INDIRECT ECONOMIC BENEFITS OF TRANSPORT INFRASTRUCTURE INVESTMENTS

Jan Oosterhaven and J. Paul Elhorst
University of Groningen, Department of Economics, Postbus 800, 9700 AV Groningen, The Netherlands, fax: +31-50-363.7337, oosterhaven@eco.rug.nl.

Abstract

Estimating the spatial economic impacts of transport infrastructure is an unresolved issue that plagues transport economics to this day. This paper applies to the estimation of indirect economic effects and the extent in which these represent benefits that are additional to the direct transport benefits. After a discussion of the various approaches available to tackle this problem, it is concluded that a spatial computable general equilibrium (SCGE) approach offers the best perspective for future research. To illustrate this, empirical results based on a SCGE model applied to four different magnetic levitation (Maglev) proposals for the Netherlands are presented. One of the main conclusions is that a simple uniform multiplier to add additional economic benefits op top of direct transport benefits does not exist.

Keywords: Spatial general equilibrium; Market imperfections; Magnetic levitation; The Netherlands
Topic area: B7 Input-Output System and Transportation

1. Introduction

When considering the effects of transport infrastructure, one might distinguish direct and indirect effects, market and external effects, and temporary and permanent effects. Temporary effects are those that will only occur during construction, while permanent effects are related to the use of the infrastructure. Permanent direct economic effects include exploitation cost and revenues, and transport cost and time benefits for people and freight. Permanent indirect economic effects relate, firstly, to the backward expenditure effects of the exploitation and use of infrastructure and, secondly, to the so-called programme or induced effects. These are defined as the consequences of the reduction in transport cost for production and location decisions of people and firms, and the subsequent redistribution effects between regional economies with respect to income and employment of the population at large (Rietveld and Nijkamp, 2000). Naturally, these supply-driven induced effects in turn will also have demand effects. In addition to both permanent direct and indirect effects through markets there will be effects that are external to the market, such as noise, safety, emissions and environmental disturbances (in general see Rothengatter, 2000; for the indirect energy use and emissions of different freight transport systems see, for example, Bos, 1998).

This paper applies to the *permanent indirect economic* effects and benefits of transport infrastructure. We thus discuss the measurement of one of the most contentious items in a social cost-benefit analysis of transport infrastructure projects (cf. SACTRA, 1999, CPB/NEI, 2000). In paragraph 2, we give a brief overview of various approaches to tackle this problem. It will appear that a spatial computable general equilibrium (SCGE) approach offers the best perspective for future research. In paragraph 3, we present empirical results of a SCGE model applied to four different magnetic levitation (Maglev) proposals for the Netherlands. In paragraph 4, we summarise the main conclusions from our literature survey and empirical work.

2. Methods to estimate the economic impacts of new infrastructure

2.1 Introduction

There is a large amount of literature on the indirect economic impacts of infrastructure (for overviews see Vickerman, 1991, Rietveld and Bruinsma, 1998) as well as a large variety of methods to estimate these impacts (for overviews see Oosterhaven *et al.*, 1998, Rietveld and Nijkamp, 2000). In this section, we briefly review six approaches.

2.2 Micro surveys with firms

There is a rich theoretical literature on the influence of infrastructure and accessibility on the location decisions of firms. This literature started around 1900 with emphasising the importance of minimising transport cost. This is not surprising in view of the high absolute and relative transport cost of that time. Present literature tends to de-emphasise the importance of transport cost as compared to other cost such as labour cost (Dicken, 1986). An interesting extension is McCann (1998), who replaces the concept of transport cost with that of logistic costs and argues that the latter play a central role in locational decisions of most large multinational firms. Dutch empirical research seems to substantiate this (BCI/NEI, 1997); the large Dutch share in the total of all European Distribution Centres may mainly be explained by its low logistic cost to the rest of Europe, due to the port of Rotterdam and Schiphol Airport transport networks and transfer facilities.

The literature mentioned does not serve to answer the empirical question about the impact of specific types of infrastructure in specific locations (Oosterhaven *et al.*, 1998). For this aim, micro surveys with firms provide more answers. There are two strands within this line of research.

First, one finds a series of general *surveys* with questions about the importance of all kinds of location factors, including infrastructure accessibility. Naturally, the answers differ from country to country, as firms are confronted with different locational bottlenecks in different countries, and tend to bias their answers in the direction of those location factors that they want to see improved. Also, the answers differ according to the type of firms/sectors that are interviewed, as different sectors have different cost profiles and different market positions. The conclusion seems to be that centrality and the reliability of access are important, but not the actual transport cost. In fact, for most sectors, Europe presents a rather level playing field within which secondary and even subjective factors of location play an increasing role (see Pellenbarg, 1998).

