European Transport \ Trasporti Europei n. 44 (2010): 57-75

Rail investment and port competition: a case study for the Betuweroute

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Abstract

This paper presents a study on the impact of investment in the Betuweroute and alternative transport pricing schemes on port competition between Rotterdam, Hamburg and Antwerp. The Betuweroute is a 160 kilometre dedicated freight railway line connecting the port of Rotterdam with the German Ruhr area. If the line could, in the near or more remote future, attract a large share of transit freight, it will be of considerable importance for the competitive position of the port of Rotterdam relative to Hamburg and Antwerp. We use a transport network model that includes the three ports and allows for transport by road, rail and inland waterways to and from the Ruhr area. We run model simulations for scenario's with and without the Betuweroute and with and without marginal social cost pricing. The results show that, although the Betuweroute is a welfare reducing investment, it may indeed be of crucial importance to the port of Rotterdam.

Keywords: Transport pricing; Rail investment; Betuweroute; Port competition.

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1. Introduction

In the past, ports were fairly insulated from competitive forces, each port serving its own, more or less captive hinterland (Haralambides, 2002). Trade barriers, national borders and inadequate hinterland infrastructure were mainly responsible for this situation. Nowadays, European ports are facing major external challenges, including the grouping of container shipping lines into powerful consortia, resulting in downward pressure on prices, increased efficiency levels in maritime transport and the importance of logistical chains (Farrell, 1999). These developments, in combination with trade liberalisation associated with the emergence of a single internal EU market and technological changes, have had a considerable impact on trade flows and hence on the port industry. The result is a competitive market situation in which hinterlands are no longer captives of the port with which they have the best connection. The mobility of

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the transhipment container, together with intertwined land transport networks have simultaneously extended the hinterlands of all ports and intensified competition among these ports (Haralambides, 2002). Today, it makes little difference if a container from Asia destined for Duisburg will pass through the port of Hamburg, Rotterdam or Antwerp.

Competition concentrates on the extensive port-based logistic chains that developed in close relationship with the containerisation (Meersman et al., 2002). It is important for ports to belong to a successful logistic chain of a particular freight flow and for this purpose efficiency and other characteristics of the ports themselves are important, but also the connections with the hinterland. An adequate transport infrastructure, which should not be limited to a single mode, is an important element in any attempt to retain or increase market share.

The Betuweroute is such a potentially important transport axis. It is a 160 kilometre dedicated freight railway line connecting the port of Rotterdam with the German hinterland. This project is interesting since political decision making and calculations on its profitability were based on questionable assumptions (see Section 2). The construction of the Betuweroute was motivated by two main reasons (TCI, 2004 and Algemene Rekenkamer, 2000). The first reason for construction was to consolidate the (economic) position of the port of Rotterdam as one of Europe's key transport and distribution hubs (employment) and to facilitate the expected growth in freight traffic in the Netherlands. The second reason was environmental in nature; rail is considered as a relatively environmental friendly mode of transport and the Betuweroute was expected to be a realistic substitute for road transport. In this paper we use a transport network model to assess whether construction of the Betuweroute indeed contributes to these two goals.

The remainder of this paper is organised as follows. Section 2 discusses some ex-ante assessments of the Betuweroute. In Section 3 we present the transport model and transport network used for our analyses, while Section 4 discusses the modelling scenarios and the inputs of the model. In Section 5 we present the simulation results. Section 6 concludes.

2. Ex-ante assessments of the Betuweroute

The Betuweroute project comprises an upgrade of the existing Rotterdam Port Railway, which runs from the Europoort at Maasvlakte via the Waalhaven container rail service centre to the Kijfhoek shunting yard, and constructing of a new double-track line that parallels the A15 motorway to the German border near Emmerich. It links the port of Rotterdam to the existing German rail network at the Dutch/German border. The government decision to build the Betuweroute was taken in 1994 and was ratified by a committee and parliament in 1995. Work to upgrade the port railway started in 1997. Construction of embankments, tunnels and bridges for the A15 line began in 1998. The Betuweroute is the first double-track railway line in the Netherlands dedicated to freight transport. It was completed in July 2007. Total costs amount about 4.7 billion Euro according to recent estimates. The 25-tonne axle load Betuweroute will have a capacity of 10 trains per hour in each direction. Top speed will be 120 km/h and trains are expected to take between one-and-a-half and two hours to travel the 160 kilometres from Rotterdam to the German border.

The completion of the Betuweroute ends a period of about 25 years of planning, research, construction and last, but certainly not least, discussion. The railway line has been very controversial for many reasons. The analyses of social costs and benefits of the route to be discussed in the present section played a major role in the decision making process. A first assessment of the Betuweroute is by Knight Wendling and it was concluded that (Knight Wendling, 1991, p. 26): "the necessity of construction is endorsed by economic and social issues like environmental concern, infrastructure capacity and economic cost/benefit ratio. Also from an international perspective the Betuwe freight railway route is an indispensable link to execute EU-policy and to react appropriately to the changing position of road traffic." In the next year this conclusion was documented by a 'macro-economic and social cost-benefit analysis of the Betuwe route' (Knight Wendling, 1992) that stated that until 2010 tax revenues with a present value of 5.4 billion Euro would be forgone if the Betuwe route would not be constructed. Improvement of inland waterway transport could limit this loss to 3.45 billion Euro. The costs of the Betuweroute were estimated to be around 2.36 billion Euro and it was expected that this investment would be paid back completely by 2000.

