Social Costs of Direct and Indirect Land Use by Transport Infrastructure.

An Estimation for The Netherlands

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In this paper the social costs of land use for transport infrastructure are investigated for the Netherlands. We pay attention to the acquisition costs of land for infrastructure and the indirect costs of land use caused by transport. The paper gives an overview of the problems associated with measuring land related costs of transport infrastructure. Estimates are given of land use (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, and aircraft) on the basis of their relative transport kilometres and their passenger car equivalents. 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 appears to be 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 costs of transport are high on the political agenda in many countries (see for example Greene *et al.*, 1997). One reason concerns the issue of external costs and ways of internalising these by pricing travellers and firms in order to induce socially optimal travel behaviour. Ignoring these external 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 central role. The basic rule is that travellers should be charged the *marginal* costs.

In addition to the issue of efficiency, also issues of *fairness* often play a substantial role in transport pricing. One dimension of fairness is that users of transport infrastructure pay according to the *total* social costs they impose on society (see for example Delucchi, 1997). This leads to an approach where *average* costs should be charged to the users. However, there are other dimensions of fairness (see Rietveld, 2003). For example, subsidies to public transport could be justified when they lead to transfers towards citizens who cannot afford to purchase a car. Another example could be that similar 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 the rail infrastructure.

Let us, before addressing our study object, discuss the concept of social costs in some detail. Social costs of transport are basically equal to the sum of all costs of mobility and may be separated into internal costs, external costs and government expenditures (though there is some overlap in this categorisation). Internal costs are private expenditures on transport, apart from transport taxes. All costs that households and firms make for transport could be included, e.g. costs of depreciation and maintenance of vehicles, ships and aeroplanes, costs of insurance, fuel costs, costs of train tickets and freight prices. The internal costs are not taken into account in this study since the market mechanism charges these costs directly to the users. It is assumed here that the market mechanism ensures a correct pricing and that market failures are absent. External costs are financial costs related to negative external effects of transport that are not charged to the user. The user subsequently does not take these costs into account when making transport related decisions. Verhoef (1996) distinguishes three types of external costs of transport, i.e. external costs from actual transport activities, external costs caused by parked vehicles and external costs related to the existence of infrastructure. Though these externalities hold for all modalities, the magnitude of these external costs may differ considerably per modality. Government expenditures on mobility can be considered as external costs as long as the user does not (or only partly) take these into account in his or her mobility decision. Only if the government charges the user directly for the costs, these costs are internalised. These expenditures 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 government activities (for instance license registration et cetera), public transport subsidies and other transport related government expenditures.

In this paper we use the concept of fairness as the background for our analysis, i.e. charge users the average social costs of transport and transport infrastructure. In a recent study in the Netherlands (CE, Solutions for environment, economy and technology, 1999) estimates were made of a substantial part of these costs. In this paper we will focus on a category of average costs that was not accounted for in the CE (1999) study, i.e. the *direct* and *indirect* costs of land use related to transport. Especially in densely populated countries such as the Netherlands, the issue of scarcity of land and the negative spatial spillovers of transport activities may be very important. In international context, some of the more methodology oriented documents do (see for instance Link and Maibach, 1999 and Litman, 1995 and 2002) and some do not (see for instance DOT, 1997 and CEC, 1998) explicitly address social costs related to land use by infrastructure. The same holds for the empirically oriented studies. The results by IWW/Prognos (2002) clearly incorporate land use related costs, while this is unclear for the results by Link *et al.* (2000) and Sansom *et al.* (2001). Moreover, if land use costs are included at all, above mentioned studies only include costs of direct land use. Indirect land use costs hardly receive any attention (a notable exception being ECONorthwest, 2001).

Table 1. Overview of social costs of transport and infrastructure

Covered by CE (1999)	Covered in this study	Remaining omissions
	Variable costs	
• Infrastructure maintenance and operational costs • External costs: - Traffic accidents - Air pollution - Noise nuisance - Congestion (roads)		*External costs* • Barriers: - Waiting time at crossings - Visual barriers • Annoyance: - Stench - Vibration - Visual • Negative effects on fauna and flora.
	Fixed costs	
• Infrastructure construction costs	• Costs of direct land use • Costs of indirect land use due to: - Noise nuisance zones - Free sight zones - Zones transport hazardous goods (safety contours)	*External costs* • Barrier effects: - Detours - Visual barriers • Fragmentation of landscape • Other costs: - Presence of cars in public space - Parking congestion - Production, distribution, maintenance & destruction of cars and infrastructure (land use & emissions) - Production & distribution of fuels (land use & emissions)

Furthermore, despite the fact that some fixed levies already exist in the Netherlands, it is unclear what the magnitude of the levies are based on. The results of our analysis may therefore be seen as a first attempt at explicitly calculating average user costs related to land use per transport mode, taking into account the intensity of the use of infrastructure. Moreover, the categories of average costs that should be taken into account are made explicit. Regarding the latter, Table 1 gives an overview of the cost elements accounted for in the CE (1999) study, the cost elements covered in this study and the cost components that are still to be accounted for in future research.