The second strand of micro *surveys* tries to investigate the historical or future impacts *of specific investments*. The outcome of this type of research is often rather dubious, since the purpose of the surveys is seldom hidden, and firms tend to answer positively even if the project at hand is of little importance to their own firm. Such strategic and socially desirable answers are very difficult to evade (see NEI/TNO/RUG, 1999, for ways to circumvent some of these problems). Besides, when different variants of the same infrastructure are under investigation, a questionnaire approach becomes unwieldy. In addition, it should be noted that micro surveys do not indicate which firms (further away) are indirectly influenced by the actions of the directly affected firms (closer by).

2.2. Estimations of quasi production functions

In macroeconomics, the infrastructure debate started with the claim that the productivity decline in the U.S.A. was caused by a lack of investments in infrastructure (Aschauer, 1989). Since then a whole series of articles appeared that partly substantiated and more often weakened the original statement. The most common approach is the *quasi production function* approach:

$$Y_r^t = f(L_r^t, K_r^t, \mathit{Infrastructure\ stock}_r^t) \qquad (1)$$

Besides labour (L) and capital (K) per region or nation, per time period, several components - or the total stock - of infrastructure are included in a macro production function in order to explain the level or the change of domestic output (Y). This approach has a number of difficulties.

1. There are complicated econometric issues, relating to the one-sided nature of either the time series data (only data on different t's) or the cross section data (only data on different r's) that are used most often (see Sturm, 1998, for an overview).

2. The direction of causality is not easily detected statistically, as infrastructure may both follow and lead economic growth. To sort out the causality issue observations on a number of spatial units over a very long period of time (both t's and r's) are needed, but these are hardly available (see Van Ewijk *et al.*, 2000, for a recent Dutch attempt).

3. Measurements of the infrastructure *stock* fail to take account of the actual supply of infrastructure services that determine its productivity contribution (for instance, infrastructure "white elephants" are part of the stock but do not produce services).

4. Historically found macro elasticities are of no use when a decision about specific individual projects has to be taken, as such projects are both specific in type (line or point infrastructure, etc.) and specific in their location within the network.

As a result of these difficulties, no clear conclusion about the effects of infrastructure investment has been reached. Macro production elasticities of infrastructure are found to vary considerably among the different studies. In many studies they are found to be insignificant, and in some studies even to be negative (see Sturm, 1998, for an overview).

2.3 Partial equilibrium potential models

The inability to deal with the multi-regional use of infrastructure is probably the fundamental flaw of the stock measures for spatial units in (1). This problem may be solved if a detailed spatial division of the study area is used, and if a measure of *economic accessibility* is determined for each region r (for overviews see Jones, 1981, Rietveld and Bruinsma, 1998):

$$\mathit{Accessibility}_r = \Sigma_s\, Y_s f(c_{rs}) \qquad (2)$$

In (2), f is a downward sloping (gravity or preferably *entropy*) function of the communication cost between region r and region s (crs). The inverse of (2) gives the economically weighted average communication cost or distance of location r to the total study area. Obviously, (2) allows approximating the increase in economically useful infrastructure *services* available to a certain region that will result from investing in specific lines or nodes of the networks included. Moreover, (2) also shows that not only the region wherein the actual investment takes place will profit from improved accessibility. In fact, a whole series of regions/nations will profit from any investment as indicated by the summation and the distance function.

Using (2), the *economic potential* concept provides an approximation of the significance of changes in accessibility for the economy of the region at hand:

$$\mathit{Potential}_r = Y_r\ \Sigma_s\, Y_s f(c_{rs}) \qquad (3)$$

This almost directly follows from *the* fact that (3) is proportional to the total flow of traffic or trade from region *r* to the whole of the study area (see Jones, 1981). This in turn is proportional to the total size of the economy of region *r*.

Evers *et al.* (1987) and Evers and Oosterhaven (1988) were the first to use (3) to estimate the economic impacts of new infrastructure. They turned a variant of (3) with border dummies and a modal split parameter into a multi-sectoral potentials model, and used it to estimate the employment impacts of a proposed high-speed rail connection from Amsterdam to Hamburg. Their approach was shown to produce the "right" spatial pattern of impacts but not necessarily the right macro level of these impacts (Rietveld, 1989). Later on, Bröcker (1995) showed that the gravity type of spatial impact pattern could also be produced by the even more satisfactory use of a SCGE model.

