41st Congress of the European Regional Science Association
29 August – 1 september 2001, Zagreb, Croatia

Social Costs of Land Use Claims for Transport Infrastructure: A Survey for The Netherlands

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Abstract:
In this paper the social costs of land use claims for transport infrastructure are investigated for The Netherlands. This is a complement to the study on "Efficient pricing of traffic: estimation of the social costs of the use of transport modes" carried out in The Netherlands by CE (1999). In the present study we pay attention to the acquisition costs of land for infrastructure, the indirect costs of land use caused by infrastructure and the costs of infrastructure as barriers in - and the fragmentation of - the landscape. The paper gives an overview of the problems associated with measuring the land related costs of transport infrastructure. Estimates are given of the land use claims (in m^2) for various types of transport infrastructure. In addition some of the land related cost categories are estimated. These costs are allocated to the various transport modes (cars and trucks of various types, barges, rail, aircraft).

1 INTRODUCTION

In The Netherlands, the Centre for Energy Savings and Clean Technology (CE, 1999) dealt with the marginal social costs of mobility. One variant in the CE-study 'Efficient pricing of traffic' includes the costs for constructing infrastructure. However, amongst others, the costs for the acquisition of land needed for the infrastructure, the indirect costs caused by the land use for transport infrastructure, and the costs resulting from spatial fragmentation of the landscape are not considered in the CE-study. In this research we focused on those three omissions.

The reasoning behind this study is clear: in a small country with a high population density, such as The Netherlands, land is a scarce good and pollution levels are relatively high. One of the main policy objectives of the Dutch government concerning transport is that the users cover all costs caused by transportation.

The social costs of transport are all costs of mobility summed up. It concerns internal costs, external costs and government expenditures. In principal, the internal costs are not taken into account in this study since the market mechanism charges these costs to the different originators. In order to map out the social costs of infrastructure, it is however necessary to first give an overview of all costs concerning transport. Below, an overview of three distinguished types of social costs is given.

1. Internal costs

These costs are all private expenditures on transport, apart from transport taxes. All costs that households and firms make for transport are included, namely:

- Depreciation and maintenance of vehicles, ships and airplanes;
- Insurance;
- Fuel costs, train tickets and freight prices.

Concerning these costs is it assumed that the market mechanism ensures a correct pricing and market failure is absent. This is the reason why these costs are not explicitly considered here.

2. External costs

External costs are the financially appreciated negative external effects of transport. Since the originator is not charged with these costs, the market fails. Due to this market failure, the originator does not take these costs into account when making transport related decisions. Verhoef (1996) distinguishes three types of external costs of transport. These hold for all modalities, but the price of these external costs may differ considerably per modality:

- External costs resulting from actual transport activities and therefore belonging to the marginal social costs. These concern congestion, traffic accidents, noise nuisance, stink annoyance and the emissions of hazardous gasses.
- External costs caused by standing vehicles.
- External costs related to the existence of infrastructure: barrier effects, fragmentation of landscape and visual nuisance.

3. Government expenditures

The government expenditures on mobility are included in the external costs as long as the user does not take these into account in its mobility decision. Only if the government charges the user directly for the costs, these costs become internal. These external costs include:

- Construction and maintenance of infrastructure, including facilities for the environment and traffic safety, such as sound barriers, detector-pads and wild life viaducts;
- Traffic duties of police and justice;
- Part of the officialdom;

- Subsidies and tax expenditures.

Table 1 shows an overview of the elements already covered and the added aspects from this study. Finally, the missing components that still exist are presented.

Table 1: Overview of the cost components

Covered	This study	Remaining omissions
Marginal costs		
1. Maintenance and operational costs 2. External costs: - Traffic accidents - Air pollution - Noise nuisance - Congestion (roads)	**1. Fragmentation (nuisance and death of fauna by the use of infrastructure)**	1. Barriers: - Waiting time zebra crossing - Visual barriers - Etc. 2. External costs - Stench annoyance - Quivering annoyance
Fixed costs		
1. Construction costs	**1. Land costs** **2. Fragmentation of the landscape** **3. Indirect land use:** - **Noise nuisance zones** - **Free sight zones** - **Zones transport hazardous goods (safety contours)**	1. Barriers: - Waiting time traffic lights - Detours - Visual barriers - Etc. 2. External costs: - Presence of cars in public space - Shortage of parking lots (search / waiting times) - Indirect costs of emissions of the production and destruction of cars and infrastructure

This research is based on the determination of direct and indirect land use implications of transport infrastructure in The Netherlands. Those aspects will be dealt with in section 2. In section 3 we will further classify and summarise these implications. In order to compute the economic costs related to land use, prices per m2 have to be used for the various cases. This will be the subject of section 4. In section 5 we will make our final calculations of the land related social cost of transport. In section 6 we formulate conclusions and give some recommendations for further research.

