

# Flexibility of Freight Transport Sectors.

## An Exploration of Carriers' Responses to External Pressure on Prices and Service

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*In this paper, we explore how government policies in the field of transport may affect future freight rates, transit times, and delivery reliability. In particular, attention is paid to the 'absorptive capacity' of freight carriers, i.e. the extent to which they can reduce the effects of such policies by adapting their operations. Two policy scenarios are examined: one in which marginal social cost pricing becomes policy in the European Union, and one in which investment in infrastructure networks is insufficient to accommodate the future increase in traffic demand, inducing a strong increase in congestion. Six modes of transportation are included in the analysis, namely road haulage, rail transport, inland navigation, short sea shipping, airfreight, and deep sea container shipping. The study relied on experts' opinions and estimations, which were collected by means of a Delphi survey. The expectation is that notably road transport will face difficulties in coping with the two scenarios. Its absorptive capacity proves to be the lowest, which deteriorates its competitive position vis-à-vis other modes. Yet, a weakened competitive position of road haulage is also expected autonomously.*

### 1. Introduction

Freight transport in Europe has grown substantially in the past decades, and it is expected that this trend will only continue. Long-term modeling studies for instance indicate a growth in freight transport on Dutch territory, expressed in ton-kilometers, of 80 percent between 1995 and 2020 (AVV, 2000: 6). It is expected that a substantial part of the growth in freight transport will be realized by road transport. These developments partly contradict with current transport policy of the Dutch Ministry of Transport, as well as that of the European

Commission. In the coming years, transport policies of these governments consist of a mix of policy instruments. On the one hand these policies try to accommodate the growth in freight transport by selective expansion of infrastructure (for instance by investments in multimodal terminals or the Trans European Networks). On the other hand they aim at regulating transport demand (e.g. through taxation).

The effectiveness of policy instruments will largely depend on the responses of both carriers and shippers (i.e. the purchasers of transport services). However, so far little study has been done to systematically explore these responses. This paper describes the main results of a study that aimed to partly fill in this knowledge gap. Since it is likely that carriers will be confronted with transport policies first, the study exclusively explored carriers' responses to two specific policy scenarios. In particular, attention was paid to the flexibility or absorptive capacity of carriers, since this will determine to a large extent how shippers will perceive transport policies. Potential adaptations of shippers were excluded, but have been assessed in the Ph.D. project of the first author. The overall research question that was addressed was "how will prices and service of freight carriers develop in future, and what could be the impact of governments on these variables?"

The structure of the paper is as follows. In section 2 we will briefly discuss the conceptual framework of the study as well as some related studies. In section 3 the set-up of our study is described. Then, in section 4 through 6 the findings are presented. Finally, in section 7 conclusions are drawn and some points of discussion are raised.

## **2. Conceptual framework and related studies**

Since transport policy aims to affect transport decisions of carriers and shippers, the first step would be to identify the decisions that generate the amount of freight transport. Subsequently, shippers' transport decisions can be distinguished from carriers' transport decisions. As mentioned above the focus of this article is on the latter type of decisions. As a starting point, we consider freight transport in the context of production and distribution networks, consisting of nodes and links (cf. Bowersox *et al.*, 1986; Klapwijk, 1996, Tavasszy, 1996, and De Wit and Van Gent, 1996). The nodes are physical locations such as factories and distribution centers, where goods are kept for shorter or longer periods of time for physical transformation (production), logistical transformation (consolidation, buffer inventory), or transformation of ownership (sales). Nodes are connected by transport and communication links.

The amount of traffic that is generated by a production and distribution network is commonly affected by various factors. Based on empirical analysis, McKinnon and Woodburn for instance identified the following factors (op.cit., 1996: pp. 149-150): (a) total volume of sales; (b) the nature of the product (e.g. volume or weight); and (c) several *logistical* factors, including:

- the functional structure and spatial pattern of the production and distribution network, which affects the distances over which freight has to be transported. Relevant aspects are numbers, locations, and capacity of the nodes in the network; supplier networks; and market areas;

- scheduling of the product flow within the network: e.g. the frequency with which orders are shipped, and the required lead time and delivery reliability. This logistical factor has an important impact on modal choice and on opportunities to consolidate freight;
- management of transport resources: the process in which individual shipments are converted into physical transport movements.

Basically, the first two logistical factors generate *product flows*, consisting of individual orders that are sent with a particular frequency between the nodes in a network. In transport studies, goods flows are typically measured in ton-kilometer statistics. The management of transport resources ultimately results in particular *traffic flows*, i.e. the physical movement of the product flow by vehicles or other means of transportation, usually expressed in vehicle-kilometers. Transport is often outsourced to commercial carriers, although logistics or transport managers at shipping firms may also have a responsibility. Typical decisions that are made on this level involve for instance:

- mode(s) of transportation that will be used;
- vehicle choice;
- choice for specific transport units (e.g. containers or pallets);
- routing;
- scheduling of departure and arrival times;
- consolidation.

It seems plausible that transport policy interventions such as taxation by their very nature will first affect the management of transport resources. Therefore, in our study we focused on the potential impact of policy interventions on transport decisions at this level of logistical decision-making.

Yet, depending on the extent to which carriers and transport managers succeed in absorbing the impact of policy interventions, other logistical decisions as identified above may be affected by policy interventions as well. In this context, various studies (e.g. Goss, 1991; Gruppo CLAS, 1998; Muilerman, 2001) have demonstrated that shippers in making these other logistical decisions, are in particular sensitive to three key features of freight transport:

- freight rates (from commercial carriers or the internal rates calculated by own transport departments);
- transit times;
- reliability of deliveries.

Given their importance for other logistical decisions affecting transport demand, we examined the effects of policy interventions on these variables as well.

Transport policy interventions may affect transport operations in many ways. Much will depend on the specific design of policy interventions. For instance, in case of taxation, a fixed levy may induce other behavioral responses than a levy that varies with the amount of kilometers driven or mode of transportation used.

Various publications can be found on the impact of policy interventions on logistical and transport decisions. Most of them however have not distinguished between shippers and carriers, or between the above factors affecting transport, as suggested by McKinnon and Woodburn (1996). Studies of Dings, Leurs, *et al.* (1999), Kågeson and Dings (1999), and Voordijk *et al.* (1999) for instance provide insight into the effects of increases in kilometer operating costs on the operations of carriers. In this context Voordijk *et al.* assert that likely

responses to higher per kilometer costs are among other things a switch to other modes of transportation, in particular on long distances, or improved transport planning by an increased use of information technology (op.cit., p. 122). Other relevant studies start from a more abstract level and investigate the effects on for instance a national (macro) or sector (meso) level. Price elasticity studies are a typical example of this kind of research. They usually aim to reveal the quantitative effects of changes in carrier rates on the demand for freight services (e.g. expressed in the number of ton- or vehicle kilometers) or on the modal split (e.g. Geurs and Van Wee, 1997 and Oum *et al.*, 1990). Yet, it should be noted that still few estimates of price elasticity of freight transport demand have been described in the literature (Beuthe *et al.*, 2001: 253). In addition, price elasticity studies usually do not take into account different types of cargo (e.g. expressed in perishability or value density) or the spatial characteristics of the geographical network (e.g. accessibility to waterways) (Beuthe *et al.*, 2001: 254). Moreover, they provide little insight into the *mechanisms* that generate the change in transport demand. Other studies however focus specifically on these mechanisms. Again, distinction can be made between micro and meso/macro level studies. Macro level studies include for instance research on the key issues in shippers' modal choice or carrier choice (e.g. Gruppo CLAS, 1998; McKinnon and Forster, 2000; NEI/NEA, 1990; Van Schijndel and Dinwoodie, 2000). Relevant meso level studies focus on spatial and logistical adaptations of particular industrial sectors to higher transport costs (e.g. Muilerman, 2001), or on the adaptations of supply chains (e.g. Groothedde and Van Haselen, 1998 or McKinnon and Forster, 2000). Finally, examples of micro level studies are those of Korver and Mulders (1992) and more recently, Van Schijndel and Dinwoodie (2001), who describe the logistical responses of Dutch shippers and carriers to increased congestion on motorways.