This paper is further organised as follows. In Section 2 we discuss the methods we use to measure social costs of land use by transport infrastructure. Section 3 is dedicated to describing and calculating the direct and indirect land use for each distinguished infrastructure category, while Section 4 will discuss at what prices we value direct and indirect use of land. In Section 5 the results of our analysis, the average social costs of land use per transport mode, will be discussed and compared with the average construction costs of infrastructure calculated by CE (1999). Finally, Section 6 provides conclusions and suggestions for future research.

2. Methodology

In this paper the social costs associated with land use by transport infrastructure are estimated and allocated to the users according to the intensity with which they make use of the infrastructure. The question addressed in this section is how to measure social costs of land use. Below we subsequently discuss measuring social costs of direct land use and social costs of indirect land use.

Since transport infrastructure was and still is a public good in the Netherlands, the land used for infrastructure is paid for by the government instead of directly by the users of the infrastructure themselves. If the latter would have been the case in the Netherlands there would be no reason to conduct the underlying study since costs of land use would have already been internalised. We will have to choose from two possible methods to estimate social costs of infrastructure land use. First, we could estimate the land prices that would have resulted should the users of infrastructure have purchased the land directly. Second, we could use the prices of land that were actually paid by the government. Because this paper is not about estimating land prices of a hypothetical market but about allocating the *actual* social costs of infrastructure land use to the users according to their use of infrastructure, we have chosen to use the second method. Other important arguments in favour of the second method are that the first method would have to deal with larger uncertainties and would take much more time and resources (both because of the fact that the first method deals with a hypothetical market).

An argument can be made that neither the first method nor the second measures total social costs of direct land use by infrastructure, basically implying that some land use values are not internalised by the market. A typical example of land use values that are not or only partly valued by the market are option values. Option values result from the fact that if land is sold now for the purpose of building infrastructure, it cannot be used in the future (or possibly only at a high cost) for other more profitable purposes. If this option value is not included in actual land prices then using market values would lead to an underestimation of social costs of direct land use. Relevant questions are then whether it is likely that some option values are not included in land prices and how large these option values are likely to be. A first observation is that there seems to be a trade-off between these two variables, that is, the larger the option value, the larger the chance that the market is aware of its existence and has included it in actual land prices. A second observation is that it is likely that the central government includes option values in its spatial policies, i.e. that it does not purchase land for infrastructure purposes if it is more profitable to use this land for housing or industrial purposes. Nevertheless there may be specific cases such as the construction of an airport near a city that expands in the long run where the option value of the land used for the airport would be high. We did not explore this issue in depth, however.

The second issue is how to measure social costs of indirect land use. Indirect land use effects of infrastructure occur because the external effects of transport make adjacent land less useful. Some of these effects can be studied by hedonic pricing methods (decrease of value due to noise). But this is not the complete effect, because in addition there will be land that remains mainly unused because of the nuisance. Little is known about this effect. In the present study, we approximate it by the restrictions government puts on the use of land adjoining infrastructure. As we shall see in subsequent sections there can be a number of reasons for this, such as noise pollution and risks associated with the transport of hazardous goods. Should these land use restrictions not have been imposed, the owners (or users) of the land would face the question how to use the land. An extreme case would be that they just do not take into account the issues like noise and risks of transport of hazardous goods. In that case the costs of indirect land use would be zero, but the direct external costs of transport would of course increase (see the left column in Table 1). However, land owners will probably find that these costs are so high that they cannot be ignored. For example, the noise and risks would lead to lower rental values of dwellings in these zones. Thus, the owners are stimulated to adjust the use of the land and only build property on it at those places that are sufficiently far away. In addition, land owners could take other preventive measures such as insulation against noise. This would lead to a market-based estimate of the costs involved. In the present paper we will not adopt this approach but approximate these costs by the costs resulting from the government imposed restrictions on land use. It remains an interesting issue to what extent these restrictions are at an appropriate level. If they would be too strict, this would imply that the indirect costs are overestimated.

3. Direct and indirect land use by transport infrastructure

3.1 Direct land use

The infrastructure categories that are included in the calculation of land use of transport infrastructure are roads, railroads, waterways, ports and airports.[1] An important feature of the first four infrastructure types in the Netherlands is that they are considered public goods and that individual users do not pay according to the capacity or intensity with which they use the infrastructure. The direct land use of airports on the other hand consists of private areas of which the acquisition costs have already been charged to the user. Therefore, these costs are not included in our social cost analysis. Furthermore, the costs of direct land use by waterways are not financially allocated because the main function of waterways is water management. In this subsection we will therefore only focus on the measurement of land use by road infrastructure, railroad infrastructure and ports.