2 Direct and indirect land use (claims) by transport infrastructure

2.1 Direct land use

In our study the following infrastructure categories are included:

- Roads;
- Railroads[1];
- Waterways;
- Ports;
- Airports.

An important feature of the first four infrastructure types in The Netherlands is that they are mainly treated as public goods where users do not pay according to the infrastructure capacities they use. Airports, on the other hand, are private areas where users pay according to the intensity of use. As will be indicated in section 2.3, this has consequences for our analysis. In our study we use data on 1999.

[1] The land use of urban rail transport – tram and metro - is not included. It is about 3.3 km^2 in The Netherlands, which makes it almost negligible.

In this section we will only discuss the measurement and land use of road infrastructure.
In order to determine the land use by the road network a distinction is made between the following elements:

- Roads within built-up areas;
- Roads outside built-up areas;
- Parking;
- Gas stations;
- Service and parking areas.

In calculating the land use of roads within and outside the built-up areas we used the length of eight types of roads (from highway to forest road) and their minimal design demands[2]. This means that we do not only consider the 'paved' parts of the line infrastructure, but also the borders at both sides. Furthermore, the number of traffic lanes, bus lanes, and bicycle lanes are taken into consideration in the calculation. Excluded are the land use claims by roundabouts, clover leafs, interchanges, entrance and exit ramps, and bus stops[3].
Within the built-up area also footpaths, squares and ornamental paving are excluded. Tables 2 and 3 show an overview of infrastructural elements and their spatial claims. Considering the remarks mentioned above, the land use as presented in table 3 could be treated as minimum values.

Table 2: Road infrastructure in The Netherlands (length, number)

	Inside built up-area	Outside built-up area
Paved roads	55,217 km.	51,648 km.
Unpaved roads	1,099 km.	10,012 km.
Bicycle paths and strips	8,425 km.	10,559 km.
Parking lots	4,861,350	Not applicable
Gas stations	2,666	1,409
Service and parking areas	Not applicable	275

Table 3: Land use by road infrastructure in The Netherlands (in km^2)

	Inside built up-area	Outside built-up area
Paved roads	356.7	682.9
Unpaved roads	3.3	65.1
Bicycle paths and strips	25.3	40.3
Parking lots	119.1	Not applicable
Gas stations	0.9	1.1
Service and parking areas	Not applicable	15.8
Total	505.3	804.6

The total area of road infrastructure in The Netherlands adds up to 1,300 km^2. Road infrastructure covers about 3.9% of the Dutch total land area (33,906 km^2). As mentioned above, for almost every infrastructural element lower estimates are given. The land use by gas stations and parking space are the least solid figures in this calculation. Parking can take place on public parking spaces, on public roads

[2] For instance, the minimal design demands of a four lane highway – two lanes in each direction – is 22.1 meters without the side and middle shoulders. The side and middle shoulders vary most in size. The minimal design demands of the middle shoulder is 1.2 meters in case of a crash barrier, but might be 30 meters in case of an open shoulder. The same holds for the side shoulders. Here additional space might be reserved for future extensions of the number of lanes.
The smallest roads outside the built-up area are unpaved roads with a minimal design demand of 6.5 meters.
[3] Assume that the additional land use claim of roundabouts, clover leafs, interchanges, and entrance and exit ramps for national and provincial highways is 10%, then the direct land use of road infrastructure increases with almost 22 km^2, which is about 1.5% of the total area reported in Table 3.

and on private property[4]. Since financial valuation is the central issue in this study, we only consider the first category. The second category has already been included in the determination of the land use by the road network. Parking on private property (premises, shopping centre, industrial sites) has already been paid for by the owners. We estimated the land claims of parking on constructed public parking lots concerns places near houses. These are situated in built-up areas and are therefore reserved for passenger cars. The land use claim is determined by making assumptions concerning the relation between housing and parking values since 1970[5].