Yet despite these studies still important knowledge gaps exist, notably concerning the effects of policy interventions on (future) rates, transit times, and delivery reliability of freight transport. And, although potential adaptations of carriers are described in the literature, uncertainty exists about the *likelihood* of such adaptations in specific circumstances. Our study aimed at filling part of the knowledge gap, building upon the knowledge that was obtained in the previous studies.

### **3. Organization of the study**

#### **3.1 Methodology**

A Delphi survey was the main data source in answering the overall research question. Delphi surveys consist of "a series of repeated interrogations of a group of experts, focusing on reaching a consensus among them" (Marchau and Van der Heijden, 1998: 250). Experts are generally asked for their reaction on a set of questions in a questionnaire. The responses are fed back to the experts who can change their opinion using this group information. This process is repeated a few times. Delphi surveys are frequently employed in study contexts, dominated by a high degree of uncertainty (e.g. futures research) or with a very complex nature. In such contexts, other methods like extrapolation of statistics fail and researchers often revert to the opinions of experts. Although expert consultations can also be executed by means of interviews or ordinary surveys, Delphi surveys have a number of advantages. One,

an (indirect) exchange of opinions occurs, which can accentuate opinions or make them more complete. Two, compared to expert meetings, there is no influence of dominant persons, no (or less) influence of social desirable behavior or majority thinking, and there is time for the experts to develop or adjust opinions (Daniëls and Duijzer, 1988: 89). However, if the number of experts is small, Delphi surveys do not yield statistically representative information (Gordon, 1994: 4). Also, they tend to produce conservative estimations and enforce existing paradigms. Finally, they sometimes give little insight into the respondents' reasoning (McKinnon and Forster, 2000: 3). Because of these (potential) disadvantages Delphi surveys are often employed when no more formal analysis tool is possible. Delphi surveys are frequently conducted in transport studies; see for instance Marchau (2000) for a general overview or McKinnon and Forster (2000) for studies in freight transport and logistics.

### 3.2 Empirical focus

The Delphi survey focused on road haulage, inland navigation, rail transport, airfreight, deep sea shipping, and short sea shipping to and from the Netherlands. Each of these transport modes is however characterized by a high degree of heterogeneity. One, they serve various market segments (e.g. bulk freight, containers, or tankers; full truck load or less-than-truck load services, etc.). Two, market conditions -and hence rates- often vary across transport relations (see for instance Table 1). Three, large cost differences exist between countries. Recent research for instance demonstrated that the operating costs of Italian road haulers are 44 percent higher than those of their Greek colleagues (Nieuwsblad Transport Dossier, March 23, 2001)<sup>1</sup>. Four, costs – and hence rates- fluctuate in time; since 2000, the share of fuel costs in total costs for instance has increased. Five, costs and rates vary between firms; it is for instance well known that self-employed drivers often do not calculate all (operating) costs. Due to this heterogeneity, generic statements about 'the road haulage sector' or 'the inland navigation sector' are barely possible. In order to acquire more in-depth knowledge, it was decided to focus in this research on one important transport flow per mode of transportation, expressed in freight volume, cargo unit, and distance covered (see Table 2). This approach implies that the survey results are not necessarily representative of other transport flows, but rather indicative<sup>2</sup>.

**Table 1. Road haulage rates on various connections (1993/1994)**

Route	FTL rate from UK (in £)	FTL rate to UK (in £)
London-Milan	800	1.400
London-Paris	350	700
London-Frankfurt	500	800
London-Amsterdam	400	700
London-Antwerp	250	400

Source: Cooper *et al.*, 1994: 262.

<sup>1</sup> Another example originates from Hensher and Brever (2001: 138) who compare cost structures of short sea shipowners in a number of countries. They found large differences between countries; in 1994 the average share of manning costs in total costs in the VS was for instance 58 percent against only 28 percent in the UK.

<sup>2</sup> The Delphi panel was provided with background information about the transport flows under study (i.e. average prices, cost structures of carriers, distances, transit times, and reliability of arrivals).

**Table 2. Transport flows examined in the Delphi survey**

Transport mode	Transport flow
Road haulage	Container haulage from Rotterdam to Duisburg (Germany)
Inland navigation	Container shipping from Rotterdam to Mannheim (Germany)
Rail transport	Container rail transport from Rotterdam to Milan (by shuttle)
Short sea	Transport of wood and forest products from Sweden to the Netherlands
Airfreight	General cargo transport from Amsterdam to Tokyo
Deep sea	Container shipping from Rotterdam to Singapore

### 3.3 Experts consulted

Given the central research question, we selected 130 persons with expertise regarding operational management of transport operations, pricing strategies of carriers, options to avoid or adapt to policy interventions, and who could make plausible estimations of the ultimate effects of transport policies on rates, transit times, and delivery reliability. A broad pool of experts was approached within the transport sector, shipping firms, interest groups, academia, research institutes, the Ministry of Transport, and the environmental movement<sup>3</sup>. By doing so, we aimed to get insight into possible biases on the part of the experts. This broad approach is motivated by the observation in another Delphi survey that shippers and carriers had completely different expectations with respect to future carrier rates (Cooper *et al.*, 1994: 251). Although expertise in itself is difficult to measure, Table 3 provides an indication of the Delphi panel's knowledge base.

**Table 3. Indication expertise of the Delphi panel**

	Number of years of experience			Expertise with respect to more than one mode	Expertise obtained in more than one position
	> 5 years	2-5 years	< 2 years		
Number of experts	58	6	0	46	32
In % of total panel	91%	9%	0%	72%	50%

### 3.4 Transport policies examined

We were interested in the attitude of the experts regarding different future developments. One way to measure that is to use different scenarios: mutually different, coherent descriptions of future developments. Two scenarios were examined, in which priorities in transport policy result in the following situations:

- “Fair and efficient pricing”: it is assumed that all external social costs of transport are passed on to freight carriers. Such policy has been promoted for a long time by for instance the European Commission (EC, 1998; 2001);

<sup>3</sup> We mainly looked at working experience (e.g. function as a planner or route manager at a transport firm; logistics managers at shipping firms; and researchers involved in cost and price developments in freight transport or evaluations of transport policy).

- “Strong increase in congestion”: in this scenario, it is assumed that transport policy making purposefully limits extension of infrastructure capacity (financial shortage, push to limit freight transport). Due to that policy the infrastructure renewal program is assumed to be insufficiently effective in accommodating the growth in (freight) traffic demand, which leads to a strong increase in congestion on infrastructure networks.

These policy scenarios were chosen because governments can affect carrier costs -and hence rates- directly through taxation, whereas transit times and reliability of freight transport heavily but indirectly depend on the degree of congestion, which in turn can be affected through the level of investments in infrastructure<sup>4</sup>. An additional argument is that the scenarios chosen are plausible for all transport modes examined in this research, which enables some comparisons between the transport sectors (although tentatively given the observed heterogeneity of transport sectors). Finally, the scenarios describe plausible directions in which transport policy may develop; a full internalization of all costs of freight transport has been advocated for years, whereas the forecasted dramatic growth in (freight) transport has not induced large-scale investments in new infrastructure (yet). However, taxation and congestion are factors that to some extent occur in both scenarios. The two scenarios therefore assumed a *substantial* increase in either taxation or congestion.