Road infrastructure
In order to determine the land use by road infrastructure, a distinction is made between ‘Roads within built-up areas’, ‘Roads outside built-up areas’, ‘Individual parking spaces’, ‘Gas stations’ and ‘Service (and parking) areas along highways’. In calculating the land use of roads inside and outside the built-up areas we use data from Statistics Netherlands (CBS, 1996 and 1997) on the length of eight types of roads (from highway to forest road). Furthermore, we use data from the research agency of the Dutch Ministry of Transport, Public Works and Water Management (AVV, 1986 and 1992) on minimal design demands of roads outside the built-up area and data from the Information and Technology Centre for Transport

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

and Infrastructure (CROW, 1996) on the design of infrastructure inside the built-up area.[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, cloverleaves, interchanges, entrance and exit ramps, and bus stops.[3] Within the built-up area, pavements, squares and ornamental paving are also excluded.

As for land use of individual parking spaces, we exclude both private parking spaces because they represent internal costs, and parking spaces on public roads because their land use is included in the land use of roads as described above. Unfortunately, for the remaining category of parking spaces (public parking spaces on parking lots) no direct data on land use are available. However, parking norms in the Netherlands indicate that the number of public parking spaces per house is on average 1.5. The number of houses in 1999 in the Netherlands amounts to 3.240.900 (CBS, 2000) and the size of a parking space is approximately 24.5 m^2 (Arcadis, 1998). The land use by public parking spaces then amounts to 119.1 km^2 (3.240.900 x 1.5 x 24.5 m^2). Since public parking lots are situated solely inside the built-up area, they are reserved for passenger cars and delivery vans. The costs associated with land use by parking spaces are therefore allocated to these transport categories only.

The exact number of gas stations in the Netherlands is unknown. The 'Branche Behartiging Tankstations' estimates that there are approximately 4075 gas stations of which 275 along motorways.[4] The latter is important since their land use will be included in calculating the land use by service and parking areas and will thus be excluded here. Since the spatial design of gas stations is not standardised, we have to make a number of assumptions regarding spatial design of elements of gas stations and on the number of elements for gas stations inside and outside the built-up area (see Bruinsma *et al.*, 2000, for details). The surface of gas stations inside and outside the built-up area amounts to 341 m^2 and 966 m^2 respectively. This results in a total land use of 0.9 km^2 inside and 1.1 km^2 outside the built-up area.

Policy of the Ministry of Transport, Public Works and Water Management is aimed at having a service and parking area every 20 km along highways and a service and parking area with a restaurant every 40 km (Arcadis, 1998). Based on this we should have 240 service and parking areas along highways (120 on one side and 120 on the other). However, the previous paragraph mentioned a number of 275 gas stations along highways. We therefore assume that there are 275 service and parking areas. Given the policy mentioned above there are an equal number of service areas with and without restaurants. We therefore assume that there are 137 service areas with and 138 service areas without a restaurant. On the basis of some examples in Arcadis (1998) we estimate land use of a service and parking area inside and outside the

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[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, cloverleaves, 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.

[4] 'Branche Behartiging Tankstations' is basically an organisation for the protection of interests of gas stations. Information was got by contact over the phone.

built-up area at 50,000 m^2 and 65,000 m^2 respectively. The total land use of service and parking areas then amounts to 15.8 km^2.

Table 2. Estimations of road infrastructure in the Netherlands (length, number), 1998

	Inside built up-area	**Outside built-up area**
Paved roads	55,200 km	51,650 km
Unpaved roads	1,100 km	10,000 km
Bicycle paths and strips	8,400 km	10,550 km
Individual parking spaces	4,860,000	N.A.
Gas stations	2,650	1,400
Service and parking areas	N.A.	275

Source: CBS (1996 and 1997), Arcadis (1998), Branche Behartiging Tankstations.

Table 2 shows the length of several road categories and the number of relevant road related infrastructural elements. Table 3 gives an overview of the direct land use of these types of infrastructure in the Netherlands. The total area of road infrastructure in the Netherlands adds up to 1,300 km^2, which is approximately 3.9% of the total Dutch land surface (33,906 km^2). Considering the remarks above, the figures presented in Table 3 should be considered minimum values. Furthermore, land use by gas stations and parking spaces are the least solid figures in this calculation since a number of assumptions had to be made on their spatial design.

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	N.A.
Gas stations	0.9	1.1
Service and parking areas	N.A.	15.8
Total	505.3	804.6

Source: AVV (1986 and 1992), Arcadis (1998), CBS (1996 and 1997), CROW (1986), Branche Behartiging Tankstations.

