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Bruinsma, F.R.; Koetse, M.J.J.; Rietveld, P.; Vreeker, R.

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Frank Bruinsma
Mark Koetse
Piet Rietveld
Ron Vreeker

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Frank Bruinsma
Mark Koetse
Piet Rietveld
Ron Vreeker

Department of Spatial Economics
Vrije Universiteit
De Boelelaan 1105
1081 HV Amsterdam
The Netherlands
Phone: +31-20-4446096
Fax: +31-20-4446004
Email: fbruinsma@econ.vu.nl

Abstract:
In this paper the social costs of land use claims for transport infrastructure are investigated for The Netherlands. 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).*
We find that direct and indirect land use equals respectively 7.2% and 1.6% of the total area of The Netherlands. Indirect land use is especially important for aviation.
The importance of indirect land use is shown by the value of land involved. The economic valuation of the indirect land use is about 16% of the total land related costs of transport infrastructure.

1 INTRODUCTION

There are several reasons why the costs of transport are high on the politica1 agenda in many countries (see for example Greene et al., 1997)). One reason concerns the issue of extemal costs and ways of intemalising these into the prices paid by travellers and firms to induce socially optimal travel behaviour. Ignoring these extemal costs would lead to an over-exploitation of environmental resources. On the other hand, if prices charged would be too high this would lead to welfare losses because levels of transport activities would become too low. In this approach efficiency considerations play a centra1 role; the basic rule is that travellers should be charged the *marginal* costs.
In addition to this issue of efficiency, also issues of *fairness* often play a substantial role. One dimension of faimess is that users of transport infrastructure pay according to the total costs they impose on society (see for example Delucchi, 1997). This leads to an approach where *average* costs play a centra1 role. However, faimess can also be interpreted in other ways. For example, that subsidies to public transport are justified when it leads to transfers towards citizens who cannot afford the purchase of a car. Another dimension of faimess is that different infrastructure types are treated in a similar way. For example, it would be unfair when road users would have to pay for the use of roads whereas rail users would not be charged for their use of infrastructure. It is obvious that efficiency and faimess may be conflicting objectives, and that also the various faimess concepts mentioned here may be in conflict.

In this paper we will focus on one particular aspect of transport costs, i.e. the direct and indirect costs of land use related to transport. The reason is that little systematic attention has been paid to the land use costs of transport activities. Especially in densely populated countries such as the Netherlands the issue of scarcity of land and the negative spatial spill-overs of transport activities are important.

We start with some definitions. The social costs of transport are all costs of mobility summed up. It concerns intemal costs, extemal costs and govemment expenditures. In principal, the intemal 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 conceming 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 fi-om 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.

Conceming 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

Extemal costs are the financially appreciated negative extemal 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 extemal costs of transport. These hold for all modalities, but the price of these extemal costs may differ considerably per modality:

- Extemal 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.
- Extemal costs caused by standing vehicles.
- Extemal costs related to the existence of infrastructure: barrier effects, fragmentation of landscape and visual nuisance.

3. Government expenditures

The govemment expenditures on mobility are included in the extemal 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 intemal. These extemal costs include:

- Construction and maintenance of infrastructure, including facilities for the environment and traffic safety, such as noise barriers, and wild life viaducts;
- Traffic duties of police and justice;
- Other govemment activities (for instance license registration et cetera);
- Public transport subsidies and other transport related govemment expenditures.

In a recent study in the Netherlands, CE (1999) has produced estimates of substantial parts of the social costs of transport. In the present paper we use the CE estimates as a point of departure and discuss a number of additional dimensions of transport costs that are related to land use and that have not been included in this study. Table 1 gives an overview of the elements already covered and the added aspects from this study. Finally, the missing components that stil1 exist are presented.

Table 1: Overview of the cost components

Already covered by CE	Covered in this study	Remaining omissions
	Variable costs	
1. Maintenance and operational costs 2. Extemal costs: · Traffic accidents · Air pollution · Noise nuisance - Congestion (roads)		1. Barriers: - Waiting time at crossings - Visual barriers - Etc. 2. Extemal costs - Stench annoyance - Vibration annoyance 3. Fragmentation (nuisance and death of fauna by the use of infrastructure)
	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: - Detours - Visual barriers - Etc. 2. Extemal 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

Before analysing the various costs mentioned in table 1 we will first investigate in more detail the direct and indirect land use implications of transport (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 m^2 will be introduced 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

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. We use data on 1999.
In this subsection we will only discuss the measurement and land use of road infrastructure. The results of the measurement of the land use of the other infrastructure types will be briefly discussed in subsection 2.3.