2.2 Indirect land use

Indirect land use claims relate to limitations on the use of land located near infrastructure. Three categories are distinguished: transport of hazardous goods (expressed in risk contours), noise nuisance zones and free sight zones. Note that indirect land use claims are only investigated if land use restrictions based on spatial planning regulations exist. For instance, zones where noise nuisance is experienced but no building restrictions exist by spatial planning regulations are not taken into account. The reason is that noise nuisance should be valued in this case directly as an external effect, and not via its impact on indirect land use.

Transport of hazardous goods

Concerning the transport of hazardous goods, the Ministry of Transport considers two types of risks that can result in a limitation of land use. First, an individual risk exists that is defined as the chance that a fictive unprotected person is exposed to the hazardous good when it escapes, explodes or inflames. Second, a group risk exists that is defined as the chance that more than N victims for different categories of victims arise. For both individuals and groups risk contours are drafted for restricted land use of the considered area. These restrictions are most strict for houses and less strict for office buildings with a low occupation.

Routes for hazardous goods limit land use possibilities for parts of sites that are situated along the *road network*. The routes for hazardous goods on the road network are to a large extent determined by the deliveries of LPG via the road network. The indirect land use claim alongside the road network as a result from the transport of hazardous goods for the Netherlands is 21 km^2 (RIVM, 1999).

In addition, there are strict requirements for LPG gas stations for receiving a license. Technically, this is not a limiting measure, since the surroundings of the gas station are not obliged to adjust, but the gas station itself will not receive the licence for a LPG installation when it does not satisfy the requirements. In other words: the costs are internalised by means of regulation. From this point of view, indirect land use claims by gas stations do not exist and are therefore not considered in this study.

The Dutch Ministry of Transport considers the transport of hazardous goods by *train* to be safe. Therefore, no limiting measures exist concerning construction in areas adjoining tracks where transport of hazardous goods takes place[6]. However, in the surroundings of 14 railway yards, zones are determined where construction of houses is prohibited because of the increased risks resulting from the stationing

[4] The land use for all three categories together is about 550 km^2, assuming three parking places per vehicle (in 1997 there where about 7 million motor vehicles – cars, vans, trucks, and motor cycles - registered in The Netherlands).

[5] The standard for the number of parking lots per house varies between 1 and 2 over the municipalities in The Netherlands. To determine the land use of parking lots we took an average of 1.5 parking lot per house constructed in the period 1970-2000.

[6] This means that, in the case of hazardous materials transported via rail, there are no external costs related to indirect land use. However, the lack of safety zones around railway tracks means that there are

and shunting of trains that transport hazardous goods. The indirect land use claim by these railway yards is 3 km^2 (RIVM, 1999).

For *waterways* no limiting land use measures are formulated. This is not so much due to the safety of the transport system, as to the low intensity of such transport on the waterway network.

Concerning aviation, external safety risk contours are determined for a number of *airports*. These contours relate to the risk of an aircraft crashing. The total indirect land use claim within these external safety risk contours is, according to the RIVM (1999), for the airports Schiphol, Maastricht, Rotterdam and Eelde 50 km^2. However, this area is not included in the financial valuation, because the external safety risk contours are within the noise nuisance zones of the concerning airports (see below). Assigning these safety areas of airports would mean double counting.

Noise nuisance zones

The Wet Geluidshinder (Law on Noise nuisance) introduces the concept of 'noise nuisance zones along *roads*'. A noise nuisance zone consists of an area on both sides of the road where attention must be paid to noise, that is, if houses or other functions sensitive to noise exist in this area or are planned in this area. To asses the noise nuisance by road traffic, the government determined that the total area suffering from a noise nuisance level of more than 50 dB(A) caused by interlocal traffic (traffic on the main network outside built-up areas) is not allowed to increase with respect to 1986. This area was 2,664 km^2 in 1986 and has increased until 1991 to 2,900 km^2; after that level it has stabilised.

The measures as presented to stabilise/reduce the noise nuisance levels are basically focused on reducing the noise production at the source:

1. Silent road surfaces (ZOAB) on the main network;
2. Maintain maximum speed limits;
3. Decreasing car use;
4. Increasing noise requirements for vehicles;
5. If necessary: extra noise barriers.

In conclusion, although a large area is disturbed by noise nuisance of road traffic (2,900 km^2), this will not be included in this study since this disturbance is not related to land use restrictions[7].