Railway infrastructure

For the calculation of direct land use by railway infrastructure we use data from the land register of the Dutch Railway Company (Kadaster NS) and further information provided by Railinfrabeheer (a subdivision of the Dutch Railway Company). The land register distinguishes the use of land of three subdivisions of the Dutch Railway Company, i.e. Railinfrabeheer, NS Vastgoed and NV Nederlandse Spoorwegen. The land in hands of Railinfrabeheer all lies outside the built-up area, while the land in hands of the other two subdivisions lies within the built-up area. In total, the direct land use by railroad infrastructure in the Netherlands amounts to 125.3 km^2, of which 59.4 km^2 inside and 65.9 km^2 outside the built-up area.

Ports

In general it is difficult to determine the direct land use on the *landside* of ports because there is no uniform definition for port infrastructure as yet. It is however clear that nearly all land on the landside of ports is sold or rented to private companies. As such, the costs associated with this type of land use are already internalised by the users and we will not include them in this study. We will instead focus on the waterside of ports. Two elements are of interest here, i.e. the surface of port basins and the surface of areas in ports that serve as a place to stay overnight for inland navigation. The data for the first element are got from the 'Meetkundige Dienst Eindhoven' and are based on digital topographical maps. They estimate the land use of seaports and inland ports to be 47.4 km^2 and 9.15 km^2 respectively. As for the total area meant for overnight stay, AVV (the above mentioned research agency of the Ministry of Transport, Public Works and Water Management) estimated it at 3.15 km^2 based on the geographical information system 'Vaarwegkenmerken in Nederland 1998'.

3.2 Indirect land use

Indirect land use relates to government imposed restrictions on the use of land located near infrastructure. There are three reasons for the government to impose these restrictions, namely transport of hazardous goods (expressed in risk contours), noise nuisance zones and free sight zones. For reasons of clarity, note that indirect land use claims are only investigated if land use restrictions based on spatial planning regulations exist. For instance, costs associated with zones where noise nuisance is experienced but where no building restrictions exist by spatial planning regulations are *not* taken into account. The argument is that noise nuisance in this case should be valued directly as an external effect, and not via its impact on indirect land use. Below we will discuss for every type of infrastructure the indirect land use implications due to transport of hazardous goods, noise nuisance zones and free sight zones.

Transport of hazardous goods

Concerning the transport of hazardous goods, the Ministry of Transport, Public Works and Water Management 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 do 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 deliveries of LPG (Liquefied Petroleum Gas). The indirect land use claim alongside the road network as a result from the transport of hazardous goods for the Netherlands amounts to 21 km^2 (RIVM, Research for Man and Environment, 1999). In addition, there are strict requirements for LPG 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.[5] 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).
Concerning aviation, external safety risk contours are determined for a number of *airports*. These contours relate to the risk of an aircraft crashing where people at the ground level are exposed to. The total indirect land use claim within these external safety risk contours is 50 km^2 for the airports Schiphol, Maastricht, Rotterdam and Eelde (RIVM, 1999). 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). Valuing these safety areas of airports would lead to double counting when also the noise zones would be evaluated.
Finally, 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 water.

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, 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)[6] 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. It increased to 2,900 km^2 in 1991 but has stabilised after this period. The measures to stabilise/reduce the noise nuisance levels are basically focused on reducing the noise production at the source. These measures include silent road surfaces (ZOAB) on the main network, increasing noise requirements for vehicles, maintaining maximum speed limits, decreasing car use and, if necessary, extra noise barriers. However, 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 on land use. The expectation of Railned (organisation that determines the capacity on the Dutch railway network) is that 0.7

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[5] 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 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.

[6] The term dB(A) means decibel measured with a certain weighting method called method A.

[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 that people in dwellings experience is usually taken into account, but that other aspects of nuisance such as for people outside dwellings and for fauna are usually ignored in studies of this type.

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, i.e. the 35 Ke[8] day zone, the Laeq-26 dB(A) night zone[9] and the 47 BKL (noise measurement scale for small aeroplanes) zone. The latter zone concerns smaller aeroplanes and is applied for the remaining four regional and small airports used for scheduled line services and charters. The first two zones are relevant when considering larger civil aeroplanes and are applied for Schiphol and Maastricht. For Schiphol however, a larger zone than the 35 Ke zone, called the protection zone, should be used to calculate indirect land use.
The protection zone reflects the indirect land use claim by Schiphol caused by noise nuisance. Within this zone it is forbidden to build new houses or other buildings with functions sensitive to noise, such as hospitals and schools. 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. This figure should be decreased with the internal area of the airport, equal to 26.8 km^2, to prevent double counting. For the remainder of the protection zone it is possible to separate the area into ‘inside 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 is 144.7 km^2 and 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 (Rijks Luchtvaart Dienst). 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.[10] 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 area 40.2 km^2 and within built-up area 3.3 km^2).