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 lots;
- 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 (fi-om highway to forest road) and their minima1 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, cloverleafs, interchanges, entrance and exit ramps, and bus stops[3].

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[1] The land use of urban rail transport – tram and metro - is not included. It is about 3.3 km' in The Netherlands, which makes it almost negligible.
[2] For instance, the minima1 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 minima1 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 minima1 design demand of 6.5 meters.
[3] Assume that the additional land use claim of roundabouts, cloverleafs, 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", which is about 1.5% of the total area reported in table 3.

Within the built-up area also pavements, squares and ornamental paving are excluded. Tables 2 and 3 show an overview of infrastructural elements and their spatial claims. Considering the remarks above, the land use as presented in table 3 could be treated as minimum values.

Table 2: Road infrastructure in The Netherlands (length, number), 1998

	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 infrastmctural element lower boundary 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 and on private property[4]. Since financial valuation is the centra1 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 estimate the land claims of parking on public parking lots constructed alongside public roads. These are situated in built-up areas and are therefore reserved for passenger cars. The land use claim is determined by making assumptions conceming the relation between housing and parking values since 1 970[5].

[4] The land use for all three categories together is about 550 km', 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 take an average of 1.5 parking lot per house constructed in the period 1970-2000.

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 extemal effect, and not via its impact on indirect land use.
Whereas we restricted ourselves to roads in our discussion on the measurement of the direct land use, we discuss the indirect land use for all transport modes.

Transport of hazardous goods
Conceming the transport of hazardous goods, the Ministry of Transport considers two types of risks that negatively affect 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 intemalised 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 conceming 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 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.

Conceming aviation, extemal 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 extemal safety risk contours is 50 km^2 for the airports Schiphol, Maastricht, Rotterdam and Eelde, according to the RIVM (1999). However, this area is not included in the financial valuation, because the extemal safety risk contours are within the noise nuisance zones of the conceming airports (see below). Valuing these safety areas of airports would lead to double counting when also the noise zones would be evaluated.

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 govemment determined that the total area suffering from a noise nuisance leve1 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 leve1 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;

[6] This means that, in the case of hazardous materials transported via rail, there are no extemal costs related to indirect land use. However, the lack of safety zones around railway tracks means that there are potential extemal costs when accidents would take place. These should in principal be taken into account in the direct extemal effects of the transport of hazardous materials via rail.

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) is that 0.7 billion Euro would be needed to adjust the railway yards to the required noise nuisance limits. In addition, Railned expects that at least 800 kilometres of track must be provided with noise barriers to adjust the railway tracks to the required noise nuisance limits (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 smal1 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 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 intemal 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 smal1 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

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7 Again the extemal 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.

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 leve1 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 (rivers and canals) is about 215.8 km^2.

Note that the foreland of rivers usually remain unbuilt due to flood risks. 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, a distinction will be made between locations inside or outside the built-up area. The direct land use concerns the space occupied by 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%.

[8] The indirect land use claims by all regional and smal1 airports is 9.0 and 176.7 km' inside and outside the built-up areas, respectively.

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

In particular roads and waterways claim relatively much land, considering direct land use. Conceming 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, govemment 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).

Table 4: Overview of direct and indirect land use by infrastructure in The Netherlands, 1999

	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

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 4 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. Implications of transport related land use for the valuation of the social costs of transport

After this analysis of the direct and indirect land use implications of transport we continue with an analysis of the costs involved. Table 5 presents a detailed list of these land use types and their implications for the issue of valuing the social costs of transport. The middle column classifies the land use type in terms of 'direct' versus 'indirect' as discussed in section 2. The next column indicates whether or not the entailing land use has been included in the claims reported in table 4. The right hand column indicates whether or not the pertaining type of land use will be included in the computation of the social costs.

Most *direct* land use claims have already been included in the areas reported in table 4 and will also be included in the computation of social costs. 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.

Conceming *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 of hazardous goods* play a role in road traffíc, 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 counting.