A similar approach holds for the noise nuisance of *railways*: policies aim at limiting the noise production at the source, without imposing restrictions to land use. The expectation of Railned (organisation that determines the capacity on the Dutch railway network) that 1.5 billion guilders (2.2 guilders is 1 Euro) is needed in order to adjust the railway yards to the required noise nuisance limits shows that noise is a main concern. In addition, Railned expects that at least 800 kilometres of track must be provided with noise barriers (Railned, 2000).

In The Netherlands three noise nuisance zones are defined considering *airports*: the 35 Ke day zone, the Laeq-26 dB(A) night zone and the 47 BKL zone. The first two are zones for the larger civil airplanes and are applied for Schiphol and Maastricht. The latter zone concerns smaller airplanes and is applied for the remaining four regional and small airports used for scheduled line services and charters.

The protection zone reflects the indirect land use claim by Schiphol caused by noise nuisance. Within this zone new houses or other functions sensitive to noise (hospitals, schools) can not be realised. However, it is allowed to replace existing houses within this area. Moreover, within this area no

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potential external costs when accidents would take place. These should in principal be taken into account in the direct external effects of the transport of hazardous materials via rail.

[7] Again the external cost of noise should be measured here directly via transport volumes, not via indirect land use. Note that the noise nuisance on people in dwellings is usually taken into account but that other aspects of nuisance hindrance such as people outside dwellings and fauna, are usually ignored in studies of this type.

restrictions exist for the development of industrial sites. According to Nyfer (1999) the surface of this zone is 258.0 km^2. However, this figure should be decreased with the area of the airport to prevent double counting. The airport area is 26.8 km^2. For the remainder of the protection zone it is possible to separate the area into 'within built-up area' (8.4 km^2) and 'outside built-up area' (223.5 km^2). The net figure for the area outside the built-up area (excluding water and nature) of the protection zone (144.7 km^2) will be included in the financial valuation for land with limited land use possibilities outside the built-up area.

The indirect land use claim by the regional and the small airports is determined by noise nuisance contour maps, obtained via the Dutch Aviation Authority. Only the indirect land use claims by the airports used for scheduled line services and charters (Maastricht, Rotterdam, Eelde, Twente and Eindhoven) are included in the financial valuation[8]. In determining the net area of indirect land use claims outside built-up areas for those regional airports, the same ratio is used as applied for the protection zone of Schiphol (outside built-up areas 40.2 km^2 and within built-up areas 3.3 km^2).

Free sight zones

For *waterways* a free sight zone for shippers over the riverbanks has to be taken into account in order to ensure safety of traffic. The width of the free sight zone on the banks varies from 10 to 30 metres, depending on the type of ship that is allowed on the waterway and the level of urbanisation of the area. Applying these guidelines – with the exclusion of fairways in seas and large lakes that offer adequate sight – the indirect land use claim by waterways is about 215.8 km^2.

Note that the river forelands should possibly be free from building due to flooding danger. Thus there might be an overestimation of the indirect land claims by waterways. The indirect land use claim by rivers is, however, less then 20% of the total indirect land use claim by waterways.

2.3 Overview of direct and indirect land use

The above findings on land use will be summarised and, where possible, assigned to their location inside or outside the built-up area. The direct land use concerns the space of the physical infrastructure in The Netherlands. The indirect land use claims are lots adjoining infrastructure with restrictions on its use based on spatial planning regulations. This means that zones that experience noise nuisance, but without regulatory restrictions for land use, are not included in this study. Also, we made sure that no double counts occur. For example, only the area of noise nuisance zones is included in the indirect land use claims of airports and not the smaller zones resulting from the safety contours (see section 2.2 on transport hazardous goods).

Table 4 shows an overview of the direct and indirect land use by transport infrastructure in The Netherlands.

We assumed that:

- The direct and indirect land use by waterways and the indirect land use by roads resulting from the transport of hazardous goods are divided according to the share of built-up area in The Netherlands, for 10% within the built-up area and for 90% outside the built-up area.
- The arrival and departure flight routes and the noise nuisance zone of airports are generally found above the least densely populated areas. For this reason, the share that lies above built-up areas is set at 5% instead of 10%.
- Ports and railway yards are located within the built-up area (note that built-up areas include both residential and industrial areas. We do not consider indirect land use related to ports. For those

[8] The indirect land use claims by all regional and small airports is 9.0 and 176.7 km^2 inside and outside the built-up areas, respectively.

activities where hazardous goods play a role, the indirect land use effects are assumed to be internalised by imposing that the firms concerned pay for the safety zones around their transhipment and storage activities.