The Knight Wendling conclusion is remarkable for a number of reasons. In the first place, Knight Wendling was asked by Dutch Railways (NS) to compare two alternatives: a reference case in which freight transport by rail would completely disappear, and one in which freight transport would grow to 65 million ton per year. The latter figure was based on a target set by NS, which is generally considered as ambitious. This implies that Knight Wendling did not itself assess the effect of construction of the Betuweroute on freight transport. In other words, the direct effect of the Betuwe route on the development of the volume of freight transport was taken as given (that is, incorporated in the self-imposed target set by NS) rather than estimated. Also, the reasoning in the Knight Wendling report is macro economic and stresses the indirect or secondary effects. Later on it became clear that a substantial part of the effects reported by Knight Wendling were 'image' effects for the Rotterdam port that are absent in conventional economic models.

The large macro-economic benefits suggest that it is unnecessary to care much about the returns to the investment in terms of user fees. The capital invested in the Betuwe route would soon be paid back by (other) tax revenues, at least if the optimistic assumptions about the development of freight transport were accepted. A later analysis by the CPB (1993) concluded that even after subtraction of the 'image' effects the Betuwe route still appeared to be a worthwhile investment. The CPB report, however, also did not provide an independent assessment of the development of freight transport in general, let alone of the demand for transport over the Betuwe route. In fact, an independent assessment that investigated the demand for freight transport over the Betuweroute under particular conditions of price and quality was never conducted.

The Knight Wendling analysis took for granted that that the voluminous flows of goods to be transported by rail in the ambitious NS scenario made it necessary that a new route should be constructed. However, from a CPB (1995) study it is clear that upgrading the Rotterdam Port Railway and doubling the existing railway between Rotterdam and Utrecht served to postpone any capacity problems for freight transport to (at least) 2009. Recent figures by Statistics Netherlands (CBS) indicate that about 29 mln tonnes of freight were transported by rail in 2005 in the Netherlands (see http://statline.cbs.nl/statweb/?la=en) and there are no serious indications of capacity problems even though the Rotterdam-Utrecht railroad has not been doubled and the Betuwe route was not yet available.[1] Moreover, there appears to be no interest at all in freight transport over the Betuwe route immediately after its completion in July 2007. We conclude therefore that even this seemingly trivial step in the argument was less innocent than it seems to be at first sight.

Also the assumptions on the environmental superiority of rail transport can be questioned. A study by the RIVM compared the environmental effects of transporting an equal amount of freight by road and rail, and found relatively modest differences (see Van Wee et al., 1994). Moreover, early environmental assessments ignore new developments in truck technology that mitigate the environmental damage caused by trucks. It was also pointed out that the Betuweroute was expected to generate a substantial amount of additional freight, which would increase pollution, etc. The conclusion emerged that the environmental effects of the Betuweroute could safely be ignored.

In view of these conclusions the most surprising aspect of the Betuweroute appears to be that so many people were convinced that neglecting this opportunity for investment in rail infrastructure would cause significant damage to the Dutch economy. A tentative explanation for this conviction could be the following. At the end of the 1980s there was considerable anxiousness among Rotterdam entrepreneurs about the future of road transport: congestion problems and environmental policies were regarded as major threats to the fast and cheap transport towards the German hinterland. In particular, there was concern about the better rail connection of Hamburg and the emerging plans to improve the railway connection between the port of Antwerp and Germany by upgrading the so-called ‘Iron Rhine’. Clearly, the construction of a modern railway dedicated to freight transport and providing a direct connection between Rotterdam and Germany would imply a major competitive advantage in case rail transport would indeed become an important substitute for the use of trucks. These strategic considerations were combined with ambitions of Dutch railways who regarded the Betuweroute as the last opportunity to save its cargo division and the willingness of Dutch politicians to invest substantially in (apparently) environment-friendly transport modes instead of in roads. The result was a very costly project, the benefits of which are still unclear.[2]

3. The transport model and transport network

The model used for our analysis is the MOLINO II model developed at the K.U. Leuven. The model structure allows for an economic assessment of improvements in a transport network with various nodes, links and paths. A full description of the model is outside the scope of this paper, and we restrict our discussion in this section to highlighting the features that are crucial for understanding and interpreting the results presented in the following sections.[3]

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[1] In the Knight-Wendling scenario total freight transport by rail would be equal to 30 million ton by 2000.

[2] See TCI (2004) for an extensive description of the political decision making process leading towards the construction of the Betuweroute.

[3] See De Palma et al. (2007) for a detailed description of the MOLINO II model.

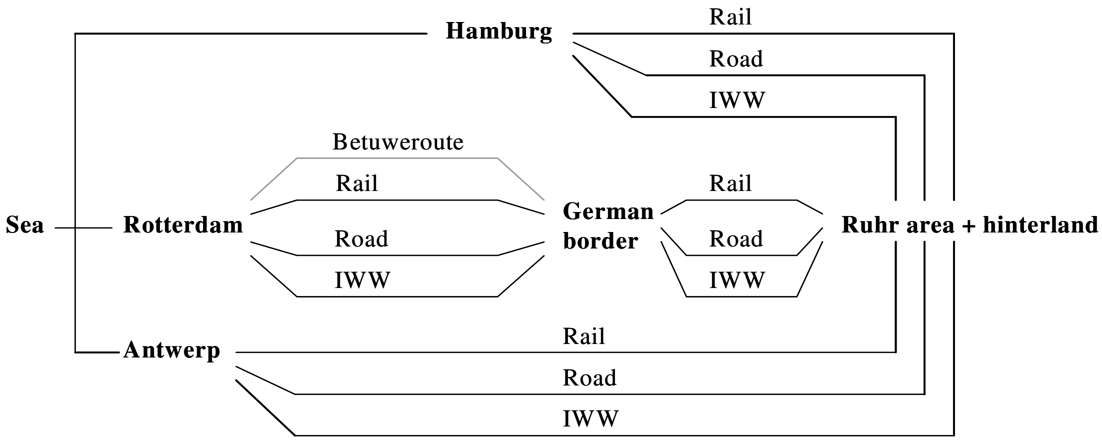

Figure 1: The transport network analysed in our case study (IWW is inland waterways).