2.4 Regional and macro economic models

Incorporating equation (2) in equation (1) does provide a solution to the last two problems of the quasi production function approach. To solve the first two problems a structural equation approach is needed. The conceptual basis of a more comprehensive approach is given in Figure 1 (adapted from FNEI, 1984, and Rietveld and Nijkamp, 2000). The dotted arrow represents the direct cross-effect of (generalised) transport cost savings on the demand for all non-transport products, whereas the other arrows represent the indirect economic effects of these savings. The origin of these effects is transport cost and timesavings.

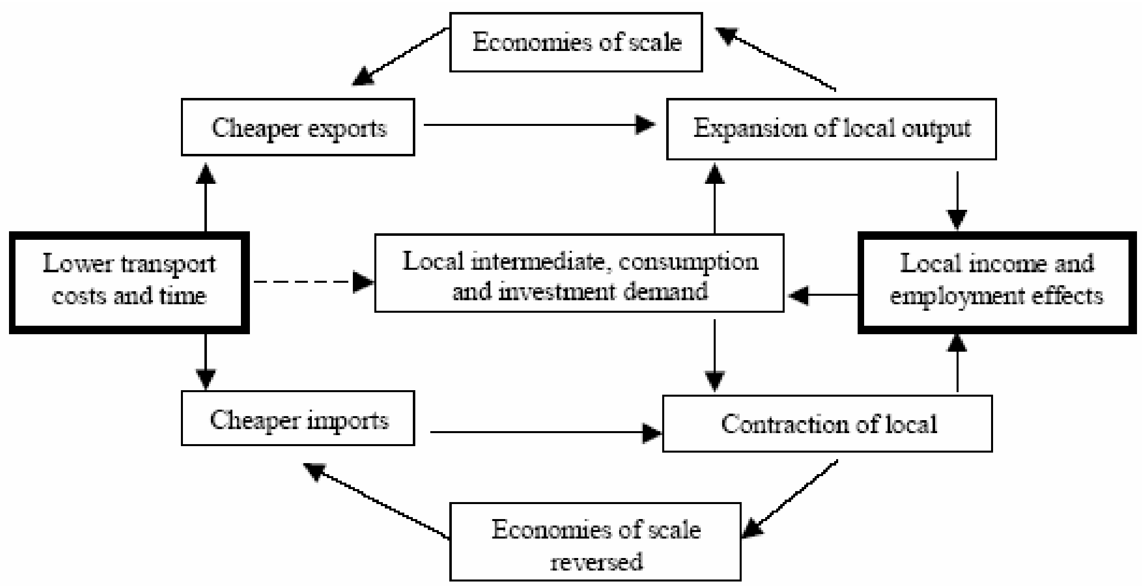

Figure 1. A conceptual model of transport infrastructure impacts

Figure 1 demonstrates that new or improved infrastructure may have positive as well as negative economic effects. For some sectors and products increased accessibility may boost a region's exports, whereas for other sectors and products it may lead to increased competition on its home market and a contraction of local output, income and employment. Both positive and negative effects may well be enhanced because of (firm internal) economies of scale. These findings will be further modified and complicated because of interindustry and consumption demand feedbacks, which may lead to further (external) cluster and agglomeration economies for other, not directly affected firms.

As may be clear from Figure 1, regional and national economic models need to be multisectoral in order to capture the sectorally different nature of the primary impacts of infrastructure. Also the exogenous cost reduction impulse needs to be calculated in such a way that the sectorally different impact on import, export and domestic prices will be captured. Hence, a detailed transport module is needed to generate this information. But even then, regional and national economic models will suffer from a lack of spatial dimension, except for the presence of imports and exports to the rest of the world. Consequently, they will still have great difficulty to differentiate the impact of transport infrastructure investments between regions.

2.5 LUTI and SCGE models

We have tried to make clear that spatially detailed models provide the only way to adequately model the economic impact of new transport infrastructure. In this section, we will discuss and compare two broad classes of such models, namely land-use/transportation interaction (LUTI) models and spatial computable general equilibrium (SCGE) models.

LUTI models consist of linked transport models and "land-use", or better: location models. They mostly employ a *system dynamics* type of modelling and are primary developed to predict future growth and to analyse policy scenarios for large urban conglomerations (for example, Lee *et al.*, 1995). There is a whole series of such models for different conglomerations. LUTI models have a decades long history of gradual development and are nowadays typically very disaggregated with numerous spatial zones, sectors, household types, transport motives, modes of transport, etc. (for overviews see DSC/ME&P, 1998, Wilson, 1998).

SCGE models typically are comparative static equilibrium models of interregional trade and location based in *microeconomics*, using utility and production functions with substitution between inputs. Firms may operate under economies of scale in markets with monopolistic competition of the Dixit-Stiglitz (1977) type. Empirical applications of this last approach are found in Venables and Gasiorek (1996) and Bröcker (1999). Interesting theoretical simulations with a SCGE model with a land market are found in Fan *et al.* (1998). These models are part of the new economic geography school (Krugman, 1991, Fujita *et al.*, 1999) and are around for less than a decade. In other words, we are comparing a mature methodology, possibly at the end of its life cycle, and a new methodology that is still in its infancy.