### 3.5 Questionnaire

The questionnaire consisted of two parts. The first part contained a number of propositions concerning possible developments in the behavior of freight carriers that may affect rates, transit times, and reliability. Examples include the use of route planning systems and co-operation between transport companies. Some propositions are not realistic in the present situation, but were included in order to prevent experts to reason exclusively from existing paradigms. Propositions on the possible developments in the transport were derived from a literature review, professional literature, and policy documents (see Runhaar *et al.*, 2001, for more details). The propositions were largely identical to each of the six transport modes that were examined in the survey. The experts were asked to indicate the likelihood of each of the propositions in case of (a) scenario 1, in which ton-kilometer charges are introduced, (b) a strong increase in congestion, as described in scenario 2 and (c) in case none of these scenarios will occur: the autonomous scenario. An illustration of part of the questionnaire is given by figure 1.

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<sup>4</sup> Apart from that, congestion causes delays and hence affects carriers' costs (Van Schijndel and Dinwoodie, 2000: 235). This was incorporated in the scenario; see section 6.

[Partial research on road haulage]  <b>Question 1: Which developments until 2010 do you expect in container haulage from Rotterdam to Duisburg?</b>  <i>Possible developments:</i>	<b>No scenario</b> How likely do you consider these developments between now and 2010, if neither scenario eventuates?						<b>Scenario 2: Pricing sce</b> How likely (...)	
	Very likely	Likely	Unlikely	Very unlikely	Differs between firms	Do not know	Very likely	Likely
1. The use of trip and route planning systems will increase	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Carriers will acquire more return cargo	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
(...)								

Figure 1. Illustration of the first part of the questionnaire

The goal of the first part of the questionnaire was to explore the most likely changes in behavior of carriers affecting rates, transit times, and reliability, in each of the scenarios. This focus could in turn explain the estimations of developments in rates, transit times, and delivery reliability that were asked in the second part of the questionnaire. These estimations were asked against a base index value of 100 for early 2001; estimations of rates, transit times, and reliability performance in 2001 were included in the questionnaire. Carrier rates and transit times were expressed in indices, with intervals of 25 percent deviations from the base case (2001 = 100); reliability was expressed in three values, namely 'worse', 'equal', or 'better', compared to the situation in 2001. Using this two-fold approach, we tried to meet the criticism that Delphi surveys would give little insight into the respondent's reasoning. Moreover, although experts were given the opportunity to add propositions to the questionnaire, this was done only incidentally. Hence, we expect that the questionnaire addressed most relevant possible developments.

### 3.6 Response and number of response rounds

During the Spring of 2001, 186 surveys were sent to 130 experts; some experts received multiple surveys. 68 Experts responded by returning one or more questionnaires (52 percent of the experts; 47 percent of the number of questionnaires that were sent out). For more detailed information, see Table 4.

The Delphi survey consisted of six partial researches, one for each of the transport modes under study. In the surveys on road haulage, inland navigation, rail transport, and short sea shipping, a relatively high response rate was realized. Also, a relatively large number of experts were involved in these surveys, which makes the outcomes less sensitive to (deviant) opinions of individual experts. In contrast, the surveys on airfreight and deep sea shipping yielded a lower response. Hence, their results should be considered with more caution.

**Table 4. Response rates**

Partial research (by transport mode)	Questionnaires sent out	Response first round		Response second round	
		Percentage	N	Percentage	N
Road haulage	58	44.8%	26	31.0%	18
Inland navigation	41	46.3%	19	34.1%	14
Rail transport	33	57.6%	19	42.4%	14
Airfreight	15	46.7%	7	33.3%	5
Deep sea shipping	19	26.3%	5	21.1%	4
Short sea shipping	20	55.0%	11	30.0%	6
Total	186	46.8%	87	32.8%	61

After the first response round, group opinions were fed back by showing the scores for each of the questions in the questionnaire (in percentages), marked on a form similar to the original questionnaire. Experts were invited to reconsider in particular those questions that had not yielded a ‘sufficient’ degree of consensus, which due to a lack of unambiguous criteria in Delphi literature, was defined as follows:

- With respect to the propositions in the first part of the questionnaire, at least 60 percent of the experts considered a certain proposition likely or very likely, c.q. unlikely or very unlikely;
- With respect to the estimations of carrier rates, transit times, and delivery reliability, at least 50 percent of the experts have selected the same predefined interval.

Eventually, for all subsidiary surveys, two reaction rounds were held for three reasons. One, a relatively high degree of consensus was reached after these two rounds. Overall, consensus was attained for 69 percent regarding the propositions and 57 percent regarding the estimations of rates, transit times, and reliability. Two, 41 percent of the experts had not changed their original opinion in the second reaction round. Finally, the drop-out rate after the second reaction round was relatively high (see Table 4); hence a third round would most likely yield an incomplete view of changes in the degree of consensus and the ‘persistence’ of non-responding experts.

### 3.7 Analysis and interpretation of the Delphi results

In the analysis of experts’ estimations of prices and service levels of freight transport in all three scenarios, explanations were notably sought in the expected developments in behavior of carriers. In this way differences in behavior could be compared to changes in prices or service levels. Additional research (literature, interviews with carriers and interest groups) was conducted in order to find explanations for autonomous trends in freight prices and service levels.

## 4. Autonomous expectations regarding generalized transport costs

The first step consisted of an inventory of experts’ expectations regarding autonomous trends in carrier rates, transit times, and delivery reliability between 2001 and 2010. As the Figures 2

and 3 show, for all modes a real increase in rates is expected, which means a discontinuity in the trend over the past decades<sup>5,6</sup>. Yet, the expected rate increase is small, except for road haulage. For road haulage, airfreight, and deep sea shipping, the expected trends in rates more or less coincide with the results of a similar Delphi survey, conducted in 1999 (McKinnon and Forster, 2000). For inland navigation, rail transport, and short sea shipping, our results were not in line with the 1999 survey. This may have three causes. First, we focused on specific transport flows, whereas McKinnon and Forster focused on the transport modes in general. Second, between the two surveys, 1.5 years elapsed in which diesel prices rose considerably. Finally, McKinnon and Forster did not distinguish between inland navigation and short sea shipping.

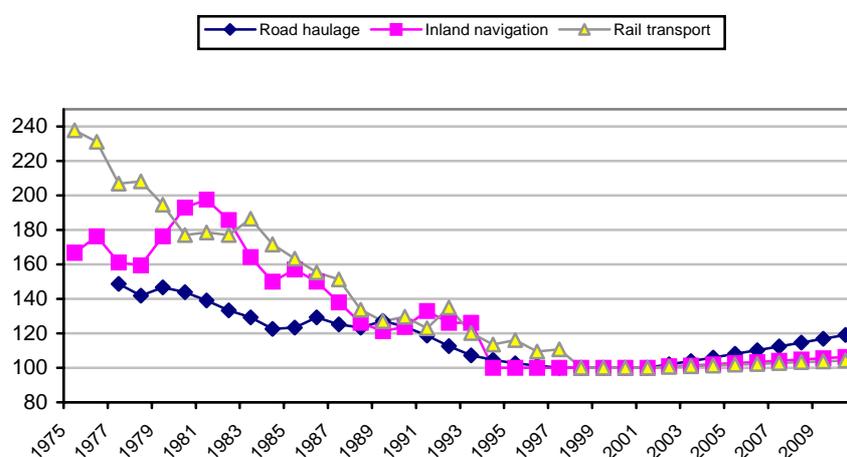


Figure 2. Historical and expected trends in freight rates (continental transport) in indices (2001 = 100). Please note: figures exclude short sea shipping, due to a lack of historical rate data.