- Road infrastructure consists of a large number of components (paved roads, unpaved roads, parking places, cycle tracks, gas stations, service areas, etc.). The most important components are presented in the table.

Table 4: Overview of direct and indirect land use by infrastructure in The Netherlands

	Direct land use (km^2)		Indirect land use (km^2)	
	Inside built-up area	Outside built-up area	Inside built-up area	Outside built-up area
Road	505.3	804.6	2.1	18.9
Of which:				
- Roads	360.0	748.0		
- Parking lots	119.1	Not applicable		
City rail	3.3	Not applicable	Not applicable	Not applicable
Railways	59.4	65.9	3.0	Not applicable
Waterways	130.2	1,172.2	15.7	200.1
Ports	59.7	Not applicable	Not applicable	
Airports				
- Schiphol	Not applicable	26.8	8.4	222.8
- Regional	Not applicable	16.7	about 3.3	about 61.9
- Small	Not applicable	5.5	about 5.7	about 114.8
Total	757.9	2,091.7	38.2	612.8

In particular roads and waterways claim relatively much land, considering direct land use. Concerning indirect land use claims, especially the space for free sight zones along waterways and the noise nuisance zones of airports lay restrictions on the land use of lots adjoining infrastructure. It should be noted that the noise nuisance zones by roads and railways are relatively large. However, government policies are directed towards the prevention of noise production at the source (infrastructure, car and train); there are no regulations restricting land use alongside roads and railways. The noise nuisance by roads and railways, however, does disturb nature (see section 4).

The total direct land use by all modalities together is, according to our calculations, over 2,850 km^2, which equals 7.2% of the total area of The Netherlands. If we consider the land-tied infrastructure only (waterways and ports excluded) then the land use is almost 1,500 km^2, which equals 4.4% of the total land area. The indirect land use claim is 650 km^2 of which almost two-third concerns noise nuisance zones by airports. The indirect land use claim, the area for which restricted land use regulations are formulated, adds almost 23% to the direct land use of infrastructure in The Netherlands. The bottom row of table 7 shows that of total land use, 60% relates to direct land use outside the built-up area. Direct land use by infrastructure within built-up area and indirect land use outside built-up area are both responsible for about 20 % of total land use by infrastructure. Only 1% of the total land use by infrastructure relates to indirect land use within the built-up area.

3. Determination of the cost components

Table 5 shows an overview of elements for which the land use implications have been determined and which have been financially allocated.

Table 8: Overview of cost components

Subject	Cost component	Direct / Indirect	Determina-tion of m^2	Financial allocation
Parking	Parking space	Direct	Yes	Yes
	Public road	Double count	No	No
	Private area housing	Direct	No	No
	Private area business	Direct	No	No
Roads	m^2 road infrastructure	Direct	Yes	Yes
	Hazardous goods routes	Indirect	Yes	Yes
	Service areas	Direct	Yes	Yes
	Gas stations	Direct	Yes	Yes
	Noise nuisance zones	Indirect	No	No
Rail	m^2 rail	Direct	Yes	Yes
	m^2 railwayyard	Direct	Yes	Yes
	Hazardous goods (railwayyard)	Indirect	Yes	Yes
	Noise nuisance zones	Indirect	No	No
	m^2 city rail	Direct	Yes	No
Waterways	m^2 minimum width waterways	Direct	Yes	No
	Hazardous goods routes	Indirect	No	No
	Noise nuisance zones	Indirect	No	No
	m^2 inland ports	Direct	Yes	Yes
	m^2 sea ports	Direct	Yes	Partly*
	Building free zones	Indirect	Yes	Yes
Airports	m^2 airport area	Direct	Yes	No
	Routes hazardous goods	Indirect	Yes	No
	Noise nuisance zones	Indirect	Yes	Yes
Segmenta-tion	Segmentation outside built-up area	Not space related	No	Yes
Barrier effect	Barrier effect	Not space related	No	No
Parked vehicles	Nuisance by parking	Not space related	No	No
Parking congestion	Waiting time in parking	Not space related	No	Yes

*20% from the area of seaports is allocated to inland shipping for joint use

Regarding the *direct* land use claim, for all infrastructural elements the land use claim has been determined and will be financially allocated. Exceptions are:

- *Parking*. Parking on the public road (not on the parking lots) does not lead to additional land use claims since it is already included in the land use of roads. To prevent double counting this is not included here. The costs for parking on private sites are already attributed to the landowners, since they had to buy extra space for these parking lots. Therefore, this is not included in our research.
- *Waterways*. The land use implications by waterways are not financially allocated because the main function of waterways is water management..
- *Airports*. This concerns private areas for which the acquisition costs of land are paid by the user.