[9] Remember that intemal costs of transport are not considered in this study (see section 1).

Table 5. Classification of land uses and implications for the social costs of transport.

Subject	Cost component	Direct / Indirect	Land use claim included in table 4	Included in computation of social costs
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 railway yard	Direct	Yes	Yes
	Hazardous goods (railway yard)	Indirect	Yes	Yes
	Noise nuisance zones	Indirect	No	No
	m^2 citv 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
Segmentation	Segmentation outside built-up area	Not space related	No	Yes
Barrier effect	Banier 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

- *Noise nuisance zones* are only relevant for airports; for relatively large zones limitations have been formulated conceming 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 free from buildings 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 use

The market for land in The Netherlands is defínitely not a perfect market: the government interferes heavily in order to deal with externalities and this has implications for land values[10]. The levels of the expropriation compensation vary slightly among provinces. But other factors play a role as well: for example the location of agricultural land near urban fiinges 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 the information on the prices of various types of land transactions 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 (at the urban fringe): 23 Euro per m^2;
- Outside the built-up area: 10 Euro per m^2.

The price per m^2 inside the built-up area is based on the average compensation landowners receive when their agricultural land is expropriated for urban expansion (either dwellings or industrial sites). The price outside the built-up area is the average compensation they receive when the land alongside the new infrastructure remains in use for agricultural purposes.

For *indirect* land use claims it is not so easy to develop an appropriate evaluation of the opportunity costs. One might be tempted to use the same figures as for the direct land use claims, but this would obviously lead to an overestimate, because it might well be that the constraints imposed are not binding. For example, if the land affected by transport in an indirect way is used for agriculture, and if this would also be the case when there would not be such a constraint, the actual costs involved are zero. Our approach to indirect land use can be summarized as follows:

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[10] 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) have been approached. Information on acquisition costs is hard to obtain. Some evidence is reported in Bruinsma et al. (2000).

- Within the built-up area: 50% of the vacant land is built on valued at a leve1 of 68 Euro per m^2;
- Outside the built-up area: 20% of the vacant land is built on valued at al leve1 of 4.5 Euro per m^2.

When the spatial planning regulations no longer forbid the construction of dwellings or industrial premises alongside infrastructure we assume that within the built up area 50% of the land will actually be built on. The other 50% will – according to the overall land use in urban areas - remain having a public function (park, infrastructure et cetera). The average value of land inside the built-up area on which it is allowed to build is about 91 Euro (compared to a value near zero when it is not allowed to build on). However, it would lead to an overestimate when we would value this land use claim at the leve1 of 91 Euro. The point is that the urban land use involved will take place elsewhere (we assume at the urban fringe0 where the value of the land is about 23 Euro. Therefore, the actual loss of value due to the indirect land use claim -when it is active- equals 91-23 =68 Euro per m^2.

However one can altematively built on land in the urban fringes. The value of agricultural land in the urban fringes is – as mentioned above – 23 Euro. Thus the preferential surplus value of urban land compared to land in the urban fiinges is 91 – 23 = 68 Euro per m^2.

Outside the built up area land is less scarce. It is not reasonable to expect that a high percentage of the land will be built on in case spatial planning restrictions will disappear. We assume that only 20% of the land will actually be built on. The remainder of the land will remain in its original function. Following the above reasoning one might come to the conclusion that the surplus value is the price of agricultural land receiving an urban function (23 Euro) minus the value of agricultural land (2.2 Euro). However in our opinion this is not a correct measurement. The main argument is that one could altematively build houses and/or industrial sites somewhere else. In that case on another location the value of land will rise by nearly 21 Euro. However, there is some preferential advantage to build dwellings and/or industrial sites on the location affected by the indirect land use restriction. In our computation of the social costs we use – quite arbitrary – a difference in value of about 4.5 Euro per m^2.

The costs of fragmentation of land by infrastructure deserve special attention. As a starting point, we use the Defence Expenditures method for calculating the costs of fragmentation. In this method, the expenditures of the govemment and firms on mitigating measures are used to calculate the annual costs of fragmentation. Data on expenditures that are made to counter this fragmentation are available; they are assumed to be depreciated in 35 years, similar to infrastructure expenditures. 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 expenditures of preventing fragmentation by roads as well as expenditures of preventing fragmentation by railways. However, the mitigating costs do not fully cover the actual costs of damage due to the construction of infrastructure. Expert meetings in The Netherlands indicated that the actual damage due to the fragmentation of the landscape by infrastructure might be estimated to be about 5 to 10 times higher than the expenditures on mitigating measures. In our computation of the social costs we take 5 times the prevention costs of fragmentation as a rather conservative estimation of the actual damage of fragmentation due to the construction of infrastructure.