Free sight zones
For waterways a free sight zone for ships 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 (rivers and canals) is about 215.8 km^2. Note here that the foreland of rivers usually remains unbuilt due to flood risks. There might therefore 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

[8] ‘Ke’ stands for ‘Kosten eenheid (unit)’, named after Professor Kosten who defined how to best measure noise produced by aeroplanes. The maximum Ke value in the Netherlands is 35 Ke.
[9] ‘Laeq’ stands for ‘Lawaai equivalenten’ or ‘Noise equivalents’. It measures the amount, length and frequency of aeroplane noise in bedrooms. The maximum Laeq is 26 dB(A).
[10] The indirect land use claims inside and outside the built-up areas by all regional and small airports is 9.0 km^2 and 176.7 km^2 respectively.

indirect land use claim by waterways. Therefore, if it exists at all, overestimation is probably small.

3.3 Overview of direct and indirect land use

Table 4 gives an overview of the direct and indirect land use by transport infrastructure in the Netherlands. In the calculations we had to make an assumption on how we divide direct and indirect land use by waterways on the one hand, and indirect land use of roads resulting from the transport of hazardous goods on the other, between land use inside and outside built-up areas. We have assumed that these land use claims are divided into land use inside and outside the built-up area according to the share of built-up area in the Netherlands, which is 10%. Furthermore, 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, we estimated the share that lies above built-up areas to be 5% instead of 10%. Finally, 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 concerned pay directly for the safety zones around their transhipment and storage activities.
Regarding *direct* land use, roads and waterways put a relatively large claim on land. Regarding *indirect* land use claims, especially the space for free sight zones along waterways and the noise nuisance zones of airports put restrictions on land use of lots adjoining infrastructure. It should be noted that the noise nuisance zones by roads and railways are relatively large. However, since government policies are directed towards the prevention of noise production at the source (infrastructure, car and train), no regulations restricting land use alongside roads and railways exist.

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 infrastructure *of which*	505.3	804.6	2.1	18.9
- Roads	360.0	748.0	2.1	18.9
- Parking lots	119.1	-	-	-
City rail	3.3	-	-	-
Railways	59.4	65.9	3.0	-
Waterways	130.2	1,172.2	15.7	200.1
Ports	59.7	-	-	-
Schiphol airport	-	26.8	8.4	222.8
Regional airports	-	16.7	≈ 3.3	≈ 61.9
Small airports	-	5.5	≈ 5.7	≈ 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 landtied 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. This figure of 4.4% seems to be slightly higher than the 4.0% mentioned by the Statistic Netherlands (CBS, 1997). However, the Statistics Netherlands only counts roads, railroads and airports, whereas we added land use for parking lots as well. Without parking lots the land use of infrastructure will be 4.0% in our study.

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

Subject	Cost component	Direct / Indirect	Included in Table 4	Included as social costs
Parking	Public parking spaces	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
	m2 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**

* Of the land use (km2) of seaports 20% is allocated to inland shipping for joint use. The other 80% is allocated to seaports only. Social costs of sea ships are not included in this study.

** The indirect land use outside the built-up area of Schiphol airport included in this study is 144.7 km^2. For the other airports the indirect land use inside and outside the built-up area is 3.3 km^2 and 40.2 km^2 (see Section 3.2).

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. From the bottom row of Table 4 we can derive that 60% of total land use 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 total land use by infrastructure relates to indirect land use within the built-up area. We end this section with a detailed overview of the direct and indirect infrastructure land use categories and whether or not they are included in the calculation of average social costs of land use by transport infrastructure (see Table 5).

4. Valuation of land

The market for land in the Netherlands is definitely not a perfect market. The government intervenes heavily in order to deal with externalities and this has implications for land values. 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 fringes can affect the value of land to a great extent. Next to the acquisition costs of land, the acquisition costs of 'objects' should be taken into account. 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. Below we discuss the various land prices we will use for calculating the social costs of land use by transport infrastructure. In Table 6 these land prices are summarised.