Concerning *indirect* land use claims a number of categories can be distinguished: indirect land use claim by routes hazardous goods, noise nuisance zones and free sight zones. Also, segmentation and barrier effects occur due to the presence of infrastructure.

- *Routes hazardous goods* play a role in road traffic, railway yards and airports. Note, however, that with airports the indirect land use claim is not financially allocated because this zone lies completely within the noise nuisance zone and allocation would lead to double count.

- *Noise nuisance zones* are only relevant for airports; for relatively large zones limitations are formulated concerning building possibilities. As mentioned above, no noise nuisance zones for roads and railways exist on which limited land use possibilities are imposed.
- *Free sight zones* only play a role in waterways. For safety reasons, part of the bank of rivers and canals has to be building free in order to ensure a good sight for inland shipping.
- *Segmentation and barrier effects*. For this category no land use claim can be determined. Segmentation is allocated on the base of costs made in taking mitigating measures and the remaining costs for damage. As far as we know there are no adequate operational approaches for the financial valuation and the ultimate allocation of costs related to barrier effects. In section 6, some recommendations can be found.

4. The financial valuation of land

The market for land in the Netherlands is definitely not a perfect market: the government interferes heavily in order to deal with externalities and this has implications for land values. In order to get some insight of the acquisition costs of land for infrastructure a number of regional divisions of Rijkswaterstaat (the department of the Ministry of Transport responsible for the provision of infrastructure) are approached. With this – mostly confidential - information concerning specific infrastructural projects (for different types of infrastructure and with a national coverage) an overview has been made of the acquisition costs on the base of expropriation compensations. The range observed in the expropriation compensation is only partly determined by the district where the land is obtained. However, other factors play a role as well: the location of agricultural land near an auction can affect the value of the land to a great extent. Next to the acquisition costs of land, the acquisition of 'objects' should be taken into account when purchasing land. The purchase of objects (houses, hotels, restaurants and agricultural and non-agricultural objects) leads to high compensation for the value of premises, income loss, moving and restructuring costs, etc.

Based on this information on the prices of various types of land transaction the following land prices will be used to compute the land related costs of infrastructure:

For direct land use claims the following acquisition costs are used:

- Within the built-up area: 50 guilders per m^2 (1 euro is 2.2 guilders);
- Outside the built-up area: 22 guilders per m^2.

For indirect land use claims the differences in the land prices of the available land compared to the land price of alternative locations are used, namely:

- Within the built-up area: 50% of the vacant land is built on against a surplus value of 150 guilders per m^2;
- Outside the built-up area: 20% of the vacant land is built on against a preferential surplus value of 10 guilders per m^2.

The costs of fragmentation of land by infrastructure deserve special attention. The expenditures that are made in stopping this fragmentation are assumed to be depreciated in 35 years, similar to infrastructure expenditures[9]. Considering the annual identical depreciation, interest costs are determined on the base of the real interest rate of 4% (Dutch Ministry of Finance, 1995). The interest costs and depreciation costs over 35 year together form the total costs of preventing fragmentation. This calculation holds for both the

[9] We use the Defence Expenditures method for calculating the costs of fragmentation. In this method, the expenditures of the government and firms to mitigating measures are the starting point for calculating the annual costs of fragmentation. A number of assumptions need to be done in order to estimate the total costs of fragmentation.

expenditures of preventing fragmentation by roads as well as expenditures of preventing fragmentation by railways.

5. Results

This section presents the results of this study. These results will be added to the findings from the CE-study. The land related costs concern mainly fixed costs of infrastructure. For this reason, the results from this study are mainly a completion of the MMK+A variant in the CE-study. In this variant both the marginal external costs of transport as well as the fixed, average costs of infrastructure are included.
The main difference between this study and the CE study is the applied method of cost calculation. The construction costs in the CE-study consist of a redemption component and an interest component, while the acquisition costs only consists of an interest component. This difference is not the consequence of a conscious choice, but a direct result from the fact that land maintains its value in time. Therefore, land is not redempted.
In this section we will use the presentation of CE as much as possible. In section 5.1 we will add the acquisition costs calculated in this study to the construction costs calculated in the CE-study. Section 5.2 will discuss the contribution of the results of this study to the complete results of the CE-study. This will be done using two graphics in which the MMK+A variant from the CE-study and the results from this study are combined.