Various causes underlie the expected real increase in carrier rates. From a literature review and interviews in the transport sector, it appeared that cost increases are likely to be caused by higher taxation. E.g. the Dutch kilometer charge for all road transport, the German kilometer charge for heavy freight vehicles, and the infrastructure levy in Dutch rail transport. But also rising wages and productivity losses due to increased congestion will contribute to cost increases. Yet, at the same time the Delphi participants expect that between 2001 and 2010,

<sup>5</sup> The historical data are derived from Dings, Janse, *et al.* (1999) who used data provided by specialized and often-consulted data sources. These sources include NEA (road haulage), Drewry Shipping Consultants and UNCTAD (deep sea shipping), AVMARK (airfreight), CBS (road haulage and inland navigation), as well as data provided by transport companies (i.e. European airlines and Railion). Data of rates between 1997/1998 and 2001 lacked. Yet despite the fact that in 2000, a large but merely temporal increase in fuel rates appeared, data of for instance TLN (2001: 95) on road haulage rates did not show a structural change in the development in carrier rates. Therefore, we assumed that no changes in rates occurred between 1997/1998-2001. The data between 2001 and 2010 originate from the Delphi survey, in which experts were asked to estimate real rates in 2010, expressed in indices (2001 = 100). Based on these estimations, we calculated compounded annual growth rates for the period between 2001 and 2010.

<sup>6</sup> Unfortunately, for short sea shipping historical data on rates lacked. Yet, there are no indications that in short sea shipping, rates would have shown an upward trend.

carriers will improve productivity, for instance by an increased use of planning systems and advanced information technology, reduced fuel consumption, and by increased efforts to acquire return cargo.

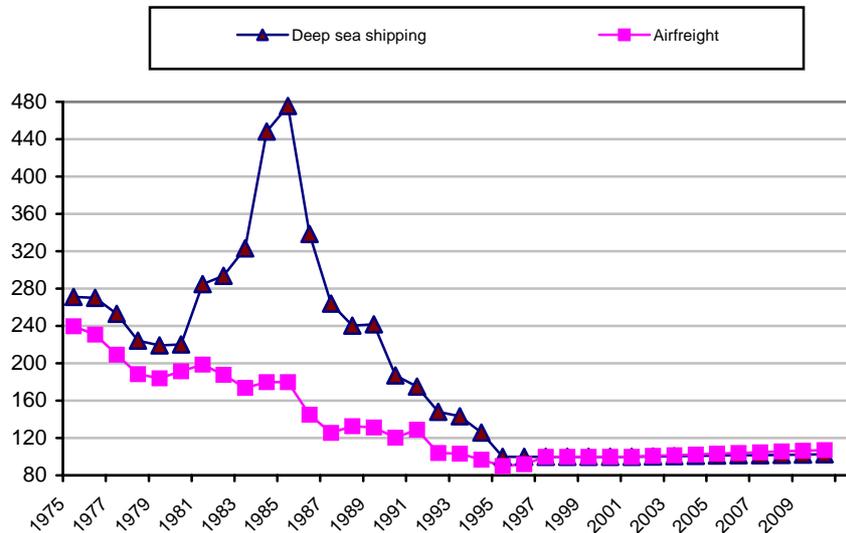


Figure 3. Historical and expected trends in freight rates (intercontinental transport) in indices (2001 = 100)

Regarding transit times, for all modes of transportation with the exception of road haulage, a reduction is expected between now and 2010. For road transport, this is contrary to the trend from the 1970s onwards (MuConsult, 2001: 54). The reliability of freight transport, expressed in the number of overdue arrivals, is expected to remain the same or even improve, except for airfreight and road haulage (see Table 5). Apparently, for the latter modes an increased congestion is foreseen.

**Table 5. Average expectations regarding transit times and reliability in 2010, compared to 2001**

	Road haulage	Inland navigation	Rail transport	Airfreight	Deep sea shipping	Short sea shipping
Transit time	+ 9.6%	- 6.9%	- 4.8%	- 4.2%	- 7.5%	- 1.25%
Delivery reliability	Same/worse	Better/same	Better	Same/worse	Same/better	Better/ same

Concluding, the respondents expect that road transport will face most difficulties in the near future, resulting in higher rates, longer transit times, and possibly a reduced delivery reliability. This may deteriorate its competitive position vis-à-vis intermodal transport.

## 5. Expected effects of the “fair and efficient pricing” scenario

### 5.1 The scenario

The inventory of autonomous expectations of the Delphi participants regarding generalized transport costs mainly served as a base case to assess the effects of policy interventions on future generalized transport costs. In the first policy scenario that was examined, it was assumed that within European Union, full social cost pricing becomes policy as from the end of 2001. Hence, all external costs of freight transport are passed on to carriers, including the cost of infrastructure maintenance, traffic control, emissions, and traffic fatalities and injuries. Passenger transport was assumed not to be levied for the moment. The external social costs are assumed to be passed on as an extra charge per ton-kilometer, imposed on all transport companies that carry freight to, from, or within the EU<sup>7</sup>. Table 6 shows the initial levies in €-cents per ton-kilometer, both absolute and relative to current revenues per ton-kilometer.

**Table 6. Charges in scenario 1 and current revenues in €-cent per ton-kilometer<sup>8</sup>**

	Road haulage (*)	Inland navigation (*)	Rail transport (*)	Airfreight (*)	Deep sea (**)	Short sea (**)
Charge/tonkm	5.54 ct.	2 ct.	2.43 ct.	5.94 ct.	0.67 ct.	0.671 ct.
Current rev/tonkm	18.02 ct.	3.58 ct.	3.27 ct.	21.15 ct.	0.91 ct.	0.91 ct.
Charge as % of revenue	30.7%	55.9%	74.3%	28.1%	73.6%	73.6%

Sources: External costs: (\*): Dings, Janse, *et al.*, 1999; (\*\*): T&E, 1993.

Current revenues are average rates early 2001 and include loading and discharge. Data were collected from anonymous carriers, shipowners, forwarders, and interest groups in behalf of transport operators. Average load of containers: Deelen *et al.*, 1999.

### 5.2 Hypothesized effects, based on the literature

Due to the ton-kilometer charge, unit costs per ton and per ton-kilometer will be significantly raised. We hypothesized that carriers might respond to this in two ways. First, they may try to raise load factors by a higher level of consolidation of less-than-truck or -container loads or by a more active acquisition of return cargoes. Although the ton-kilometer charge will remain the same irrespective of the raise of the load factor, a higher load factor may enable carriers to spread operating costs (e.g. writing-off, fuel, and administrative costs) over a larger volume of cargo, thus lowering operational unit costs (cf. Johnson and Wood, 1996: 461). In this way,

<sup>7</sup> There might be practical difficulties in measuring ton-kilometers. For modes such as rail transport and inland navigation, measurement could take place at transshipment terminals that are often used. In road haulage however much freight is loaded and discharged at a wide variety of locations. An alternative however could be use of measurement systems in road surfaces that are for instance currently used in the Netherlands in order to reduce over-loading.