5. Results

This section presents the results of this study in terms of social costs of transport. The infrastructure related costs will be allocated to transport modes in order to obtain insight into the social costs per transport mode. These results will be added to the findings from the CE-study mentioned in section 1.
In this section we will follow the graphical 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 CE-study and the results from this study are combined.

5.1 Costs of land use for various transport modes: a comparison with construction costs

The results for passenger and goods transport are summarised in tables 6 and 7 respectively. The average costs are computed by dividing the total costs involved by the transport volume per infrastructure type. In case more than one transport mode makes use of a certain infrastructure type, the costs have been allocated according to the intensity of use (see Bruinsma, et al., 2000, for details).
In both tables a distinction is made between five cost categories, namely:

- *Acquisition costs of land; urban*

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

- *Acquisition costs of land; rural*

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

Table 6: Land related costs and construction costs 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	Construction 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 500km	-		0.02	0.09	1.05
Airplane 1500 km	-		0.01	0.03	0.33
Airplane 6000 km	-	-	0.00	0.00	0.08

* These figures are computed as airport related costs divided by traveller kilometer. Hence, the costs are much higher for short haul trips than for long haul trips.

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	Construction 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 combi.	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 6000km			0.00	0.02	0.35

*In Eurocent per vehicle kilometre

- *'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 infi-astructure per modality as calculated by CE (source: CE, 1999).

5.1.1 Direct costs

Overall we may conclude that the acquisition costs per passenger kilometre for infi-astructure 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 smal1 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 con tours 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 construction costs as computed by 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.