As is clear from the previous sections we focus on the impact of the Betuweroute on the competition between Rotterdam, Antwerp and Hamburg for international freight transport. We concentrate attention on freight that arrives from over the North Sea and moves to the hinterland beyond the German border, in which the Ruhr area still occupies a central position. This international freight may use the ports of Rotterdam, Hamburg or Antwerp and from there use (existing) rail, road or inland waterways. The Betuweroute is meant as a substantial improvement in the available rail infrastructure and for this reason we model it as a separate mode/link. A special characteristic of the Betuweroute is, of course, that it is only available until the German border, which is therefore included as a separate 'node' in the part of the network that connects Rotterdam with its hinterland. Figure 1 presents the transport network used for our analyses.

The actors in the MOLINO II model are users of this transport network. They are assumed to have a common structure of their utility or production functions, which can be described by a decision tree. One of the actors are producers that have a demand for international freight transport. Their production function has – at the highest level – two arguments: other inputs and international transport. The latter should be interpreted as a composite commodity, whose value is determined by the various transport types. The idea is that any level of production can be realised with various combinations of transport and other inputs and that the actual amount of transport used will depend on its relative price. The composite commodity 'transport' is determined by peak and off-peak transport by means of a lower-level production function. At a still lower level, the amounts of peak and off-peak transport are determined by the links of the network used. For international freight transport these links are determined by the port used (Rotterdam, Antwerp or Hamburg) and the transport mode (road, rail or inland waterways). We treat the Betuweroute as a separate mode, which is only relevant for transport that passes through the port of Rotterdam.

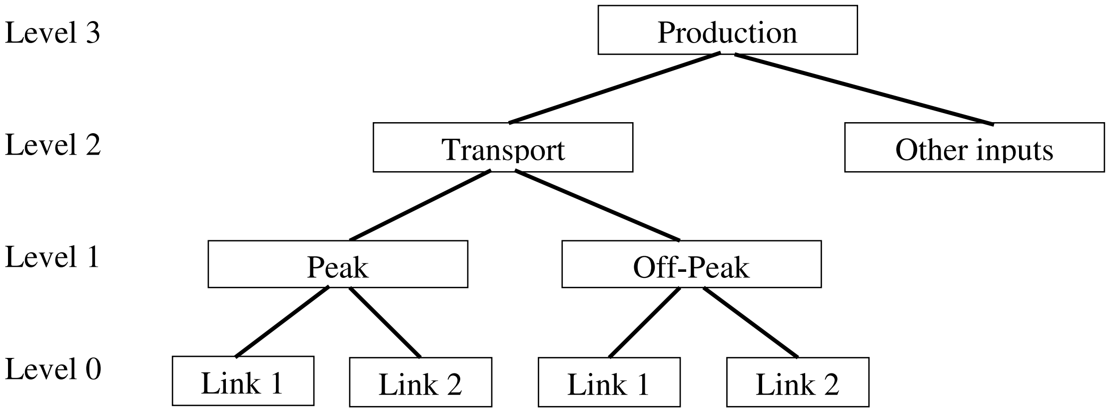

Figure 2: Example of the production function with two links.

The production function can be described by the nested decision tree in Figure 2. A producer who wants to make a certain number of units of the final product first decides how many units of transport and other inputs to use. In the next step, he decides how this total amount of transport is determined by peak and off-peak transport. Then he decides if the required amounts of peak and off-peak transport are to be transported by road, rail or inland waterways and from Rotterdam, Antwerp or Hamburg. For simplicity we have assumed in that figure that only two links have to be distinguished, whereas in reality there are 9 or 10 (depending on the inclusion of the Betuweroute in the set of links). For each level of the production structure a CES-function is assumed to be relevant. Such a function is characterized by a constant elasticity of substitution. For two inputs, the CES function looks as:

$$x = \left(a\, y_1^{\sigma} + b\, y_2^{\sigma}\right)^{1/\sigma}, \tag{1}$$

where x denotes the amount of output, y_i the amount of input i, a and b are scale coefficients, and σ is the crucial parameter of this function because it determines the elasticity of substitution between the two inputs as well as the price elasticities of their demand.

There are two other actors that make use of the network. There are producers with a demand for domestic freight transport, which results in transport flows that originate from one of the three ports and that have the German hinterland as their destination. These producers are located in the German Hinterland and their production structure is almost the same as that of producers with a demand for international freight transporters. The only difference is that the number of links is restricted to 3 or 4 (in case of Rotterdam with the Betuweroute as one link). Part of the network is also used for passenger transport. The generation of this type of transport is modeled by means of a utility function that is also of a nested CES type. The nesting structure is analogous to that for the producers, taking into account that inland waterways are not used for passenger transport. We abstract from international passenger transport and introduce four actors generating transport. The origin-destination combinations of these four actors are: Hamburg – German hinterland, Antwerp – German hinterland, Rotterdam – German border, and German border – German hinterland.

The three actors in the model interact with each other if they use the same network link. This interaction is modeled through a travel time function, which gives the travel time on a particular network link as a function of the total flow of transport of the network. Travel time (*tt*) on a certain link is given by the following speed-flow relation:

$$tt = \frac{l}{v}\left(1 + \alpha\left(\frac{\sum_j pce_j \times q_j}{c}\right)^{\beta}\right), \qquad (2)$$

where l is length of the link, v is maximum free-flow speed, pce_j is passenger car equivalent for vehicle type j, q_j is the number of vehicles of type j per hour, c is free-flow capacity, and α and β are (exogenous) congestion function parameters. In this equation the total transport flow is defined as the weighted sum of the number of vehicles, with pce_j values used as weights. For instance, for road transport a truck is typically counted as equivalent to three passenger cars, implying that $pce_j = 3$ for j equal to trucks.