<sup>8</sup> The external cost data for sea shipping are based on T&E (1993). These data are not completely representative, since they are based on ro-ro vessels. More specific data however lacked. Apart from that, the data are to some extent outdated; yet, we assumed that social cost reductions which may have occurred (e.g. due to lower emissions) have been compensated by opposite effects (e.g. inflation since 1993).

carriers may succeed in limiting the cost increase caused by the ton-kilometer charge. Secondly, carriers may try to offset part of the initial cost increase by economizing on other costs, e.g. fuel use. Due to the competitive environments in which most carriers operate, it is not likely that shippers will accept a simple raise in rates without compensatory measures undertaken by carriers.

### 5.3 Delphi results

In order to assess the extent to which carriers can offset the initial cost increase, we employed the following method. First current revenues per ton-kilometer were raised with the ton-kilometer charge that was assumed to be introduced by the end of 2001, which indicates the initial impact of the ton-kilometer charge. This figure however can not be compared with the expected rates in 2010 in scenario 1 for an assessment of the eventual price effect of the ton-kilometer charge (and by that, the absorptive capacity of carriers). The reason is that 2010 rates are also affected by factors that are partly exogenous of the scenario: they are considered as autonomous developments. For instance for road haulage an autonomous price increase of nearly 20 percent was expected. This is caused by increased congestion, growing fuel scarcity on the global market as well as by increased taxation, perhaps in part based on the idea of “fair and efficient pricing” (see section 4). Therefore there might be some overlap in both scenarios. Nevertheless rate increases in case of the ton-kilometer charge would be much higher than in the autonomous scenario, indicating certainly no *complete* overlap. Since we could not assess the exact size of the overlap, we compared the initial price effect of the ton-kilometer charge with the price effect in 2010 *on top of* autonomous price increases (see figure 4). In this way we assessed the absorptive capacity of carriers, although due to the scenario overlap the initial price increase in scenario 1 and hence absorptive capacity might be overestimated.

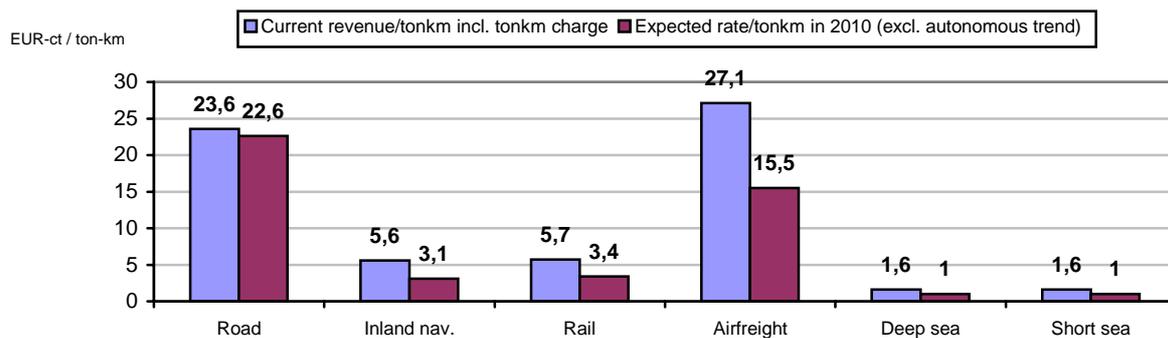


Figure 4. Comparison between freight rates in 2001, including ton-kilometer charge, and expected freight rates in 2010

Road carriers are expected to absorb about one quarter of the ton-kilometer charge; the rest will be passed on to shippers or will lead to lower profits of carriers (which is another type of absorption<sup>9</sup>)<sup>10</sup>. The other transport sectors are expected to absorb a larger share of the charge;

<sup>9</sup> Given the low margins in transport however the scope for the latter type of absorption is not considered large.

hence their rates will be raised less. Apart from the relatively high ton-kilometer charge that is assumed to be imposed on road transport, will the competitive position of road transport in this scenario also be deteriorated by the relatively low absorptive capacity. In inland navigation and airfreight, carriers were expected to adapt operations in such a way that cost savings will even *exceed* the initial cost increase due to the ton-kilometer charge<sup>11</sup>. Apparently experts expect the ton-kilometer charge to act as a catalyst for new investments or another organization of transport operations that will raise overall efficiency in these modes. The ways in which the ton-kilometer charge is expected to be absorbed differs per transport sector. The ton-kilometer charge will reinforce the autonomously expected increased acquisition of return cargo, except in the case of short sea shipping. Currently, however, usually low rates exist for return cargo. Therefore, carriers often do not wait for return cargo but turn back to deliver the next shipment (Voordijk *et al.*, 1999: 129). Raising load factors by cargo exchange between carriers is considered likely in inland navigation, rail transport, airfreight, and in short sea shipping. Additionally, in all waterborne transport a reduction in fuel use by slowing sailing speed is expected (without affecting reliability of arrivals). The Delphi panel was not asked about the reasons for the expected reduction in fuel use but possible explanations are: (a) since the ton-kilometer charge would be related to emissions a reduction in emissions might lead to lower surcharges; (b) the cost increase would in part be compensated by cost reductions elsewhere (i.e. fuel costs). The latter strategy might in particular be effective in deep sea container shipping because of a high share of fuel costs in total costs (De Wit and Van Gent, 1996: 269; Prince, 2001: 63-67). The expected reduction in average sailing speed indicates that the experts expect that shippers using waterborne transport will be more sensitive to transport costs than to transit times, similar to what was found in other studies (e.g. HCG (1992) for inland navigation). A scaling-up of average firm size due to the ton-kilometer charge is expected in rail transport and all sea borne transport. Adaptations in transport equipment, such as vessels or trucks, are expected in all sectors except for road haulage and deep sea container shipping. Finally, it is expected that road carriers, airlines, and deep sea container carriers will more often refuse small or unprofitable shipments. In conclusion, the logistical organization of carriers is expected to be quite flexible to adapt to the new cost conditions.

In waterborne transport, transit times are expected to increase as compared to the autonomous scenario, which is mainly explained by the above-mentioned efforts to reduce fuel use by slowing sailing speed. Regarding the other modes, transit times are expected not to change or only marginally as compared to the autonomous scenario. A positive effect of the ton-kilometer charge on reliability is expected in road haulage, rail transport, and aviation. In road transport, this may be explained by improvements in truck capacity utilization and a better spread of freight traffic over networks and in time. In rail transport and airfreight, however, congestion is notably caused by increasing passenger traffic; hence, the above explanation will probably not apply. An alternative explanation is that air and rail carriers will try to compensate for the higher transport costs by an improved quality of service. In inland navigation and deep sea container shipping, the ton-kilometer charge is expected to affect

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<sup>10</sup>It is not likely that part of the absorptive capacity of *rail* transport will in fact be caused by subsidies because of two reasons: (a) this was not mentioned by experts (although they had the opportunity to add propositions); (b) it would be contrary to the scenario.

<sup>11</sup>For this purpose, compare the ton-kilometer charge (in €-cents) from Table 6 with the differences between the two bars in figure 4 (also in €-cents).

reliability negatively. In inland navigation, this may be explained by increased efforts to improve load factors. In deep sea shipping, an explanation may be that in contrast to the autonomous scenario, it is expected that carriers will not call at other ports; apparently, the experts expect that in the current ports of call, congestion will increase in future. Finally, no changes in reliability are expected in short sea shipping. This may be explained that in the transport flow under study (i.e. wood and forest product transport from Sweden to the Netherlands), arrival dates are known only a few days before actual arrival.