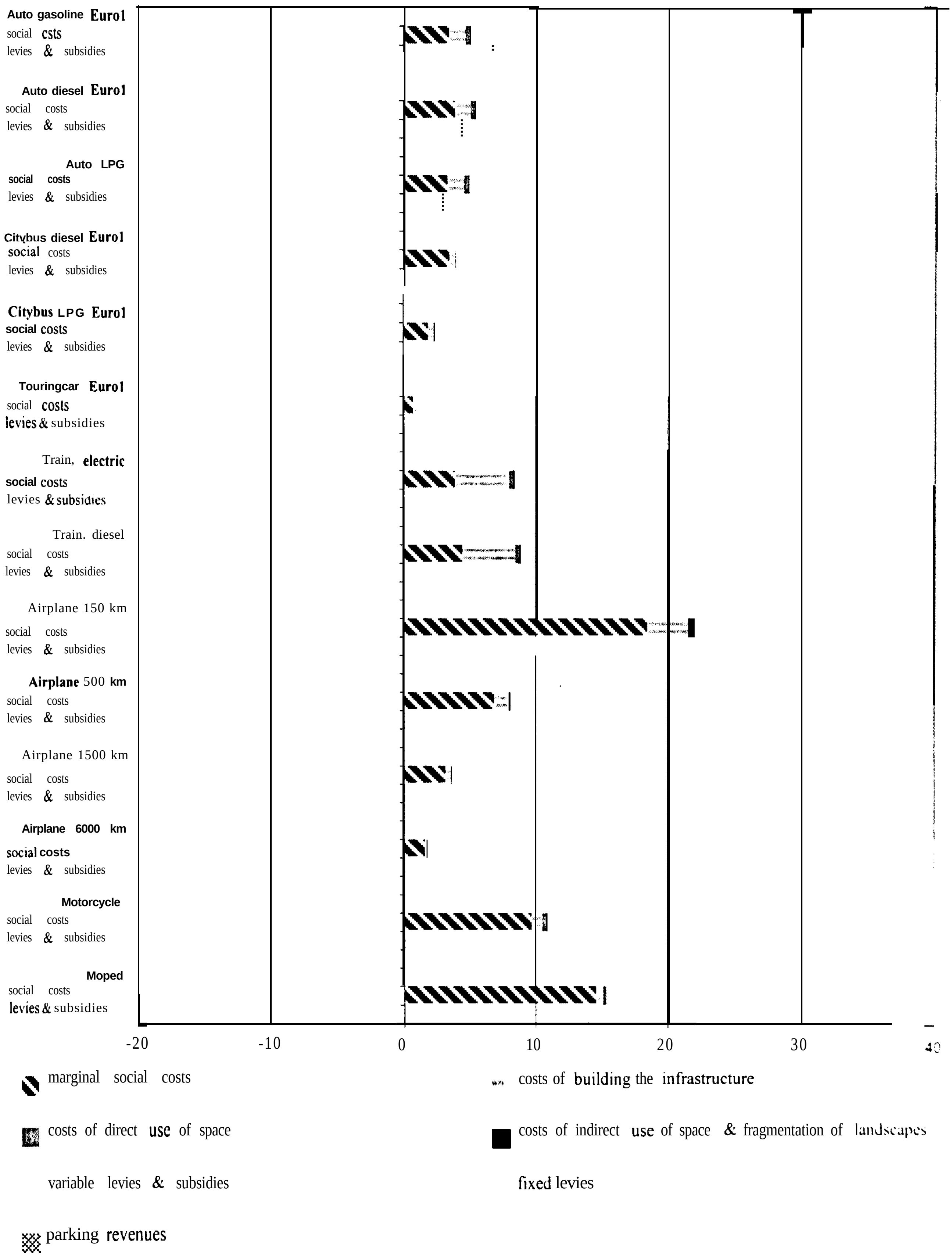

Figure 1: Social costs and levies & subsidies in passenger transport (in Eurocent per passenger kilometres)

