG) generators could be installed to prevent expensive filtration of pollutants and emissions and to further reduce noise levels.

Schipco BV soon realized that in the conservative industry of inland transport, economical incentives are much more decisive than environmental implications. Even when a sustainable innovation proved to have similar operating costs and service level, inland transport organizations would hesitate to take the risk. But there was a more unexpected barrier. The limited availability of small barges is maintained by financial institutions that are only willing to invest in efficient large capacity barges that generate a high return on investment. In addition, the demand for the traditional bulk cargo that is most suitable for smaller barges appears to be decreasing, which may prove to be yet another barrier for the transition to smaller barges.

6. Discussion of main findings

Both road transport and inland navigation achieve a good performance on economic indicators. Both modes have a high share in the modal split, yet they do not compete on price. Inland navigation is able to offer competitive freight rates together with low energy consumption and high-energy efficiency. In addition, the level of congestion that is present with road transport does not harm inland navigation. Road transport on the other hand provides faster delivery with a high overall capacity. Rail transport does not excel on any specific indicator and receives an average score. Rail transport performs well on social and environmental indicators as it is a safe and relatively clean form of transport. It has the lowest emission rate per ton-km on almost every type of emission. Inland navigation is not far behind, except for sulfur dioxide (SO_2). Road transport is the largest contributor of emissions. However, road transport accomplished significant emission reductions; sulfur dioxide emissions are close to zero. The gap with the other modes is still large but if rail transport and inland navigation keep refraining from innovations the gap could close even further. However, it appears that only sustainable innovations that also contribute to profitability will succeed. Moreover, while the market observes a lack of small barges, the conservative nature of the inland navigation sector and the focus of financial institutions on efficient ships push towards larger ships instead. This further limits the opportunities for tier 2 and 3 innovations.

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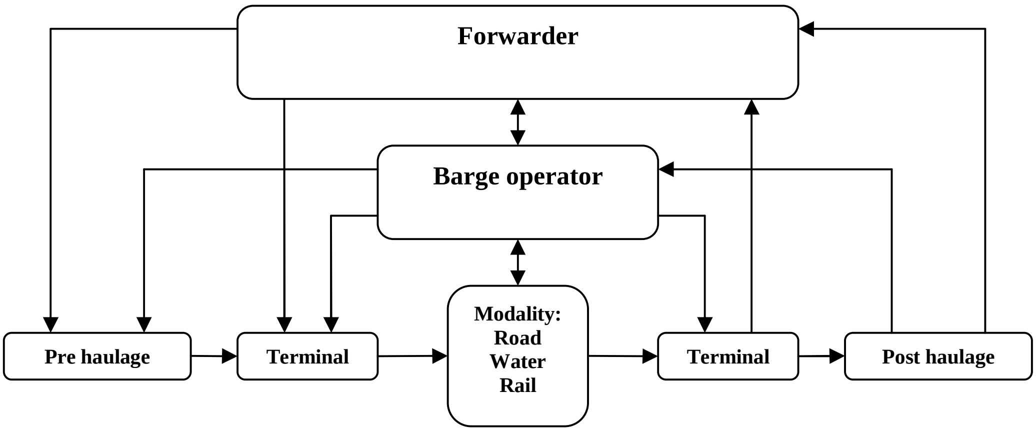

Figure 1: Structure of inland transport chain (based on Van Der Horst and De Langen, 2008)