## **6. Expected effects of the “strong increase in congestion” scenario**

### **6.1 The scenario**

The second policy scenario that was examined, assumed that investments in new infrastructure or in better infrastructure capacity management, will not be sufficient to accommodate the expected growth in (freight) transport. Consequently, between 2001 and 2010 congestion will increase. It should be noted however that the nature of congestion varies for each mode of transportation. For instance, queuing is only to a limited extent possible for rail transport and airfreight, in contrast to the other modes. This is mainly caused by the relatively rigid infrastructure capacity allocation systems employed in these transport sectors. Once ‘slots’ are deployed, queuing in order to wait for new slots on the rail, in the air, or at nodes, is only possible to a limited extent. Although delays often occur, both in rail transport and in airfreight, it appeared that the experts consider scenarios in which transit times initially increase by ten percent or more due to congestion, too unrealistic. Hence, the congestion scenario was disregarded for rail transport, whereas an adapted scenario was constructed for airfreight<sup>12</sup>. For the remaining transport modes, the scenario described a substantial increase in congestion by the end of 2001. Even for these modes, the nature of congestion differs. In road transport, congestion is assumed to occur on transport links, whereas in the other modes congestion is notably assumed to exist in ports and terminals<sup>13</sup>. The questionnaires contained quantitative indications of the assumed increases in transit times, which were considered plausible in case carriers would not adapt their operations.

### **6.2 Hypothesized effects, based on the literature**

The congestion scenario initially leads to longer transit times and reduced delivery reliability, but also to higher costs due to productivity losses (e.g. expressed in the number of addresses a truck can visit during a round trip). This may provoke various responses, which probably will depend on the shippers’ demands. Often shippers make a choice for road transport, in

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<sup>12</sup>In the partial survey on airfreight, it is assumed that demand for airport slots could be 25 percent higher if sufficient slots would be available.

<sup>13</sup>These scenario differences are caused by the fact that only plausible causes of future congestion on the examined transport flows were taken into consideration. For instance, in the partial research on inland navigation, internal, confidential studies conducted by the Dutch Ministry of Transport showed that even if inland shipping would increase dramatically, no substantial delays in Rhine shipping were to be expected. In contrast, delays already often occur in the Rotterdam harbor, and more delays due to higher traffic intensity are not imaginary.

particular because of the high level of reliability. Therefore, it is expected that carriers will try to reduce as much as possible the negative effects of congestion on this service quality indicator, even if this leads to higher rates. In contrast, in short sea shipping, usually relatively low-valued bulk is transported, which is more sensitive to transport costs than to changes in transit times or delivery reliability. In that sector, operating costs and lead times are to a large extent related since manning costs, making up some 30 percent of total costs, vary with sailing time. Hence, in short sea efforts are expected that aim at reducing costs and lead times, rather than measures to maintain a reliable arrival.

### 6.3 Delphi results

In order to assess the absorptive capacity of carriers regarding delays, the same method was employed as in the previous section. As Figure 5 shows, the respondents expect that the extent to which the initial delays affect transit times in 2010 varies significantly between the modes. Remarkably, for inland navigation a disproportional increase in transit times is expected. This is only in part explained by the fact that in the transport flow in inland navigation under study (i.e. container shipping from Rotterdam to Mannheim) multiple ports are visited; in short sea shipping this is also the case. The experts did not explain the reasons of the disproportional increase in transit times. It might be speculated that the planning of terminal operators that are called at by inland shipowners is less flexible than de planning of terminal operators visited by short sea shipowners (e.g. due to relatively small capacity for transshipment). Another possible explanation could be that short sea carriers have more options to cope with delays in ports by increasing average speed. The panel namely expected that in this scenario fuel use would decrease at a lower rate than in the autonomous scenario. Apart from that the transport flow in short sea transport involved a much larger distance than the flow in inland navigation (i.e. an average of 1,800 kilometer versus 590 kilometer), which obviously offers more opportunities to cope with delays in ports. Another remarkable result is that for all modes of transportation, a deterioration in reliability is expected, despite the increasing importance shippers attach to this transport quality (e.g. Muilerman, 2001: 156; Stank and Goldsby, 2000: 72-73). Finally, for all modes of transportation it is expected that carrier rates will increase more than in the autonomous scenario. Main reasons include lower productivity due to congestion, the efforts that have to be made to reduce the negative effects of congestion (such as more efficient logistics planning or the use of advanced information technology), and higher prices for infrastructure capacity.

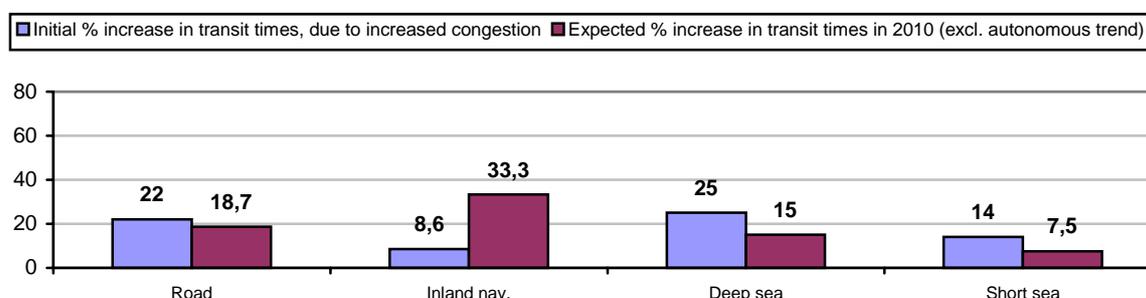


Figure 5. Comparison of assumed delay due to the congestion scenario and expected delay in transit times in 2010

Similar to the ton-kilometer charge scenario, different responses of transport companies are expected. The strong increase in congestion will provide an additional stimulus to carriers in road haulage, inland navigation, and short sea shipping to intensify the use of planning systems, whereas more in advance planning of departures with shippers is considered likely in all modes except for airfreight. The use of larger transport means is expected in all sectors but inland navigation. Changes in departure times, including more overnight transport, are only expected in road haulage, short sea shipping, and deep sea shipping. In the other modes, flexibility in scheduling apparently is low. This is partly explained by the rigid infrastructure allocation systems in air transport, and partly by the fact that inland shipowners depend on arrivals of deep sea container vessels as well as on terminal operators. In short sea shipping, and road haulage, load factors may be raised due to intensified cargo exchange between carriers. This enables the expected use of larger transport means in these sectors. In deep sea shipping it is expected that shipowners will more often postpone departure until a higher load factor or more return cargo is acquired. Consequently, fewer sailings may be necessary to carry a given amount of cargo. Finally, in road haulage it is expected that carriers may avoid part of the delays by adapting route choice, whereas in airfreight, deep sea shipping, and in short sea shipping, other (air)ports will be called at.

Operators of sea transport prove to possess the largest absorptive capacity, which can be explained by the fact that “maritime transportation (...) has a very flexible network structure, *including* the nodes (ports)” (Rodrigue *et al.*, 1997: 88). Ports are no fixed and obligatory points of transshipment, in particular in case of competition between ports. Consequently, deep sea and short sea carriers have the choice of using several different infrastructures in an efficient manner. In other modes of transportation, infrastructure networks can be used in a less flexible way.

Unfortunately, few studies are available that addressed similar questions and hence could have been used as a benchmark for our study. An exception however is the survey by Van Schijndel and Dinwoodie (2000), addressing how effective carriers and shippers, located in the Netherlands, consider particular measures to deal with congestion. Attractive responsive measures included more overnight driving, the use of larger trucks, and less frequent deliveries (e.g. by postponing departure) (Van Schijndel and Dinwoodie, 2000: 237). These results coincide with our findings, although in our survey the variety of options is larger (including e.g. more cargo exchange between carriers).