The travel time function in equation (2) was originally developed for road transport and is sometimes referred to as the Bureau of Public Roads (BPR) travel time function. In our model it is also used for rail transport and inland waterway transport. *Travel time cost* is equal to travel time as given by equation (2), multiplied by the value of time. The generalised prices used at each level are the sum of unit resource costs, costs of travel time, i.e., including internal time costs of congestion, and tolls (if present).

The calibration of the model starts by choosing reasonable values for the elasticities of substitution σ for all levels of the production or utility functions of all actors. For the given values of generalized travel costs, optimizing behavior then generates the transport flows as functions of these elasticities of substitution and the scale parameters of the utility and production functions, which have been denoted as a and b in equation (1). These parameters are determined exactly by the values of the transport flows in the initial situation. We run the model from 2000 to 2025. The transport related output of the model consists of transport flows on the various links in 2025. The output also contains yearly figures on net user surplus (equal to passenger transport user surplus minus freight transport user costs), profits of the infrastructure operators and external costs. These ultimately result in total welfare, implying we can compare welfare situations between scenarios.

4. Modelling scenarios and model inputs

Our network analysis focuses on the implications of the Betuweroute on port competition. Using the network in Figure 1, but without the Betuweroute, as our baseline network, and current pricing as our baseline pricing scheme, our modelling analysis first considers the implications of the new Betuweroute infrastructure. Second, it investigates the impact of an alternative pricing scheme, i.e., marginal social cost pricing plus a mark-up for costs of infrastructure maintenance and operation. This results in 4 four different scenarios that are summarised below:

- Scenario 1 (baseline scenario): Current pricing, without Betuweroute;

- Scenario 2: Marginal social cost pricing plus mark-up for costs of infrastructure maintenance and operation, without Betuweroute;
- Scenario 3: Current pricing, with Betuweroute;
- Scenario 4: Marginal social cost pricing plus mark-up for costs of infrastructure maintenance and operation, with Betuweroute;

Under marginal social cost pricing the external costs of congestion, greenhouse gas emissions, local pollution, noise and accidents, and costs of infrastructure maintenance are incorporated in the generalised prices.

Important to note is that in our model the central government is the owner, manager and operator of all links, except the Betuweroute. The Betuweroute is operated and managed by a single separate entity. Therefore, except for the Betuweroute, all issues related to differences between private and public ownership, and between differences in organisational structures, are left out of the equation.

Regarding inputs of the model, passenger and freight flows for specific routes are generally not available. This means that many assumptions are necessary. Ultimately, local and specific route knowledge is needed in order to calibrate the existing flows on the network links. In order to get some idea on the distribution of freight and passenger transport demand over the different links we use the ETIS database, which contains freight and passenger transport flows for origin-destination combinations at the NUTS 2 level. Specifically, we derive the freight and passenger flows from Rotterdam, Antwerp and Hamburg to the Ruhr area, and vice versa. Of course, total transport flows are larger than the resulting flows, but this at least give us an idea of the distribution of international flows over the three links (for details see Koetse and Rouwendal, 2008).

To get an idea on absolute figures we use data on realised rail freight flows on the East-West axis from Statistics Netherlands (see http://statline.cbs.nl/statweb/?la=en). This figure turns out to be a factor 24 higher than the figure drawn from the ETIS database. We therefore multiply all freight flows by rail by 24. Total domestic freight by rail in the Netherlands over the East-West axis is 0.28 times international freight. Domestic freight in The Netherlands is upgraded accordingly. Total international road freight transport from Germany to Netherlands and the other way around is 68 mln tonnes. This is approximately a factor 17 higher than flows obtained from the ETIS database. We adjust the figures accordingly. Since data for Germany and Belgium are not available, we apply the same scaling factor to road freight transport from Antwerp and Hamburg. Total water freight transport for freight loaded in Rotterdam with destination Germany, Austria or Switzerland, and the other way around, is around 90 mln tonnes. This is a factor 2.3 higher than in the ETIS database, which is used as a scaling factor for water transport. We make the simplifying assumption that purely domestic transport is zero, i.e., every tonne transported over Dutch waters is transported to Germany. Since data for Germany and Belgium are not available, we apply the same scaling factor to inland navigation transport from Antwerp and Hamburg. The different scaling factors for the different modes imply that the ratios between modes obtained from the ETIS database are lost. However, the ratios within modes, and between routes, remain intact. Absolute figures on passenger transport on specific routes are hard to come by. This is why we use the same scaling factors for passenger transport. Although this potentially erroneous assumption has no direct impact, it may influence the results through the congestion functions. Finally, in order to make a distinction between transport flows during peak hours and off-peak hours, we assume that 70% of freight transport and 80% of passenger transport takes place during peak hours, for all modes. The resulting passenger and freight transport flows on the links in our network are presented in Table 1.

Table 1: Initial quantities in tonnes on the various paths in the network in 2000 (Betuweroute is excluded because initial flows are unknown).