5.1 Costs of land use: a comparison with construction costs

Table 6: Results for passenger transport (in Eurocent per passenger kilometre)

	Acquisition costs of land Direct land use claim; urban	Acquisition costs of land Direct land use claim; rural	'Opportunity costs Indirect land use claim; urban	'Opportunity costs' Indirect land use claim; rural & segmentation	Construc-tion costs CE-study
Car	0.77	0.19	-	0.06	1.15
City Bus	0.13	0.05	-	0.01	0.30
Touring car	0.05	0.02	-	0.00	0.11
Motor bike	0.71	0.25	-	0.07	0.76
Moped	0.35	0.13	-	0.04	0.38
Train	1.11	0.13	-	0.11	4.02
Airplane 150km	-	-	0.09	0.38	2.99
Airplane 500 km	-	-	0.02	0.09	1.05
Airplane 1500 km	-	-	0.01	0.03	0.33
Airplane 6000 km	-	-	0.00	0.00	0.08

The results for both passenger and goods transport are summarised in tables 6 and 7 respectively. In both tables a distinction is made between five cost categories, namely:

- *Acquisition costs of land; urban*

These are costs related to acquisition land for infrastructure within the built-up area (direct land use claim urban)

- *Acquisition costs of land; rural*

These are costs related to acquisition land for infrastructure outside the built-up area (direct land use claim rural)

- *'Opportunity costs'; urban*

These are costs related to indirect land use by infrastructure within the built-up area (urban). This cost category concerns the 'opportunity costs' of land which has limited land use possibilities because the existence of nearby infrastructure negatively affects opportunities to use this land.

- *'Opportunity costs'; rural, and costs of segmentation*

These costs are similar to the last category but outside the built-up area. Also, the costs related to segmentation of land by infrastructure are included in this category.

- *Construction costs CE-study*

In order to make it possible to compare the results with the results of the CE-study a column is included with the construction costs of infrastructure per modality which are calculated by CE (source: CE, 1999).

Table 7: Results for goods transport (in Eurocent per tonkilometre)

	Costs of acquisition land Direct land use claim urban	Costs of acquisition land Direct land use claim rural	Opportunity costs Indirect land use claim urban	Opportunity costs Indirect land use claim rural & segmentation	Construc-tion costs CE-study
Delivery van *	0.92	0.30	0.00	0.09	1.83
Truck solo < 12t	1.06	0.38	0.12	0.12	2.29
Truck solo >12t	0.30	0.11	0.04	0.03	1.14
Truck combination	0.21	0.08	0.02	0.02	0.97
Train	1.11	0.10	0.10	0.08	7.10
Inland ship	2.17	0.00	2.34	0.02	0.81
Airplane 6000 km	-	-	0.00	0.02	0.35

*In Eurocent per vehicle kilometre

5.1.1 Direct costs

Overall we may conclude that the acquisition costs per passenger kilometre for infrastructure outside the built-up area are much lower than the acquisition costs for infrastructure within the built-up area. The reason is the higher land price within the built-up area. This effect outweighs the less intensive use of infrastructure outside urban areas.

5.1.2 Indirect costs

Hazardous goods routes

Indirect costs of roads are partly caused by the transport of hazardous goods, both within as well as outside the built-up area (other indirect costs outside the built-up area concern costs caused by segmentation). Of course, these costs only refer to goods transport (trucks).

The indirect land use implications outside the built-up area are rather small when measured in monetary terms. Because of the higher land price the indirect land use claim as a result of hazardous routes within the built-up area has costs per ton kilometre for trucks that transport less than 12 tonnes. For larger trucks they are much smaller.

Safety contours of hazardous goods in railway yards

The indirect costs of trains within the built-up area completely consist of costs caused by the indirect land use claim by railway yards. Also, these costs are only allocated to goods transport. Although the costs per ton kilometre are somewhat higher than for example the costs of the routes of hazardous goods

on roads, they remain limited. They form a minor addition to the results of CE and the direct acquisition costs of land.

Free sight zones and waterways
The costs per ton kilometre for inland shipping as a result of indirect land use claims by free sight zones are substantial. Outside built-up areas these costs are negligible however.