Table 6. Financial valuation of land (in Euro per m^2)

	Inside built-up area	Outside built-up area
Direct use of land	23.0	10.0
Indirect use of land	68.0	4.5

In order to get insight into the acquisition costs of land for infrastructure, a number of regional divisions of Rijkswaterstaat (a department of the Ministry of Transport, Public Works and Water Management responsible for the provision of infrastructure) have been approached.[11] For a detailed description of how we arrived at the land prices in this study see Bruinsma *et al.* (2000). Based on the information of 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 the acquisition costs inside the built-up area (at the urban fringe) varied from 18 to 27 Euro. Therefore, we assume that the average acquisition costs inside the built-up area are 23 Euro per m^2. This price is based on the average compensation landowners receive when their agricultural land is expropriated for urban expansion (either dwellings or industrial sites). Outside the built-up area the acquisition costs varied from approximately 6.5 to 13.5 Euro. The average acquisition costs are therefore assumed to be approximately 10 Euro per m^2. This price is the average compensation landowners 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 valuation as for the direct land use claims, but this would obviously lead to an overestimation because it might be that the constraints imposed are not binding. For example, if the land affected by transport in an

[11] It is reassuring to observe that the average acquisition costs of land provided by the regional directions of Rijkswaterstaat were in congruence with acquisition costs of land provided by other studies on land prices (see specifically Kolpron, 1998). Other information sources were Aalbers et al. (1999), CPB (1999) and TauwMabeg (1998).

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. 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 would 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 built-up areas on which it is allowed to build is on average approximately 91 Euro (compared to a value near zero when the land is not allowed to be built on). However, it would lead to an overestimation of costs when we would value indirect land use at this price. The argument is that under the restrictions, building will take place elsewhere. In this situation the difference in land prices between this location and the restricted location should be our measure of value. We have assumed that instead of building at the now restricted areas, building will take place at the urban fringe where the value of the land is on average approximately 23 Euro. Therefore, the actual loss of value due to indirect land use equals 91-23 = 68 Euro per m^2.
Outside the built up area land is less scarce. Therefore, it is not reasonable to expect that a high percentage of the land would be built on in case the spatial planning restrictions are removed. We assume that only 20% of the land outside the built-up area (opposed to the assumed 50% inside the built-up area) would actually be built on should the restrictions be removed. The remaining 80% of the land is assumed to retain its original function. Following this 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 measure. The main argument is that because of the restrictions at the preferred location, houses and/or industrial sites will be built at other locations. In this case the value of land will rise by somewhat less than 23-2.2 Euro, because this is not the most preferred location and hence the pertaining bid price must be lower. In our computation of the social costs we use, quite arbitrarily, a difference in value between the most preferred and the second best location of approximately 4.5 Euro per m^2.

5. Results

This section presents and discusses the results of our study. In the first subsection the land related costs will be allocated to the relevant transport modes in order to obtain insight into the social costs of land use per transport mode. These results will be compared to the findings from the CE (1999) study on the construction costs per transport mode mentioned in Section 1. In the second subsection we will discuss the sensitivity of the results to changes in the most important assumptions made in this study.

5.1 Costs of land use for various transport modes

Because land does not lose its value over time, the social costs of land use consist of interest costs only. This in contrast to for instance construction costs of different types of infrastructure (see CE, 1999), which consist of interest costs plus depreciation costs. Interest costs are calculated at an interest rate of 4% per year (according to the official guideline of the Dutch Ministry of Finance, 1995). In Table 7 the total interest costs of land use are summarised.

Table 7. Overview of interest costs of land use by infrastructure (in mln Euro per year)

	Direct land use		**Indirect land use**	
	Inside built-up area	**Outside built-up area**	**Inside built-up area**	**Outside built-up area**
Road infrastructure *of which*	436	305	2.9	0.7
- Roads	327	299	2.9	0.7
- Parking lots*	108	-	-	-
Railways**	54	26	4.1	-
Waterways	-	-	21	7.3
Ports	20	-	-	-
Airports	-	-	1.6	6.7
Total				

* Allocated to passenger cars and delivery vans only.

** For the allocation of railway costs to passenger and goods transport we conform to the CE (1999) study. The costs are allocated for 80% to passenger transport and for 20% to goods transport.

As we can observe, social costs of direct land use are substantial in absolute terms, especially for road infrastructure. In contrast, social costs of indirect land use are relatively small compared to social costs of direct land use. An exception is the social cost associated with the free sight zones alongside waterways, bot inside and outside the built-up area. Also social costs of noise nuisance zones near airports are somewhat higher than other costs of indirect land use.

In order to divide the social costs of direct and indirect land use over the relevant transport modes, we use the intensity with which the different transport modes make use of the infrastructure. The intensity measure is calculated by multiplying the transport kilometres per vehicle type with its passenger car equivalent (pae). Mainly because we also want compare our results to some of the results from the CE (1999) study, we use the same figures on transport kilometres and pae as in the CE (1999) study (see Bruinsma *et al.*, 2000, for details). The resulting costs per passenger transport category are divided by the transport kilometres times the number of average passengers, resulting in the average costs per passenger kilometre. Regarding goods transport the average costs per transport mode are divided by the transport kilometres times the average weight transported, resulting in the average costs per ton kilometre. The results for both passenger and goods transport are summarised in Table 8.