		Passenger		*Local freight*		*Transit freight*	
		Peak	Off-peak	Peak	Off-peak	Peak	Off-peak
Rotterdam-German Border	Road	95,000	41,000	124,000	53,000	-	-
	IWW	-	-	-	-	-	-
	Rail	28,000	12,000	2,000	500	-	-
Rotterdam-Ruhr	Road	48,000	20,000	124,000	53,000	17,000	4,000
	IWW	-	-	50,000	13,000	144,000	36,000
	Rail	14,000	6,000	7,000	1,800	28,000	7,000
Antwerp-Ruhr	Road	16,000	6,800	257,000	64,000	49,000	12,000
	IWW	-	-	51,000	13,000	11,000	2,800
	Rail	2,000	800	35,000	8,500	3,500	1,000
Hamburg-Ruhr	Road	82,000	35,000	55,000	14,000	37,000	9,500
	IWW	-	-	1,700	500	500	200
	Rail	64,000	27,000	94,000	23,000	52,000	13,000

With respect to the Betuweroute there are no appraisals that contain explicit freight flow predictions, so an assumption is necessary here. Assuming a capacity of 680 tonnes per train (see Table 3) and an estimated number of trains per year of 20,000 (personal communication with Keyrail, operator of the Betuweroute), we arrive at a freight flow on the Betuweroute of approximately 14 million tonnes in 2008. We set initial quantities on the Betuweroute in 2000 such that in 2008, in the scenarios with the Betuweroute and given the parameter values stated below, a freight flow of 14 million tonnes on the Betuweroute is obtained. The maximum speed on the Betuweroute is set at 1km/h per hour in 2000, effectively keeping the flows on the Betuweroute at zero. In the scenarios with the Betuweroute we increase the maximum speed to 100 km/h in 2008.[4] Other assumptions on the Betuweroute are that tolls are 0.33 Euro per tonne per trip, capacity is 20 trains per hour (10 in each direction), operation and maintenance costs are 20% lower than those of existing rail infrastructure.[5] Finally, investment in the Betuweroute is estimated at 4.7 billion Euro (EC, 2005). Finally, transport flows have increased substantially in the past, so we implement a generic yearly growth rate of 2% (percentage change is measured over the yearly transport flow output of the model, not

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[4] In order to calibrate the model using identical data in all scenarios we calibrate the model with a maximum speed on the Betuweroute of 1 km/h. In the scenario's with the Betuweroute we increase the speed to 100 km/h in 2008. We set quantities on the Betuweroute in 2000 such that in 2008, for the scenarios with the Betuweroute, a transport flow of 14 million tonnes is obtained. This flow is substituted to the Betuweroute from other links. For the scenarios without the Betuweroute maximum speed simply remains at 1 km/h from year 1 to 25, which effectively keeps transport flows over the Betuweroute equal to zero.

[5] Keyrail expects that costs of maintenance and operation can be reduced by 20% (at a minimum) vis-à-vis costs of current practice in rail maintenance and operation (see www.keyrail.nl).

over the initial figures). Within the context of the model this implies that congestion becomes more and more important over the years.

Values of general, not link specific parameters are listed in Table 2. Some remarks are in order here. Parameters α and β are the congestion function parameters in equation (2), where α determines the impact of an increase in traffic flows on travel time, and β determines the curvature of this relationship. The latter parameter is set equal to 1.5, which implies that the relationship is slightly non-linear. The parameter α is set equal to 0.2. This implies that for a trip of an hour under free-flow conditions and a *q/c* ratio of 2, i.e., the number of vehicles is twice as large as the capacity, there is a delay of around 9 minutes. This appears to be reasonably in line with actual experience. Further, the passenger car equivalent (PCE) of a truck is set at 3 according to European standards, i.e., a truck is assumed to take up 3 times as much space as a car on the road. In the marginal social cost pricing scenario's it therefore gets assigned a larger part of the external costs of congestion. Transport share is set at 0.05, which means that 5% of all consumption is spent on transport.

Table 2: General (not link-specific) parameters.

Parameter	*Value*
α	0.2
β	1.5
PCE truck	3
Transport Share	0.05
Elasticity periods passenger	0.2
Elasticity periods freight	0.2
Elasticity transport passenger	0.8
Elasticity transport freight	0.8
Elasticity paths passenger	1.5
Elasticity paths freight	1.5
Life Time infrastructure	35 years
Interest	4%

Important for the results of the model are the various substitution elasticities. Substitution elasticities between periods and between transport and other consumption are set equal to 0.2 and 0.8, respectively. The main consequence of this assumption is that time loss due to congestion leads to relatively small shifts from peak to off-peak transport flows, which of course also depends on the amount of congestion and the share of congestion costs in total resource costs. Substitution between paths for freight transport is assumed to be elastic; the elasticity is set at 3. Finally, the life time of the Betuweroute is set at 35 years and the discount rate is equal to 4%.

Table 3: Link-specific inputs (units of measurement are given below the table).

Variable		***Rotterdam – German Border***				***German Border – Ruhr***			***Antwerp – Ruhr***			***Hamburg – Ruhr***		
		Road	**Rail**	**IWW**	**Betuwe**	**Road**	**Rail**	**IWW**	**Road**	**Rail**	**IWW**	**Road**	**Rail**	**IWW**
Duration		8	12	8	12	8	12	8	8	12	8	8	12	8
Length		160	160	160	160	95	95	95	225	225	225	355	355	355
Capacity		8,800	20	12	20	8,800	20	12	8,800	20	12	8,800	20	12
Maximum Speed		68	60	8	100	68	60	8	68	60	8	68	60	8
Occupancy	Passenger peak	1.2	500	-	-	1.2	500	-	1.2	500	-	1.2	500	-
	Passenger off-peak	1	200	-	-	1	200	-	1	200	-	1	200	-
	Freight peak	15	680	1,900	680	15	680	1,900	15	680	1,900	15	680	1,900
	Freight off-peak	15	680	1,900	680	15	680	1,900	15	680	1,900	15	680	1,900
Resource costs	Passenger	0.54	12	-	12	0.89	12	-	0.89	12	-	0.89	12	-
	Freight	0.89	12	45.00	12	0.89	12	45.00	0.89	12	45.00	0.89	12	45
Variable MC	Passenger	0.51	386	-	-	0.3	230	-	0.71	543	-	1.12	857	-
	Freight	19.3	706	84	706	11.5	419	50	27.1	992	119	42.8	1565	187
Fixed OPC		7,600	57,000	41,000	45,600	4,500	34,000	24,000	10500	80000	57000	17,000	125,000	90,000
VOT	Passenger peak	6.7	6.7	-	-	6.7	6.7	-	6.7	6.7	-	6.7	6.7	-
	Passenger off-peak	6.7	6.7	-	-	6.7	6.7	-	6.7	6.7	-	6.7	6.7	-
	Freight peak	2.9	0.76	0.18	0.76	2.9	0.76	0.18	2.9	0.76	0.18	2.9	0.76	0.18
	Freight off-peak	2.9	0.76	0.18	0.76	2.9	0.76	0.18	2.9	0.76	0.18	2.9	0.76	0.18
External Costs	Passenger peak	0.033	0.969	-	-	0.033	0.969	-	0.033	0.969	-	0.033	0.969	-
	Passenger off-peak	0.033	0.969	-	-	0.033	0.969	-	0.033	0.969	-	0.033	0.969	-
	Freight peak	0.175	1.381	1.204	1.381	0.175	1.381	1.204	0.175	1.381	1.204	0.175	1.381	1.204
	Freight off-peak	0.175	1.381	1.204	1.381	0.175	1.381	1.204	0.175	1.381	1.204	0.175	1.381	1.204