## 7. Conclusions and discussion

The purpose of this article was to explore how and to what extent freight carriers can be expected to absorb the effects of policy interventions that initially have a negative effect on transport service performance in these sectors, expressed in rates, transit times, and delivery reliability. Shippers were excluded from the analysis. A prospective approach was applied allowing for an *ex ante* evaluation of two possible future transport policy scenarios. In the first scenario all external social costs produced by freight transport are passed on to freight carriers by means of a ton-kilometer charge. In the second scenario investments in infrastructure will not meet the expected future increase in demand for infrastructure capacity. The analysis is based on experts' expectations, which are collected by means of a Delphi survey. Per mode of transportation, the focus was on a particular transport flow since

transport modes often serve very distinct market segments. As a consequence the conclusions are only indicative of transport modes in a more general sense.

The expected effects of the two policy scenarios on future carrier rates, transit times, and delivery reliability were assessed by comparing them with the autonomously expected trends up to 2010. Most experts envisage that real rates will slightly increase, which will mean a discontinuation of the historical, downward trend in rates. For road transport, however, a relatively high rate increase of almost 20 percent is expected. Regarding transit times, for all modes of transportation with the exception of road haulage, a reduction is expected between now and 2010. The reliability of freight transport, expressed in the number of overdue arrivals, is expected to remain the same or even improve, except for airfreight and road haulage. Apparently, the latter modes will face increased congestion.

The expectations of the Delphi participants regarding the effects of the two policy scenarios that were examined, indicate that the absorptive capacity of road haulage is the lowest. Hence, if the scenarios become true, road transport will face a deterioration of its competitive position vis-à-vis rail transport, inland navigation, and short sea shipping. Moreover, this effect is on top of the autonomously expected relatively strong reduction in attractiveness of road transport due to higher rates, longer transit times, and possibly a lower level of delivery reliability. In particular for long distance transport this is an effect that corresponds with goals in transport policy aiming at realizing a modal shift towards collective means of transport where possible. Internalization of external costs therefore will not endanger the competitive position of alternative modes to road transport. For short distance transport, where road transport is by far the most preferred mode of transportation, the scenarios might ultimately have an impact on the prices of goods and services for the end consumer.

The research encompassed a time period of nearly 10 years. A longer time horizon could have revealed a larger absorptive capacity of the freight transport sector in the context of the two policy scenarios. In addition, a longer time horizon could have revealed other responses of carriers. Most responses that the participants of our research envisaged, are short-term actions, e.g. the acquisition of more return cargo. Only a few long-term responses were mentioned, such as expected changes in vehicle size, which imply substantial investments in fleet renewal, and changes in average firm size. In a time horizon of more than 10 years, increased congestion may for instance accelerate the development of underground logistical systems. However, we believed that in our research design, assuming a longer time horizon would have raised the complexity of the questionnaire, and subsequently might have led to less reliable outcomes. To study longer time horizons, the research design should be more exploratory, e.g. use open answers instead of closed answers as we did.

The applied Delphi technique potentially suffers from a number of methodological shortcomings. In the survey set-up, we explicitly gave attention to these pitfalls (see section 3). A number of issues however deserve more discussion. One, no complete consensus (as predefined by us) was achieved. Yet, we decided to stop after the second reaction round since non-response would otherwise give a biased picture (and lead to complete consensus, neither). Two, it appears that the answers given vary with the experts' professional background. The direction of this deviation is not unambiguous, however (see Table 7). Hence, we have not been able to correct the Delphi results for this type of bias.

**Table 7. Differences in experts' expectations regarding the impact of the two policy scenarios on rates, according to professional background**

	Road haulage	Inland navigation	Rail transport	Airfreight	Deep sea shipping	Short sea shipping
<b>Transport sector:</b>						
- Scenario 1	+	--	≈	-	+	++
- Scenario 2	+	--	n.a.	-	-	++
<b>Shippers:</b>						
- Scenario 1	-	--	≈	n.a.	n.a.	n.a.
- Scenario 2	-	+	n.a.	n.a.	n.a.	n.a.
<b>Other:</b>						
- Scenario 1	-	++	≈	+	-	--
- Scenario 2	-	+	n.a.	+	+	--

Note: + : higher rate increase expected;  
 - : lower rate increase expected;  
 ≈ : almost equal increases expected;  
 ++ : substantially higher rate increase expected;  
 -- : substantially lower rate increase expected;  
 n.a.: no data, either because the scenario does not apply or because no such experts had responded.

Three, we focused on one important transport flow per mode of transportation. Additional research is required to test whether the outcomes are generic for other transport flows. In this context, we believe that using the same methodology and questionnaire for other transport flows will notably yield different outcomes vis-à-vis the level of absorptive capacity of carriers. The extent to which for instance delays in loading in ports can be compensated by a higher sailing or driving speed will probably be related to transport distances. However it is plausible that the identified responses of carriers to the scenarios are more generic. The questionnaire namely included very general adaptations that were found in the literature (e.g. increased use of route planning systems); they are probably not specific to the transport flows examined. Four, in order to reduce complexity and to maintain a level of comparison of the responses, we assumed a fixed load unit and disregarded load characteristics, such as value density<sup>14</sup>. Yet, we recognize that these characteristics may be of influence on future developments in generalized transport costs, as well as on the effects of the two scenarios. Five, the Delphi results reflect estimations by a broad pool of experts, which provide an overall sense of the magnitude of the absorptive capacity of freight transport operators, rather than absolute predictions. For more precise estimations of carriers' responses to policy scenarios or the impact on rates, transit times, and reliability, additional research is requested. One way to perform such research is to apply stated preference techniques to reveal logistics decision making patterns (see e.g. Muilerman, 2001). Such research might alternatively be based on an analysis of the past, hence suffering less from uncertainties that exist in

<sup>14</sup>For instance, containers usually contain a large variety of cargo, the value of which may differ heavily. In the US, for instance, the average value of cargo in the category of "non-metallic materials" in 1993 averaged about \$ 11 per ton, whereas "apparel" averaged \$ 19,249 per ton (Forkenbrock, 2001: 322). Obviously, a shipper of the first type of cargo will be much more sensitive to a change in carrier rates than a shipper of the latter category of cargo, which may also affect the carriers responses to for instance a ton-kilometer charge.

prospective research such as ours. On the other hand, one has to recognize that in open systems, such as the transport system, uncertainty will exist as “the system cannot be fully controlled but is subject to impacts of many factors. Therefore it is difficult to predict which developments in these systems are likely in the future” (Ubbels *et al.*, 2001: 11). The differences in expectations in autonomous trends in carrier rates between our study and similar studies that are held a few years ago, may stem from unforeseen developments, such as the fuel crisis in 2000. At the same time, the validity of our results may have been reduced by for instance the consequences of the terrorist attacks on 11 September 2001. Although part of the uncertainty can be coped with in scenarios, uncertainties remain with respect to the behavior of carriers. Yet, we believe that in prospective studies such as the one upon which this article is based, the methodological choices made yield valuable contributions to the improvement of our knowledge.