The practical feasibility of LUTI models is large. Especially the transport sub-models are known to be rather adequate in estimating all kinds of transport price and quantity impacts of policy measures in the transport sector itself. Given the scientific uncertainty around the location behaviour of firms and the decrease of the relative cost of freight transport over time, this does not hold to the same degree for the impact of transport measures on the location of industrial activities. Since the relative time cost of passenger transport has been increasing over time, due to increased congestion and rising real incomes, the location of service activities can be explained much better. However, as the location of most service activities primarily follows that of people and industrial activities, its location choices mainly play a role at the intra-urban level. Consequently, the strength of LUTI models especially lies in estimating the impact on *intra-urban* location decisions rather than in estimating the interregional location effect of transport measures.

Finally, most LUTI models are not well equipped to translate the impacts of transport and infrastructure measures into estimates of consumer benefits, as is needed in a sound, welfare theoretically underpinned cost-benefit analysis (CBA). In the best LUTI models consumer choices relating to transport and location decisions are modelled and estimated by means of a *discrete random utility approach*. By contrast, producer location decisions are seldom modelled by means of discrete profit maximising behaviour, while producer production and price decisions tend to be modelled by *fixed ratios*. As a consequence, most LUTI models provide reasonable estimates of direct transport user benefits, and reasonable estimates of consumer benefits in as far as the latter are based on discrete choice behaviour. The existing LUTI models, however, are not able to estimate transport benefits that are based on continuous consumer choices or discrete and continuous producer choices.

SCGE models, typically, are theoretically well suited for this evaluation task (see also Venables and Gasiorek, 1998). The SCGE modelling problem, at the moment, is not theoretical in nature, but empirical and computational. The consistent estimation of all the necessary consumers' and producers' substitution elasticities is problematic, if only because of the lack of adequate data and the lack of a tradition of estimating such elasticities at the regional level. Moreover, the calibration of these models such that they reproduce recent history and simultaneously provide plausible (that is, stable) projections is problematic too, especially because of the highly non-linear character of the behavioural equations. Another problem is that SCGE models are not yet easily understood, making it difficult for policy makers and other researchers to assess whether the results are valid.

Whether LUTI models can easily incorporate imperfect markets, and internal and external economies or diseconomies of scale, is doubtful. The strength of most LUTI models lies in their segmentation and detail, that is, they usually contain many different zones, transport modes, household types, firm types, and so on. The benefit of having such detail lies in the homogeneity of behaviour and the assumed stability of relations at that level of detail. But this detail is achieved at the cost of mathematical and theoretical simplicity, such as perfect competition, fixed ratios, linear relations and the absence of scale economies.

The present, still young SCGE models have opposite properties, namely a lack of detail and sound empirical foundation, but a sophisticated theoretical foundation and rather complex, *non-linear mathematics*. The latter is precisely the reason why SCGE models are able to model (dis)economies of scale, external economies of spatial clusters of activity, continuous substitution between capital, labour, energy and material inputs in the case of firms, and between different consumption goods in the case of households. Moreover, monopolistic competition of the Dixit-Stiglitz type allows for heterogeneous products implying variety, and therefore allows for cross hauling of close substitutes between regions. Finally, SCGE models lead to a direct estimation of especially the non-transport benefits of new infrastructure, which are absent in most LUTI models.

Whether a further piecemeal improvement of LUTI models is preferable to the implementation of a theoretical superior, but yet untested alternative, is essentially a matter of taste and belief. DSC/ME&P (1998) confess to the piecemeal improvement strategy. The further segmentation they call for may be necessary for the "best" estimation of the impacts of transport policies, but it is not sufficient for the "best" estimation of the indirect transport benefits needed for CBA. The latter requires modelling, not only of discrete choice, but also of continuous responses of consumers and producers based on, respectively, utility maximising and profit maximising assumptions. We would like to advocate the more promising but also more risky start of empirically based SCGE modelling, as illustrated in the next section.

3. Application of the SCGE model

3.1 TheMaglev rail investigations

The Dutch government has contemplated the construction of two magnetic levitation rail ("Maglev") projects, each with two variants: (1) an inner ring and an outer ring respectively connecting the four largest cities (Amsterdam, The Hague, Rotterdam and Utrecht) in the heavily urbanised economic core in the West of the Netherlands; and (2) a direct connection between Schiphol Airport in the West and Groningen City in the more peripheral, rural North, either running along the south-east or along the north-west of the "IJsselmeer", a large lake in the middle of the country. The research concerning these Maglev proposals was part of larger investigations considering different routes, different service levels (frequencies, schedules, waiting times), different price levels as well as different rail systems (also intercity and highspeed rail).