In this table, six columns are distinguished. The first two columns represent the acquisition costs of direct land use, respectively inside and outside the built-up area, and columns three and four represent costs related to indirect land use by respectively infrastructure inside and infrastructure outside the built-up area. In the fifth column the costs of direct and indirect land used are added up to get the total average social costs of land use. Finally, in the last column we present the average social costs of infrastructure construction as reported in the CE (1999) study.

Table 8. Average social costs of land use and the construction of transport infrastructure for passenger and goods transport.

	Direct land use inside	Direct land use outside	Indirect land use inside	Indirect land use outside	Total social costs of land use	Construction costs (CE, 1999)
Costs of passenger transport (in Eurocent per passenger kilometre)						
Car	0.77	0.19	-	-	0.96	1.15
City Bus	0.13	0.05	-	-	0.17	0.30
Touring car	0.05	0.02	-	-	0.06	0.11
Motor bike	0.71	0.25	-	-	0.96	0.76
Moped	0.35	0.13	-	-	0.48	0.38
Train	1.11	0.13	-	-	1.24	4.02
Aeroplane 150km*	-	-	0.09	0.38	0.47	2.99
Aeroplane 500 km	-	-	0.02	0.09	0.11	1.05
Aeroplane 1500 km	-	-	0.01	0.03	0.03	0.33
Aeroplane 6000 km	-	-	0.00	0.00	0.01	0.08
Costs of goods transport (in Eurocent per ton kilometre)						
Delivery van **	0.92	0.30	0.00	-	1.23	1.83
Truck solo < 12t	1.06	0.38	0.12	0.01	1.57	2.29
Truck solo > 12t	0.30	0.11	0.04	0.00	0.45	1.14
Truck combination	0.21	0.08	0.02	0.00	0.31	0.97
Train	1.11	0.10	0.10	-	1.31	7.10
Inland ship	2.17	-	2.34	0.02	4.53	0.81
Aeroplane 6000 km	-	-	0.00	0.02	0.02	0.35

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

** In Eurocent per vehicle kilometre.

Overall we may conclude that the costs of direct land use per passenger kilometre of infrastructure are much lower outside than inside the built-up area. The reason is the higher land price inside the built-up area in combination with the more intensive use of infrastructure outside urban areas. Costs of direct land use appear to be considerable compared to the construction costs calculated by CE (1999). Regarding passenger transport, land acquisition costs for motor bikes and mopeds are about 25 percent higher than the construction costs. For automobiles and touring cars and city busses these factors are approximately 0.8 and 0.6 respectively. Furthermore, although acquisition costs of land are highest for trains in absolute terms, they amount to only a factor 0.3 of the construction costs.

Regarding goods transport the most striking result concerns the large costs of land acquisition for inland shipping, both in absolute terms and relative to the construction costs (approximately a factor 2.7). For delivery vans and solo trucks < 12 ton these factors are approximately 0.7 and 0.6, while for the solo truck > 12 ton and the combination truck they are around 0.3. Again, land acquisition costs of trains are large in absolute terms, but fairly low compared with the construction costs – around factor 0.2.

The costs of indirect land use are much smaller than the costs of direct land use for almost every transport category and they generally amount to less than 10% of the construction costs. For road and railway infrastructure this result is largely due to the fact that the indirect land use claims are relatively small. While for airports this isn’t the case, the low price at which indirect land use outside the built-up area is valued depresses the costs of indirect land use for this particular type of infrastructure. Therefore, costs of indirect land use are small for aeroplanes too. A notable exception however are indirect costs allocated to small aeroplanes (up to 150 km), largely because for this transport mode the number of kilometres travelled and therefore the number of passenger kilometres is relatively small. An exception to the rule is the costs of indirect land use for inland shipping as a result of substantial indirect land use claims by free sight zones that are mainly located inside the built-up area (and are therefore valued at a relatively large price). The costs of indirect land use for this transport mode are even higher than the direct costs of land use, making that the total social costs of land use by inland shipping are many times higher than the construction costs.

5.2 Sensitivity of the results

In this paper assumptions had to be made regarding several issues. In this section we will discuss the sensitivity of the results to changes in the most important ones. In our opinion these are the assumptions on direct and indirect land use, on (regarding indirect land use) the percentage of the area that would be built-on should restrictions on land use be removed and on land prices. For each of these assumptions we will have to answer two questions. First, how large is the uncertainty on the values that were assumed, and second, how sensitive are the results to changes in these values (expressed, when possible, in percentage change of the results as a result of a one-percent change in the assumed values).