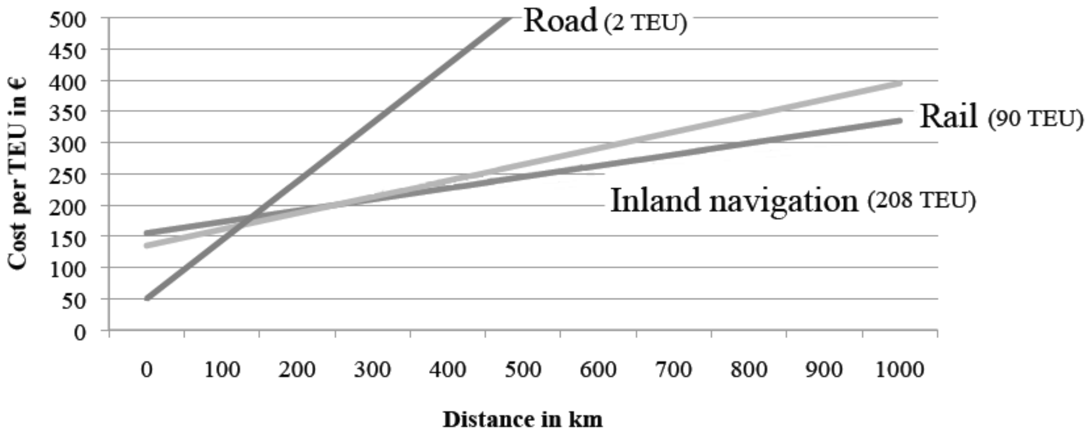

Figure 2 Total transport costs of maritime containers per modality (Rail Cargo, 2009)

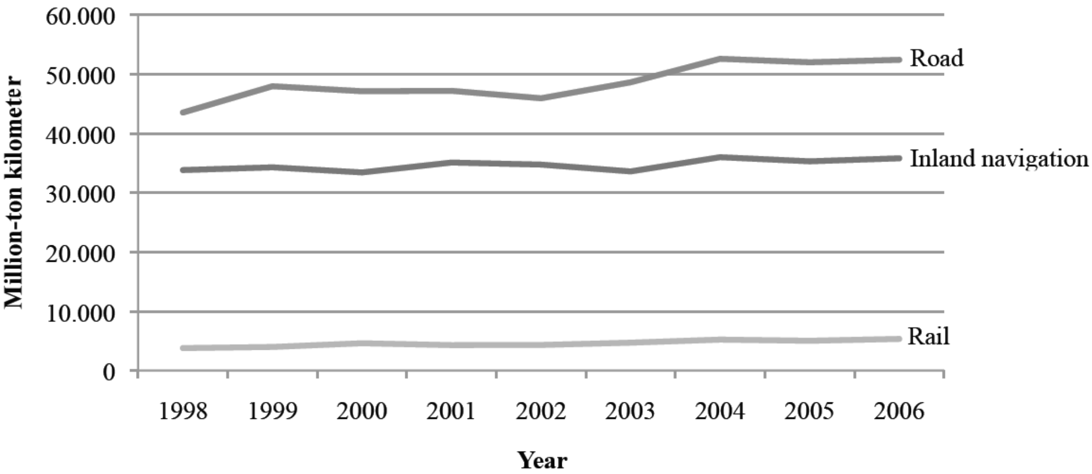

Figure 3 Transport in the Netherlands in million ton-km.

Table 1 Sustainability assessment indicators (Jeon et al., 2008)

Sustainability dimension	**Goals and objectives**	**Performance measures**
Transportation system effectiveness	Improve mobility	Freeway/arterial congestion
	Improve system performance	Total vehicle-miles travelled Freight ton-miles Transit passenger miles travelled Public transfer share
Environmental sustainability	Minimize greenhouse effect	CO_2 emissions Ozone emissions
	Minimize air pollution	VOC emissions CO emissions NO_X emissions
	Minimize noise pollution	Traffic noise level
	Minimize resource use Fuel	Consumption Land consumption
Economic sustainability	Maximize economic efficiency	User welfare changes Total time spent in traffic
	Maximize affordability	Point-to-point travel cost
	Promote economic development	Improve accessibility Increased employment Land consumed by retail/service
Social sustainability	Maximize equity	Equity of welfare changes Equity of exposure to emissions Equity of exposure to noise
	Improve public health	Exposure to emissions Exposure to noise
	Increase safety and security	Accidents per VMT Crash disabilities Crash fatalities
	Increase Accessibility	Access to activity centers Access to major services Access to open space