Each proposal has been evaluated in relation to three baseline scenarios. This contribution limits itself to the Maglev results evaluated in relation to the European Coordination (EC) scenario of the CPB (1997). With the help of regional employment allocation and regional population projection models the total number of people and jobs expected in 2020 from CPB (1997) has been divided over the 548 municipalities in the Netherlands (see TNO *et al.*, 2000). The *EC baseline scenario* further consists of a projected rail and road network for 2020 with travel times and volumes for 2020 (see further Elhorst *et al.*, 2000).

It has been assumed that the *Maglev project proposals* primarily lead to exogenous changes in the travel time matrix of public transport. We only consider the results obtained at prevailing prices of public transport (these prices are distance-dependent and in the case of Maglev of first-class level). Table 1 gives the representative travel times between the major cities for each proposal. The table demonstrates that total travel time by Maglev falls below the travel time by car on several connections, even during normal hours, which is quite unique for a public transport system. It also demonstrates that the travel time reduction is far more significant for the core-periphery projects than for the urban conglomeration projects. In addition, it is taken into account that the frequency of regular trains on some competing, existing rail links decreases due to a reduction of the expected number of passengers and that travel times by car along the corridor of the new rail links improve due to reduced congestion.

Table 1. Average travel time (in minutes) between main cities along the proposed trajectories 1)

Core-periphery projects		Car	Public T. Baseline	South-east	North-west
Groningen-	A'dam Airport	135	173	100	96
Urban-conglomeration projects		**Car**	**Public T. Baseline**	**Inner ring**	**Outer ring**
Amsterdam-	The Hague	51	98	87	98
The Hague-	Rotterdam	33	55	51	54
Rotterdam-	Utrecht	64	75	74	61
Utrecht-	Amsterdam	40	76	76	76

1) Including aggress and digress time to stations of departure and arrival.

3.2 Indirect economic impacts: methodology

As shown in Figure 2, the indirect economic effects in this study have been modelled as two independent main effects and two derived interaction effects, in both cases one on labour supply and one on labour demand.

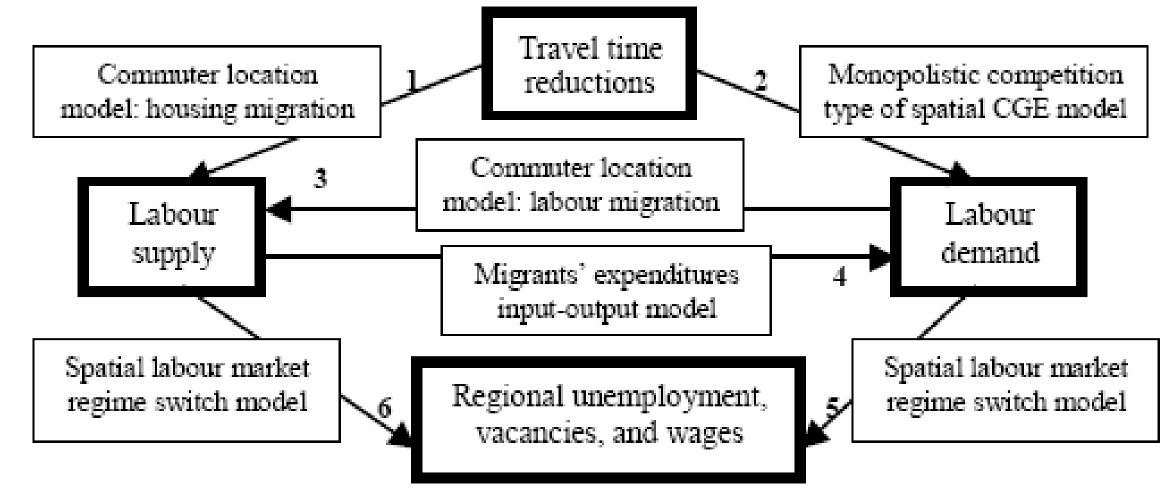

Figure 2. Modelling scheme for calculating indirect economic effects in the Maglev application