Noise nuisance contours for airports
Significant costs of indirect land use claims are observed for airports, especially for short haul trips because in this case the number of kilometres travelled is small so that the number of passenger kilometres is also small.

5.2 Addition to the CE results

Direct land use claim
In general, the influence of the acquisition costs of land on the total costs per passenger or ton kilometre can be considered important and significant, both absolute as well as relative to other costs. An extreme example is inland shipping for which the acquisition costs are higher than the construction costs.
Indirect land use claims
The influence of indirect land use claims on the costs per passenger or ton kilometre are significant only for airplanes (in particular the smaller types) and inland shipping.
Parking revenues
The parking revenues as a contribution to ‘taxes and subsidies’ are considered to be significant.

6. Missing cost components; research priorities

At the end of this paper it is important to examine which elements are still missing in the calculation of the external costs of transport. Below the omissions are classified in order of relevance, starting with the most relevant element.

1. *Damage as a result of the existence of infrastructure*

Some attention is paid to segmentation. The numbers on which the calculation is based are very limited though. Probably it is a large underestimation. The economic valuation of segmentation is just starting to develop.

2. *Waiting on intersections and junctions*

The analysis of congestion costs in The Netherlands has so far been aimed at congestion on high ways. Besides congestion on high ways there are a number of places where traffic bothers other traffic (cross sections, bridges, level crossing) which leads to longer travel times. The external costs of longer travel times are unknown, but they are likely to be high. Related forms of congestion of which we know hardly anything concern parking congestion and time loss as a result of speed differences between different traffic participants on roads and railways (see for instance Verhoef et al. 1999). This source of external costs occurs for all modalities from bicycle to airplane.

3. *Multiple land use and traffic*

In this study some simple choices concerning multiple land use are made regarding the allocation of space to traffic and other functions. An in-depth analysis is very desirable considering the increasing relevance of this subject.

4. *Types of disturbance by traffic*

No attention is paid to stench, vibrations and visual nuisance as a result of traffic. Also we limited ourselves to the effects on people. For example: dead animals as a result of traffic are left out of consideration.

5. External costs of parking

A tentative guess is that the marginal external costs of parking (for other car users and other road users) are small on the national level. However, hardly any research on these costs has been carried out. Further research is desirable.

6. Barrier effect as a result of infrastructure

The barrier effect has two dimensions, namely traffic flow dependent and non-flow dependent. As far as it is dependent on traffic volumes it has already been mentioned under 2. The non-traffic flow dependent barrier effect is often mentioned in a qualitative way in environmental impact assessment reports and in infrastructure construction proposals, but these reports and proposals offer insufficient starting points for financial quantification.

7. Types of effects: life cycle approach

The approach adopted here starts from the principle of external effects of the use of transport means. The effects of producing and recycling transport means are not considered here.

8. Types of modalities

Almost all modalities are included. Sea shipping is still missing though. Also bicycle and pedestrian have received little attention. Indeed, these cause few external effects, but the space claims are notable. Finally, urban rail infrastructure is missing (tram and subway). However, the meaning of the latter modality is small in terms of land use claims.

We may conclude that the costs of land use claims by infrastructure are mapped out to a reasonable extent. It would be interesting to be able to compare these costs to the benefits of infrastructure, including the benefits of value increase of land by infrastructure construction.

In this study, we have mainly discussed the marginal and fixed costs of transport. The question of how this should lead to an efficient system of prices is not included in this study. Broadly outlined it comes to this: prices should correspond to the marginal social costs as best as possible. A tax through the fuel excise can be considered, but is not accurate enough. A differentiated kilometre tax seems better, because this offers the possibility to confront the user with the social costs.

What about the fixed costs, including the space related costs? If congestion occurs, a congestion tax offers (under the assumption of constant returns to scale) the possibility to charge the user for long-term costs of the construction of infrastructure (Mohring and Harwitz, 1962). These long-term construction costs also include the spatial costs that are estimated in this study. Through the congestion tax, the fixed social costs of transport would then be precisely covered. If congestion does not occur, the total social costs will be higher than the short-term marginal costs. A fixed tax that corresponds with the fixed social costs could then be used. The space-related costs, which are determined in this study, will be included in this fixed tax.

Acknowledgement:

The Dutch Ministry of Transport funded the research. The authors thank Carmen Leutscher and Erna Schol for their comments on a draft version of this paper.

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