Notes:

Variable	**Unit of measurement**
Duration	Number of peak hours per day
Length	Length of the links in kilometres
Capacity	Free-flow capacity per hour
Maximum speed	Kilometres per hour
Occupancy	Occupancy rates in passengers or tons per vehicle
Resource costs	Resource costs of vehicle use in Euro per vehicle kilometre
Variable MC	Variable infrastructure maintenance costs in Euro per passenger or freight vehicle
Fixed OPC	Fixed infrastructure operation costs in Euro per day
Value of time	Value of time in Euro per hour per passenger or tonne
External costs	Euro per vehicle kilometre (external costs of congestion, greenhouse gas emissions, local pollution, noise and accidents).

Values for link-specific parameters and variables are summarised in Table 3. Note that most figures differ per mode but not per country. For example, road data for The Netherlands are transferred to Belgium and Germany. The reason is that we could not obtain specific data for Belgium and Germany.[6] When figures differ per country this is because of differences in length of the various links. For example, fixed operation costs are based on operation costs per km infrastructure in The Netherlands. Because the links differ in length, operation costs also differ by link. The same holds for variable maintenance costs. Values for maximum speeds and number of peak hours per day are based on assumptions, while length of the various links are based on own calculations. Occupancy rates for road passenger transport are based on (informed) assumptions, while occupancy rates for rail passenger transport is based on information contained in NS and Prorail (2006). Data on occupancy rates for freight transport, measured in tonnes per vehicle, are from a detailed freight transport database in The Netherlands (see NEA et al., 2005). Resource costs for the three modes, consisting of depreciation costs, interest costs, insurance costs, labour costs and other direct transport related costs, are obtained from the same source.

Further, free-flow infrastructure capacities for IWW and rail transport are based on own assumptions, while road infrastructure capacity is based on an assumption of 2 lanes per direction and 2,200 vehicles per lane per hour (see Smith et al., 1996). Values of time are important inputs for calculating costs of congestion. We use those that were used in the UNITE project (see Nellthorp et al., 2001). Finally, variable maintenance costs, fixed operation costs and external costs are derived from own calculations based on CE/VU (2004) and Statistics Netherlands (see http://statline.cbs.nl/statweb/?la=en).

Of course, the results presented in the following section depend to a certain extent to the values for the parameters and variables discussed above. Especially important are the uncertainty around initial passenger and freight transport flows, the absolute and relative magnitudes of the various costs figures, and the assumption on the substitution elasticity between paths. Sensitivity analyses should provide insight into the sensitivity of the results to changes in these values.

5. Simulation results

5.1. Welfare consequences

In Table 4 we present the results of welfare computations in four scenarios. Scenario 1 is a base case without the Betuweroute. Scenario 2 refers to the introduction of marginal social cost (MSC) pricing in the base case. Scenario 3 is the base case with the Betuweroute but without MSC pricing. Finally, case 4 refers to the situation in which both MSC pricing and the Betuweroute are introduced. The consequences of MSC pricing are according to expectation; net user surplus decreases because of lower transport demand and higher generalised transport prices, toll revenues increase, and

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[6] Although this may influence the results somewhat, it is not likely that figures for Belgium and Germany are very different from those for The Netherlands. Especially the values of time and the external costs of transport may differ slightly among these countries, but not to an extent that results would change in a qualitative sense.

external costs drop by a large amount. Comparison of the total welfare in both scenarios shows that the net effect of these developments is a substantial increase in total welfare.

Construction of the Betuweroute induces a shift from road to rail transport (see next section), and total transport on the network increases slightly. Although external costs per tonne kilometre are lower for rail than for road transport, the net effect of these developments is a slight increase in total external costs. Ultimately, in accordance with earlier Betuweroute assessments, the construction and operation of the Betuweroute is not profitable for the operator and also causes a substantial drop in total welfare. This result is reached when the Betuweroute is introduced in the base case, but also when it is introduced in a situation with MSC pricing. Not surprisingly, the main reason for this result is the large infrastructure investment costs associated with the Betuweroute.

Table 4: Welfare effects in the four scenarios in millions of Euro per year (figures are discounted sums in 2000 using a 4% discount rate).