The *first main effect* (arrow 1) relates to housing migration of the working population. When travel times diminish due to improvements in the transport network, people may increase the quality of their housing accommodation and living environment, by increasing their commuting journey length, without changing their commuting journey time. This principle has been used to develop a *commuter location model* that takes actual commuting behaviour, measured by a commuting journey time distribution matrix, as given[1], and then assigns the jobs in each employment municipality to the same or other residential municipalities (see Elhorst and Oosterhaven, 2002, for details). Furthermore, it is recognised that municipalities may have a different attractiveness as a residential area, which may be measured by either the number of houses or the available land (excluding water). The number of houses best approximates the existing physical possibilities to live within a municipality. For this reason, this variable is suitable to test the fit of the model. It appeared that - with this attractiveness variable - the working population living in the 12 NUTS-2 and the 40 NUTS-3 regions of the Netherlands could be estimated with an average error of 7%. The available land better approximates the spatial preferences of people. Research has shown that the majority of the working population has a preference for more comfortable houses built on larger lots in neighbourhoods with more green (Elhorst *et al.*, 1999). For this reason, the available land is more suitable to simulate longer run

[1] The commuting time distribution matrix used gives the percentage of commuters by mode (car during peak hours, public transport and slow transport), by time class (25 classes of 5 minutes) and by type of municipality (four biggest cities, municipalities with a railway station and municipalities without a railway station). The total matrix is based on more than 70,000 observations (CBS, 1999). Shifts within this matrix occur when people change their mode of transport and when municipalities are connected to the railway network. Modal substitution has been modelled with the help of an almost ideal demand system (see Elhorst and Oosterhaven, 2002). The matrix itself is assumed not to change over time, since the time that an average individual spends on travel remained remarkably stable over long periods of time, despite enormous increases in incomes and average speed of transport (SACTRA, 1999, p.118).

residential changes, provided that the housing market has time to adjust itself to the changes in the transport system and to these residential preferences.

The *second main effect* (arrow 2) relates to travel cost induced employment changes. If the transport costs of factor inputs and outputs change differentially in different locations, the optimal location of the firm would be expected to change. Transport at the firm level will include freight transport, personal business travel and shopping travel by the customers of the firm. In this investigation, a bi-modal (commodities/people) transport cost mark-up on f.o.b. prices has been used:

$$p^* = [f_c(d_c)]^{\pi} \cdot [f_p(d_p)]^{1-\pi} \cdot p, \qquad (4)$$

where πgives the share of commodity transport and *1-* $\pi$the share of business/shopping travel in the total transport cost per sector. The following functional form of *f* is assumed:

$$f(d) = 1 + \vartheta \cdot d^{\omega}, \qquad (5)$$

where $\upsilon$and ωdenote parameters to be estimated for freight and business/shopping travel and *d* denotes distance. For freight, the 548×548 municipality-by-municipality distance matrix has been used. For people, the 548×548 travel time matrix by car during normal hours and the 548×548 travel time matrix by public transport have been used weighted by their modal shares in business/shopping travel. Note that in the project variants only the latter matrix changes and that the modal shares change due to substitution between the two modes of transport.

Imperfect competition in transport-using sectors is an important reason why traditional location approaches may produce inaccurate estimates. In the long run, changes in market access lead to entry and exit. When inter-industry linkages are reckoned with, forward and backward linkages lead to cluster and agglomeration effects. In general, a more integrated market tends to support more firms, which charge lower prices, produce at a larger scale, and offer a wider variety of products. To estimate these effects a *spatial computable general equilibrium model* (RAEM[2]) has been developed (see Oosterhaven and Knaap, 2002, for details). Its basic structure resembles a similar model developed for the European Union by Bröcker (1999), but the model used here is more detailed in that fourteen different sectors have been specified and that trading relations between production sectors in different regions are estimated on bi-regional input-output data (RUG/CBS, 1999). The fourteen sector-specific elasticities of substitution and the four parameters of the transport cost mark-up (4)-(5) have been calibrated to the EC baseline scenario for 2020. The SCGE model forecasts production and employment for each municipality in the EC baseline scenario and for each project variant. The difference is used as an estimation of the travel cost induced employment effects. In addition, the SCGE calculates the welfare effect of a project variant. This is conceived of as the increase in utility that is achieved within the country by the lower price index of consumption and the larger variety of consumption goods available at the local level.

The *first derived effect* (arrow 3) relates to labour migration of the mobile part of the working population caused by employment changes determined in the SCGE model. The residential locations of these labour migrants are again estimated with the commuter location model. Note in this respect that the commuter location model predicts housing migration as a result of reduced travel times starting with a *given* level employment in each municipality (arrow 1), whereas this run of the commuter location model measures labour migration as a result of

[2] This is the Dutch language acronym of SCGE. At the moment RAEM is further developed together with TNO Inro (Delft) and the Free University of Amsterdam.

changes in employment opportunities (arrow 3). Total labour supply effect is the sum of housing migration and labour migration (arrow 1+3).