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## References

- AVV (2000) *Jaarrapport goederenvervoer, editie 1999 (Freight transport statistics; in Dutch)*. Adviesdienst Verkeer en Vervoer (Transport Research Center), Rotterdam.
- Beuthe, M., Jourquin, B. Geerts, J.-F. and Koul à Ndjang' Ha, C. (2001) Freight transportation demand elasticities: a geographic multimodal transportation network analysis. *Transportation Research Part E*, **37**, 253-266.
- Bowersox, D.J., Closs, D.J., and Helferich, O.K. (1986) *Logistical management. A systems integration of physical distribution, manufacturing support, and materials procurement* (third ed.). McMillan, New York.
- Cooper, J., Browne, M. and Peters, M. (1994) Will transport prices fall? *European logistics. Markets, management and strategy* (second ed.) eds J. Cooper, M. Browne and M. Peters, Blackwell, Oxford, pp. 251-291.
- Daniëls, J.J.M.C. and G. Duijzer eds (1988) *Delphi: methode of mode? (Delphi: method or hype?, in Dutch)*, Amsterdam: SISWO.
- Deelen, C, Dekker, T., and Snijders, R. (1999) *Integrale verkenningen voor haven en industrie. Werkdocument verkeer en Vervoer (Internal document; in Dutch)*. Gemeentelijk havenbedrijf Rotterdam (Rotterdam Port Authority), Rotterdam.
- Dings, J.M.W., Leurs, B.A. Blom, M.J., Bückmann, E.H., Bus, L.M., Haselen H.W.J. van and Rienstra, S.A. (1999) *Prijselasticiteiten in het goederenwegvervoer (Price elasticities in road freight; in Dutch)*, NEI/CE, Rotterdam/Delft.

- Dings, J.M.W., Janse, P., Leurs, B.A. and Davidson, M.D. (1999) *Efficiënte prijzen voor het verkeer (Efficient prices in transport; in Dutch)*, CE, Delft.
- EC (1998) *Fair Payment for infrastructure: a phased approach to a common transport infrastructure charging framework for the EU*, European Commission, Office for Official Publications of the European Communities, Luxembourg, Belgium.
- EC (2001) *European transport policy for 2010: time to decide*, European Commission, Office for Official Publications of the European Communities, Luxembourg, Luxembourg.
- Forkenbrock, D.J. (2001) Comparison of external costs of rail and truck freight transportation. *Transportation Research Part A*, **35**, 321-337.
- Geurs, K.T. and Wee, G.P. van (1997) *Effecten van prijsbeleid op verkeer en vervoer (Effects of taxation in transport; in Dutch)*, RIVM, Bilthoven.
- Gordon, Th.J. (1994) The Delphi method *Futures research methodology* ed J.C. Glenn, American Council for United Nations University, Washington.
- Goss, R. (1991) The application of the concept of generalised transport costs to freight. *Proceedings of the European transport colloquium*, ed. H.G. Smith, Delft: European Transport Colloquium Foundation, Delft, pp. 179-186.
- Groothedde, B. and Haselen, H.W.J. van (1998) *Strategisch model integrale logistiek en evaluatie (Transport and logistics model; in Dutch)*. TNO Inro, Delft.
- Gruppo CLAS (1998) *The fundamental variables which affect decisions concerning intermodal transport*, LOGIQ project, European Commission, Brussels.
- HCG (1992) *De reistijdwaardering in het goederenvervoer. Rapport hoofdonderzoek (Travel time valuation; in Dutch)*. Hague Consulting Group, The Hague.
- Hensher, D.A. and Brever, A.M. (2001) *Transport. An economics and management perspective*. Oxford University Press, Oxford.
- Johnson, J.C. and Wood, D.F. (1996) *Contemporary logistics* (sixth ed.). Prentice Hall, Upper Saddle River.
- Kågeson, P. and Dings, J. (1999) *Electronic kilometer charging for heavy goods vehicles in Europe*. European Federation for Transport and Environment, Brussels.
- Klapwijk, P. (1996) *Global economics networks*. Klapwijk Holding, Universiteit van Amsterdam (University of Amsterdam), Amsterdam.
- Korver, W. and Mulders, G. (1992) *Gedragsveranderingen bij bedrijven als gevolg van reistijdvertragingen op het wegennet. Deel 1: het goederenvervoer (Responses of shippers to congestion; in Dutch)*. TNO Inro, Delft.
- Marchau, V.A.W.J. and Heijden, R.E.C.M. van der (1998) Policy aspects of driver support systems implementation: results of an international Delphi study, *Transport Policy*, **5**, 249-258.
- Marchau, V.A.W.J. (2000) *Technology assessment of automated vehicle guidance. Prospects for automated driving implementation*. Ph.D. Thesis, Delft University Press, Delft.

- McKinnon, A. and Forster, M. (2000) *European logistical and supply chain trends: 1999-2005. Full report of the Delphi 2005 Survey*. Heriot-Watt University, Edinburgh.
- McKinnon, A.C. and Woodburn, A. (1996) Logistical restructuring and road traffic freight, an empirical assessment. *Transportation*, **23**, 141-161.
- MuConsult (2001) *De remmen los. Historische ontwikkeling van de prijs/prestatieverhouding in het vervoer (Historical development in price and quality of transport; in Dutch)*. MuConsult, Amersfoort.
- Muillerman, G.J. (2001) *Time-based logistics, an analysis of the relevance, causes and impacts*. Ph.D. Thesis, TRAIL/Delft University Press, Delft.
- NEI/NEA (1990) *Vervoerwijzekeuze in het goederenvervoer (Modal choice in freight transport; in Dutch)*. NEI/NEA, Rotterdam/Rijswijk.
- Oum, T.H., Waters II, W.G. and Yong, J.S. (1990) *A Survey of Recent Estimates of Price Elasticities of Demand for Transport*, World Bank, Washington.
- Prince, Th. (2001) Easy as ABC. *Containerisation International*, March 2001, pp. 63-67.
- Rodrigue, J.-P., Comtois, C., and Slack, B. (1997) Transportation and spatial cycles: evidence from maritime systems. *Journal of Transport Geography*, **2**, 87-98.
- Runhaar, H.A.C., Kuipers, B., Heijden, R.E.C.M. van der and Melody, W.H. (2001) *Freight transport in 2010. An exploration of future prices and quality of freight transport in three scenarios*. TRAIL Research School, Delft (also available from <http://www.tbm.tudelft.nl/webstaf/hensr/>).
- Schijndel, W.-J. van and Dinwoodie, J. (2000) Congestion and multimodal transport: a survey of cargo transport operators in the Netherlands. *Transport Policy*, **7**, 231-241.
- Stank, T.P. and Goldsby, T.J. (2000) A framework for transportation decision making in an integrated supply chain. *Supply Chain Management: An International Journal*, **2**, 71-77.
- Tavasszy, L.A. (1996) *Modelling European Freight Transport Flows*, Ph.D. Thesis, Delft University of Technology, Delft.
- T&E (1993) *De juiste prijs voor het verkeer* (Summary of the European study 'Getting the prices right' of P. Kågeson, 1993 and results for the Netherlands; in Dutch). European Federation for Transport and Environment, Brussels.
- TLN (2001) *Transport in cijfers. Editie 2001 (Transport statistics; in Dutch)*. Transport en Logistiek Nederland, Zoetermeer.
- Ubbels, B., Rodenburg, C., and Nijkamp, P. (2001) Different perspectives on the global development of transport. *European Journal of Transport and Infrastructure Research*, **1**, 9-28.
- Voordijk, H., Vieveen, A., and Bus, L. (1999) Logistiek en de groei van het wegvervoer van bouwmaterialen (Logistical trends in the construction industry and growth in road freight; in Dutch). *Tijdschrift Vervoerswetenschap*, **2**, 113-134.
- Wit, J. de and Gent, H. van (1996) *Economie en transport (Transport economics; in Dutch)*. Lemma, Utrecht.