Table 2 Sustainability indicators and measures

Economic (Litman and Burwell 2006, Litman 2008)

Indicator	**Measure**
Quality	User satisfaction ratings
Speed	Average speed per mode
Transport prices	Average price charged per mode
Quantity	Average freight load
Infrastructure costs	Facility costs such as expenditures on roads
Energy consumption	Average fuel consumption per mode
Energy efficiency	Fuel consumption per ton-kilometer
Congestion	Frequency of delay per mode
Utilisation	Utilisation rates per mode
Employment	Job opportunities
Mode split	Portion of transport made by other mode

Social (Litman and Burwell 2006, Litman 2008, Vanclay 2002, Vanclay 2004)

Indicator	**Measure**
Safety	Crash and fatality rates
Human health	Health impacts
Environment	Quality of resources

Environmental (Litman 2008).

Indicator	**Measure**
Climate change	CO2 emission rates
Other air pollution	CO, VOC, NOX, particulates
Noise pollution	Exposure to noise
Water pollution	Amount of wastewater
Resource efficiency	Depletion of non-renewable resources
Infrastructure	Impact of infrastructure
Habitat	Impact on habitat

Table 3 Infrastructural and external cost of freight transport (Dutch Inland Shipping Information Agency, 2004)

	Infrastructural costs	***External costs***	***Total***
Road	0.51	1.94	2.45
Rail	1.86	0.43	2.29
Inland navigation	0.82	0.10	0.92

Table 4 Energy use in MJ/ton-km (Dutch Inland Shipping Information Agency, 2004)

		Average cargo load (ton)	***Primary energy consumption (MJ/tonkm)***
Road	truck	7.3	4.06
	truck + trailer	19.3	1.82
	tractor + trailer	25	1.4
Inland navigation	international	1250	0.43
	national	700	0.48
Rail	Electric traction	1000	0.59
	Diesel-electric traction	650	0.73

Table 5 Registered accidents, fatalities and injuries of inland transport

	2001	2002	2003	2004	2005	2006
Number of incidents that involved at least one truck (NEA, 2008)						
Accidents	15.998	13.716	11.951	11.650	11.144	10.782
Fatalities	169	129	158	137	103	129
Hospital injuries	624	625	607	554	533	493
Number of incidents in rail transport (Rail Cargo, 2009)						
Injuries	153	136	198	200	173	210
Fatalities	28	22	38	24	25	16
Number of Incidents on inland waterways (NEA, 2008)						
Injuries	19	20	12	23	25	21
Fatalities	3	2	1	4	5	2

Table 6: NO_x, CO_2 , SO_2, CO (g/ton-km) emissions (NEA, 2008).

		1998	**2000**	**2002**	**2004**	**2006**
NO_x	Road	1.99	1.95	1.96	1.58	1.43
	Navigation	0.72	0.78	0.76	0.70	0.68
	Rail	0.38	0.36	0.36	0.31	0.27
CO_2	Road	210.63	224.47	246.12	222.65	223.73
	Navigation	49.74	53.77	52.19	48.18	46.70
	Rail	17.53	16.57	16.93	14.53	12.57
SO_2	Road	0.06	0.04	0.01	0.01	0.00
	Navigation	0.05	0.06	0.06	0.05	0.05
	Rail	0.02	0.02	0.02	0.02	0.01
CO	Road	0.87	0.76	0.68	0.50	0.40
	Navigation	0.20	0.21	0.19	0.17	0.16
	Rail	0.03	0.03	0.03	0.03	0.02

Table 7 Percentage of Dutch population subject to noise (NEA, 2008)

	1990	***1995***	***1999***	***2000***	***2001***	***2002***
Rail	5	5	6	7	6	7
Road	34	30	28	29	30	32