The *second derived effect* (arrow 4) relates to consumption-induced employment changes caused by the total migration of workers. Due to lack of data, this effect is not determined at the level of the 548 municipalities, but at level of the 40 NUTS-3 regions in the Netherlands, using a 40x40 employment multiplier matrix of working migrants (see Oosterhaven, 2001, for details). This matrix is also based on the 14 bi-regional input-output tables of the twelve provinces in the Netherlands and the greater Amsterdam and greater Rotterdam regions (RUG/CBS, 1999, Eding *et al.*, 1999). The total labour demand effect is the sum of the travel cost-induced and consumption-induced employment effect (arrow 2+4).

3.3 Indirect economic impacts: main empirical results

The objective of the urban conglomeration Maglev proposals is to strengthen the competitive position of the heavily urbanised core in the west of the Netherlands, the so-called Randstad. It has been found that, due to the redistribution of labour demand within the Netherlands (arrow 2+4), employment in the Randstad will increase by 2,400 jobs in the inner variant and by 2,750 jobs in the outer variant[3]. When looking at other regions and at intra-regional changes within the Randstad, it is found that the urban rail link strengthens the process of suburbanisation. Within the four big agglomerations, the central municipalities of Amsterdam, Rotterdam, The Hague and Utrecht experience a population decrease, whereas their surrounding municipalities close to a Maglev station experience a population increase. This sub-urbanisation process also extends to the regions adjacent to the Randstad. These regions see their number of jobs decrease, whereas their population increases. By contrast, the peripheral North of the Netherlands hardly benefits from a fast rail link within the Randstad, neither in terms of employment nor in terms of population.

The first objective of the core-periphery project between the Randstad and the peripheral North is to stimulate the economy of the latter. It has been found that employment in the North (arrow 2+4) will increases by 3,950 jobs in the south-east variant and by 8,050 jobs in the north-west variant. The working population (arrow 1+3) will increases by 4,000 people in the south-east variant and by 9,400 people in the north-west variant. In sum, the North indeed catches up. Furthermore, it may be concluded that the north-west variant is approximately twice as effective as the south-east variant, and that the core-periphery projects are far more effective in creating jobs in the North than the urban conglomeration projects.

The second objective of the core-periphery project is to relieve the (land, traffic and labour) market pressures in the Randstad. In the south-east variant 7,045 people will leave the Randstad, whereas in the north-west variant the working population in the Randstad will increase by 100 people. It implies that in this case the south-east variant is far more effective.

3.4 Labour market effects

The shifts in labour supply and labour demand have an impact on the spatial efficiency of the Dutch labour market, as illustrated by arrow 5 and 6 in Figure 2. An unemployment-vacancy regime switch model has been developed to estimate these effects. Its basic assumption is that labour surplus regions operate in the horizontal part of their labour supply curve, whereas labour shortage regions are assumed to operate in the vertical part of their labour supply curve.

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[3] From an international viewpoint, employment in the Randstad further increases by about 1,300-1,420 jobs (BCI, 2001). In the present discussion, these international results are not used any further.

First, interregional shifts in labour demand may generate *geographical matching job or productivity (dis)benefits* if – keeping regional labour supply constant – they improve (worsen) the match between demand and supply on regional labour markets (arrow 5). The four different cases are recorded in Figure 3.