	Scenario 1	***Scenario 2***	***Scenario 3***	***Scenario 4***
Passenger transport users' surplus (1)				
Total	8,987,390	8,933,051	8,987,463	8,933,145
Freight transport users' costs (2)				
Local	3,769,810	3,822,600	3,769,311	3,822,033
Transit	1,245,791	1,261,208	1,244,336	1,259,680
Net user surplus (3) = (1) – (2)				
Total	3,971,788	3,849,244	3,973,816	3,851,432
Toll revenues (4)				
Central government	–	130.4	–	130.1
Betuwe		–	53.3	171.9
Infrastructure costs				
Investment Betuwe (5)	–	–	3,434	3,434
Salvage value Betuwe (6)	–	–	483	483
Operation and maintenance costs (7)				
Operation costs central	23,784	20,063	23,807	20,089
Operation costs Betuwe	–	–	294	278
Profits operator (8) = (4) – (7) – (5) + (6)				
Central	–23,784	110,382	–23,807	109,999
Betuwe	–	–	–3,192	–3,057
External costs (9)				
Total	35,595	30,499	35,601	30,512
Total welfare (10) = (3) + (8) – (9)				
Total	3,912,408	3,929,128	3,911,216	3,927,862

5.2. Changes in transport flows

Note that there is an autonomous growth in transport flows of 2% per year and that flows may furthermore change due to differences in congestion on the various links. This implies that total transport in 2025 can be maximally 64% percent higher than that in 2000 ($1.02^{25} = 1.64$), but that transport on a specific link may show a larger increase because of differences in congestion and associated substitution of flows between routes.

Scenario 1

In Table 5 we present indexed transport flows in the year 2025 for scenario 1, with initial transport flows in 2000 set equal to 1. Compared to 2000 the local and transit freight flows on the entire network in 2025 have grown by approximately 53% (not in table). Compared to a maximum growth of 64% we may therefore conclude that congestion substantially reduces freight transport flows. Furthermore, especially rail transport in the Netherlands and Belgium increase substantially, both in a relative and an absolute sense. Apparently congestion on roads and water in these countries lead to substitution towards rail.

Table 5: Quantities on the various paths in the network in 2025 for Scenario 1 (input Scenario 1 in 2000 = 1).

		Passenger	*Local freight*	*Transit freight*
Rotterdam-Ruhr	Road	1.55	1.49	1.45
	IWW	–	1.36	1.45
	Rail	1.58	1.76	1.69
	Betuwe	–	–	–
Antwerp-Ruhr	Road	1.61	1.56	1.60
	IWW	–	1.53	1.57
	Rail	1.63	1.69	1.73
Hamburg-Ruhr	Road	1.62	1.54	1.55
	IWW	–	1.59	1.60
	Rail	1.40	1.54	1.55

When looking more specifically at total freight flows to and from the three ports (see Table 6), we see a striking reduction in the competitive position of Rotterdam. This is especially true for transit freight, which partly switches to the ports of Antwerp and Hamburg. Apparently, congestion on the links from Rotterdam to the Ruhr area, and vice versa, become problematic in the future.

Table 6: Total quantities from or to Rotterdam, Antwerp and Hamburg in 2025 for Scenario 1 (input Scenario 1 in 2000 = 1).

	Passenger	*Local freight*	*Transit freight*
Rotterdam	1.56	1.48	1.49
Antwerp	1.61	1.57	1.60
Hamburg	1.52	1.54	1.55

Scenario 2

In Table 7 we present indexed transport flows in the year 2025 for scenario 2 compared to the output in 2025 for Scenario 1. Compared to 2000 the freight flows on the entire network in 2025 have increased by approximately 24% (not in table). When we compare this figure to the growth figures in scenario 1, marginal social cost pricing apparently causes a large reduction in transport flows. There furthermore is a striking shift from road and rail to waterway transport, likely because of the relatively limited maintenance costs for waterways. Furthermore, although total freight flows have decreased, the competitive positions of the three ports are similar to those in scenario 1 (not in Table). This is not entirely surprising since we have made almost no distinction in external costs between The Netherlands, Belgium and Germany. Only external costs of congestion are different between the three regions, but they apparently do not make a substantial contribution to total external costs per kilometer.

Table 7: Transport flows going to and from the three ports in 2025 for Scenario 2 (output Scenario 1 in 2025 = 1).

		Passenger	*Local freight*	*Transit freight*
Rotterdam-Ruhr	Road	0.88	0.78	0.75
	IWW	–	0.82	0.87
	Rail	0.89	0.84	0.80
	Betuwe	–	–	–
Antwerp-Ruhr	Road	0.93	0.82	0.83
	IWW	-	0.96	0.97
	Rail	0.94	0.81	0.82
Hamburg-Ruhr	Road	0.93	0.80	0.78
	IWW	–	1.03	1.00
	Rail	0.78	0.78	0.76

Scenario 3

In Table 8 we present indexed transport flows in the year 2025 for scenario 3. For Scenario 3 the freight flows in 2025 have increased by approximately 55% compared to 2000 (not in table). Compared to an total increase of 52% in scenario 1 the additional freight link therefore has a slight positive effect on total freight transport. This is also expressed in the increase in transport flows along the Betuweroute (which is below the increase on other links because the reference year is 2008 instead of 2000).

The consequences of the Betuweroute for the port of Rotterdam in 2025 are large (see Table 9). The competitive position of Rotterdam now improves vis-à-vis Antwerp and Hamburg. However, this change in competitive position is a direct consequence of two central assumptions, i.e., our *assumption* that freight flows on the Betuweroute in 2008 resemble the transport flow estimates made by the Betuweroute operator, and our assumption that the distribution of freight to local and transit freight on the Betuweroute is identical to the distribution of freight flows on the existing rail link in 2000. In this view, the change in competitive position is there by construction, and may not be seen as pure output of the model.

Table 8: Quantities on the various paths in the network in 2025 for Scenario 3 (input Scenario 1 in 2000 = 1*).

		Passenger	*Local freight*	*Transit freight*
Rotterdam-Ruhr	Road	1.55	1.48	1.30
	IWW	–	1.36	1.12
	Rail	1.57	1.73	1.21
	Betuwe	–	1.49	1.45
Antwerp-Ruhr	Road	1.61	1.56	1.56
	IWW	–	1.53	1.53
	Rail	1.63	1.69	1.68
Hamburg-Ruhr	Road	1.62	1.54	1.51
	IWW	–	1.59	1.56
	Rail	1.40	1.54	1.51

Note: * For the Betuweroute the quantities in 2008 are set at 1.