Unfortunately, concerning the direct and indirect land use of some types of infrastructure we cannot be very precise about the possible variation in the assumptions. The results on trains and aeroplanes will not be very sensitive to the assumptions however, mainly because the assumptions on direct and indirect land use of railways and airports are based on very accurate and reliable sources. As already mentioned in Section 3, the direct and indirect land use of roads and waterways are based on minimum design demands. Therefore, the costs associated with them can be considered minimum values. How much the land use based on minimum design demands differs from actual land use by roads and waterways is unclear.

The area that would be built on should the restrictions causing indirect land use be removed was assumed to be 50 percent of the total restricted area inside the built-up area. Outside the built-up area this figure was assumed to be 20 percent. Regarding the second, it is clear that the results on costs of indirect land use change proportional to a change in the assumed values, i.e. a decline in the percentage from 50 to 40 percent would result in a downfall in results of (50-40)/50 = 20 percent. Therefore, the more actual values differ from the assumed values, the more sensitive the results on costs of indirect land use are. Unfortunately, we again do not have information on the possible variation in these figures, although in our opinion they are likely to be small. However, even if this variation is high, since costs of indirect land use do not contribute much to the total costs of land use, let alone to the total fixed costs of infrastructure, the sensitivity of absolute total costs of land use to these assumptions is bound to be small.

Regarding the assumptions on land prices we can be a bit more precise. Let us focus on costs of direct land use, being the largest cost categories. Regarding the first question, note that we have taken averages of land prices that were found in the literature and/or provided to us through personal contact. For direct land use inside the built-up area the land prices varied from 18 to 27 Euro (with an average of 23 Euro), which implies a possible variation of

approximately 20 percent. Outside the built-up area land prices varied from 6.5 to 13.5 Euro (with an average of 10 Euro), implying a possible variation of around 35 percent.
The answer to the second question is fairly simple: the results change proportional to changes in land prices. This means that if land prices are actually 10 percent higher than is assumed in our study, then so will be the estimated costs of direct land. Since we focus on costs of direct land use, being the largest cost categories, we can therefore conclude that the results are fairly sensitive to the assumptions made (up to 20 percent inside the built-up area and up to 35 percent outside the built-up area).[12]

6. Conclusions and future research

In the contemporary discussion on fair and efficient transport pricing, an issue often forgotten is land use by infrastructure. To fill this gap, this study estimates the average social costs of direct and indirect land use of several categories of transport infrastructure for the Netherlands. These costs were allocated to the different users of infrastructure on the basis of their respective transport kilometres and passenger car equivalents, resulting in average social costs of land per transport modality.

In the light of the same discussion, CE (1999) estimated the average social costs of the construction of infrastructure. Compared to the construction costs, the costs of direct land use are substantial for all transport modalities. In contrast, costs of indirect land use are generally small. Exceptions to this rule are costs of indirect land use for small aeroplanes and for inland shipping. The latter is due to the large free sight zones alongside waterways to ensure the safety of transport on water. As mentioned in the introduction, fixed levies on the use of transport infrastructure already exist in the Netherlands. In that sense some of the fixed costs of infrastructure have been accounted for. However, these levies generally do not take into account the intensity with which different transport categories make use of infrastructure. It is furthermore unclear which costs these levies are based on. From this perspective the results of this study are a first attempt at explicitly estimating the average social costs of land use by transport infrastructure and allocating these to transport modalities on the basis of their intensity of use of infrastructure.
As was briefly mentioned in the introduction (see Table 1) there are a fair number of areas for future research. Let us discuss some of the more important ones. First, in the literature much attention is paid to the external costs of the use of infrastructure. However, the existence of infrastructure is often neglected as a source of external effects. Segmentation of open space is an important issue in a densely populated country like the Netherlands. There is a clear need for the development of more refined approaches addressing the damage costs directly.
Second, the analysis of congestion costs in the Netherlands has in general focused on congestion on expressways. Besides congestion on expressways there are a number of places (cross sections, bridges, level crossing) where traffic is a hindrance to other traffic, which

[12] For indirect land use the variation is approximately 25 percent inside the built-up area. Outside the built-up area the assumed land price was fairly arbitrary, and therefore so should be the estimated variation. Since the costs associated with indirect land use are small, the possible change in absolute costs as a result of changes in the assumed prices of indirect land use are also small.

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 aeroplane.

Finally, a tentative guess is that the marginal external costs of parking (for other car users and other road users) are small at the national level. However, hardly any research on these costs has been done so far. Especially at the local level these costs may be considerable, for example, in historical city centres, which merits future research. As already mentioned above, considerable parts of these costs (if not all of them) are in the process of being internalised through parking charges.[13]

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[13] Other areas of future research include: external effects of stench, vibration and visual nuisance as a result of traffic; influence on the results of multiple land use, emissions of the production and destruction of vehicles and the production of infrastructure and fuels; estimating the social costs of sea ships, bicycle and the pedestrian.

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