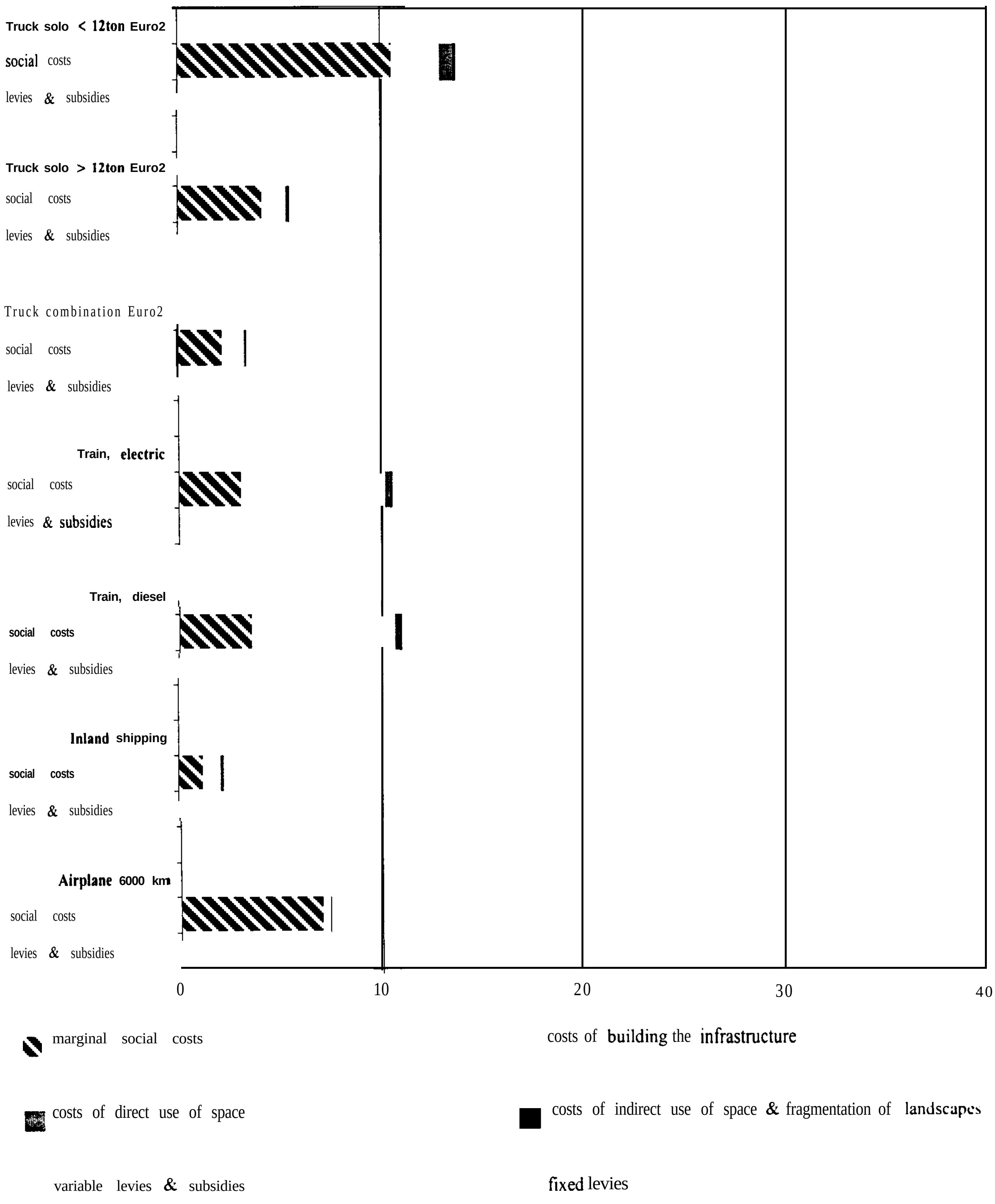

Figure 2: Social costs and levies & subsidies in goods transport (in Eurocent per tonkilometres)

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 relatively smal1 so that the number of passenger kilometres is also small.

5.2 Addtion to the overall CE results

In figures 1 and 2 the results of this study are added to the social costs, levies and subsidies of respectively passenger and good transport as computed by CE (2000). In our study we computed the following categories in figures 1 and 2:

- Costs of direct use of space;
- Costs of indirect use of space and fragmentation of landscapes;
- Parking revenues (only cars in case of passenger transport).

Which conclusions can be drawn when we add our results to the cost, levies and subsidies already computed before?

Direct land use claim

The influence of the acquisition costs of land on the total costs per passenger or ton kilometre can be considered important and significant, both in absolute and in relative terms. An extreme example is inland shipping for which the acquisition costs are higher than the construction costs.

Indirect land use andfragmentation 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[11]

The parking revenues as a contribution to 'taxes and subsidies' are considered to be significant. In 1998 the parking revenues were 257 million Euro (about 2% of all the revenues of the municipalities).

6. Missing cost components; research priorities

At the end of this paper it is important to examine which elements are stil1 missing in the calculation of the extemal costs of transport. Below the omissions are classified in order of relevance, starting with the most relevant element.

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[11] Parking revenues have not been taken into account by CE (2000). We fínd that they are not neglegeable nowadays. They are to increase considerably in the future.

1. Damage as a result of the existence of infrastructure (fragmentation)

In the literature much attention is paid to the extemal costs of the use of infrastructure. However, the existence of infrastructure is often neglected as a source of extemal effects. Segmentation of open space is an important issue in a densely populated country like The Netherlands. In section 4 we gave a conservative estimate of fragmentation costs based on a prevention cost approach. There is a clear need for the development of more refined approaches addressing the damage costs directly.

2. Waiting on intersections and junctions

The analysis of congestion costs in The Netherlands has so far been aimed at congestion on expressways. Besides congestion on expressways there are a number of places where traffic bothers other traffic (cross sections, bridges, leve1 crossing) which leads to longer travel times. The extemal 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 extemal costs occurs for all modalities from bicycle to airplane.

3. Multiple land use and traffic

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

4. Types of disturbance by traffic

NO attention is paid to stench, vibration and visual nuisance as a result of traffic. Also we limited ourselves to the effects on human beings. For example: dead animals as a result of traffic have been left out of consideration.

5. External costs ofparking

A tentative guess is that the marginal extemal costs of parking (for other car users and other road users) are smal1 at the national level. However, hardly any research on these costs has been carried out. Especially at the local leve1 these costs may be considerable, for example, in historica1 city centres. 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 stil1 missing though. Also bicycle and pedestrian have received little attention. Indeed, these cause few extemal 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 have been mapped out to a reasonable extent in this study. It should be emphasised that we focussed on the costs of transport. The question of how this should lead to an efficient system of prices has not been addresses 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 may be a reasonable proxy. However the extemal costs will depend on situational conditions. Therefore, a differentiated kilometre charge may be preferred.

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.

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