For local freight the figures for Antwerp and Hamburg are identical to those in scenario 1, which makes sense since nothing has changed there locally. For Rotterdam, local freight has increased slightly vis-à-vis scenario 1 because of the Betuweroute. Transit freight has also increased for Rotterdam, which is for a large part due to a shift back from Antwerp and Hamburg. This shift cannot be observed from the tables directly. However, observe that if transit freight has increased on the entire network, then the decrease in Antwerp and Hamburg must have been more than offset by an increase in Rotterdam.

Table 9: Total quantities from or to Rotterdam, Antwerp and Hamburg in 2025 for Scenario 3 (input Scenario 1 in 2000 = 1).

	Passenger	*Local freight*	*Transit freight*
Rotterdam	1.56	1.50	1.63
Antwerp	1.62	1.57	1.56
Hamburg	1.52	1.54	1.51

Scenario 4

In Table 10 we present indexed transport flows in the year 2025 for scenario 4. Compared to 2000 freight flows on the entire network in 2025 have grown by approximately 27% (not in table). The freight figures are lower than under current pricing (scenario 1 and 3) but higher than in the scenario with marginal social cost pricing and without the Betuweroute (scenario 2). Again we see a substitution of freight transport from road and rail to water. Note that the figures (except those for the Betuweroute) are almost identical to those under scenario 2. This implies that marginal social cost pricing in the situation with the Betuweroute has no additional effect on the competitive position of Rotterdam versus Antwerp and Hamburg.

Table 10: Quantities on the various paths in the network in 2025 for Scenario 4 (input Scenario 1 in 2000 = 1*).

		Passenger	*Local freight*	*Transit freight*
Rotterdam-Ruhr	Road	0.88	0.78	0.75
	IWW	–	0.82	0.88
	Rail	0.89	0.83	0.79
	Betuwe	–	0.91	0.87
Antwerp-Ruhr	Road	0.93	0.82	0.83
	IWW	–	0.96	0.97
	Rail	0.94	0.81	0.82
Hamburg-Ruhr	Road	0.93	0.80	0.78
	IWW	–	1.03	1.00
	Rail	0.78	0.78	0.76

Note: * For the Betuweroute the quantities in 2008 are set at 1.

6. Conclusions and discussion

The construction of the Betuweroute has been a heavily debated issue in The Netherlands. Even at the moment strong doubts exist with respect to its profitability and its potential to attract transport from other transport routes. In this paper we use a transport model to analyse some of the potential consequences of construction and operation of the Betuweroute. The network includes transport from Rotterdam, Antwerp and Hamburg to the Ruhr area, and vice versa. Net growth of demand for transport on each link is assumed to be equal to 2% per year, which ensures that congestion in the network increases substantially over time. We run the model from 2000 to 2025 and analyse transport flows and welfare effects using a specific transport network under four scenarios, i.e., with and without the Betuweroute, and under current pricing and marginal social cost pricing. Our main findings are as follows.

Under current prices and without the Betuweroute, freight flows on the entire network increase with approximately 53% in 2025 vis-à-vis 2000. Without congestion, flows would increase by 64%, which shows that congestion substantially reduces transport flows. We also see a striking reduction in the competitive position of the port of Rotterdam. This is especially true for transit freight, which partly switches to the ports of Antwerp and Hamburg. Especially the congestion on the links from Rotterdam to the Ruhr area appear to become problematic in the future. When marginal social cost pricing is introduced, thereby increasing the price of transport, freight transport on the entire network in 2025 is reduced even further, and the competitive position of Rotterdam does not improve. In the scenarios with the Betuweroute, freight on the entire network increases vis-à-vis the scenarios without the Betuweroute. This increase in generic freight transport is also expressed in substantial transport flows on the Betuweroute itself. Also striking are the consequences of the Betuweroute for the port of Rotterdam in 2025, the competitive position of which has now increased vis-à-vis Antwerp and Hamburg in 2025.

The welfare consequences of introducing marginal social costs pricing are according to expectation; net user surplus decreases because transport demand decreases and generalised transport prices increase, toll revenues increase, and external costs drop substantially. The result is a substantial increase in total welfare. However, the welfare consequences of the Betuweroute are negative. Although unit toll is higher than unit variable costs of operation and maintenance, toll revenues are not nearly enough to cover total costs of operation and maintenance. Together with the substantial investment costs this leads to a negative profit and a substantial drop in social welfare. This analysis therefore shows that, although the Betuweroute may certainly be beneficial to the competitive position of the port of Rotterdam, investment costs of the Betuweroute are too large for the investment to be sensible from a welfare perspective. Admittedly this result is partly based on earlier assumptions regarding future transport on the Betuweroute, but since these assumptions are likely biased upwards, the results should not be expected to become more favourable for the Betuweroute if more accurate actual transport flows would be used. It is therefore clear that ex ante assessments of the Betuweroute, if a sensible transport model and network had been used, could already have shown the economic consequences of the Betuwe investment. Whatever the actual outcome of the investment decision in the political arena would have been, had such an analysis been available at that stage, at least it would have been based on more objective and rational information.

Acknowledgements

This research was funded by the EC programme FUNDING, financed by the Sixth Framework Programme Priority. The MOLINO model used in this study was developed by Saskia van der Loo, José Moyano and Stef Proost at the Katholieke Universiteit Leuven, and André de Palma at the Université de Cergy-Pontoise. We are indebted to Barry Ubbels for early contributions to the paper. We also are indebted to two anonymous referees for valuable comments on an earlier version.

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