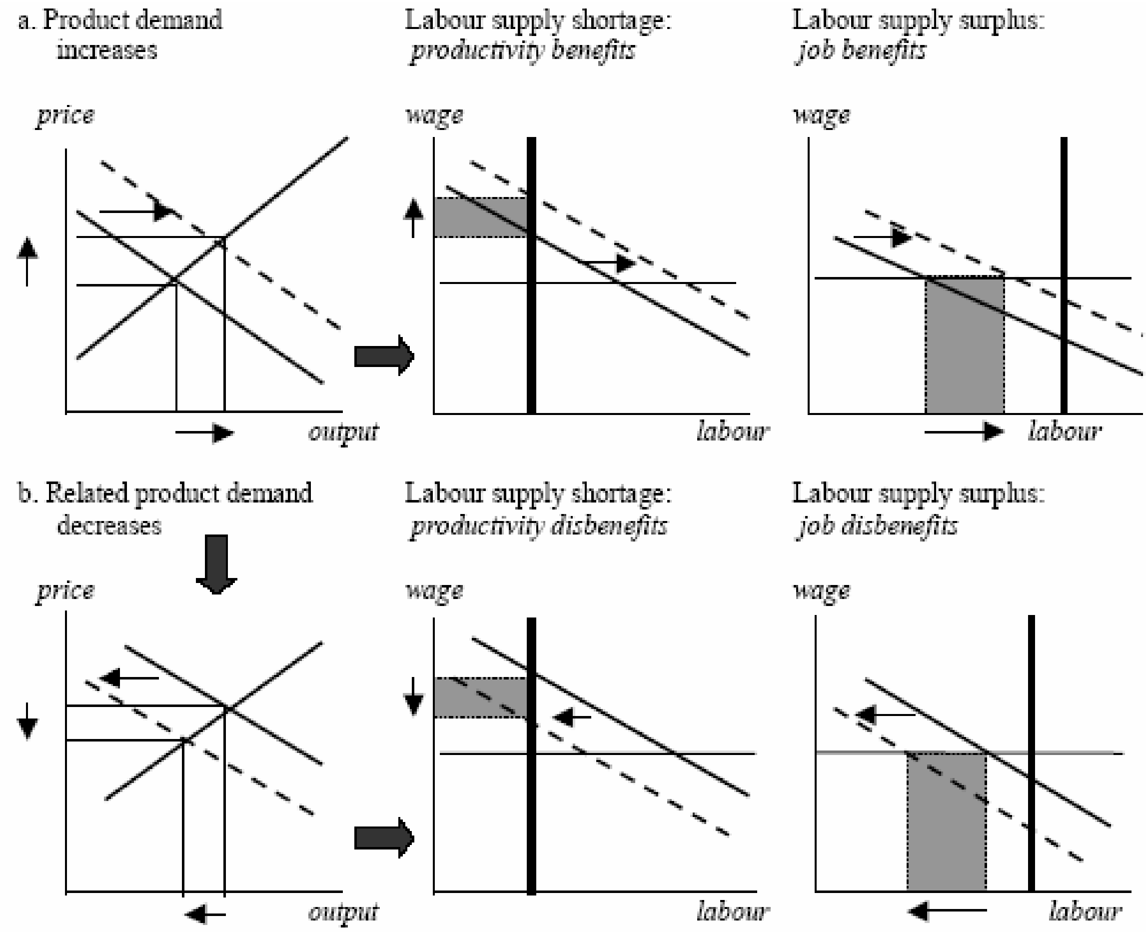

Figure 3. The effects of interregional labour demand shifts when labour supply is immobile

1. *Job benefits* occur when labour demand shifts to regions with a supply surplus. The increase in labour demand can be realised by mobilising school-leavers, unemployed and inactive working age population without raising the regional wage rate.

2. *Productivity benefits* occur when labour demand shifts to regions with a supply shortage. Withdrawal of labour from other economic activities will occur due to bidding up wages. This wage increase then displaces other economic activities in the same region whose labour productivity is lower. Consequently, it is not employment, but regional wages and labour productivity that increase.

3. *Job dis-benefits* occur when labour demand decreases in regions with a supply surplus. Unemployment will rise without affecting the regional wage rate. The equilibrium shifts to the left along the horizontal part of the labour supply curve.

4. *Productivity dis-benefits* occur when labour demand decreases in regions with a supply shortage. The number of vacancies will decrease because less productive, formerly unfilled

vacancies can now be filled. This has the effect of depressing regional productivity, as a result of which labour wages will fall. The equilibrium shifts downwards along the vertical part of the labour supply curve.

It should be stressed that these geographical matching benefits only occur when labour is immobile. In the empirical application this is assumed to be the case with people with primary and secondary education. Furthermore, in the empirical analysis the assumption made is that the productivity (dis)benefits amount to only 10% of the job (dis)benefits. This is based on a high elasticity of the *regional* demand for labour, which is plausible because of easy interregional substitution.

Second – given regional labour demand – firms may be able to access a larger pool of workers when commuting distances increase, which generates what we have called *geographical size benefits* (arrow 6, Figure 2). Qualitative size benefits may occur as firms access better suiting skills. Quantitative size benefits may occur if unfilled vacancies are filled.

In the empirical analysis the *qualitative* benefits have been approximated by the willingness to commute over longer distances. The latter has been estimated by the number of workers crossing the borders of the 40 NUTS-3 regions and by the assumptions that in 10% of these cases firms are able to access better suited skills and that labour productivity due to these better matches increases by 10%.

In case of the *quantitative* size (dis)benefits again four different cases might occur. If commuting flows shift between regions which both have a labour demand surplus or both have a labour supply surplus, the number of vacancies at the national level remains the same. If commuting flows shift from regions with a labour supply surplus to regions with a labour demand surplus, the number of vacancies decreases. Conversely, the number of vacancies increases. Just as with the geographical matching (dis)benefits, these quantitative size (dis)benefits only occur when labour is immobile. Within this labour segment, the size of these (dis)benefits further depends on the size and the willingness to commute of the inactive part of the working age population.

The labour market imperfections modelled by means of the above regime switch approach lead to both volume and price effects. The volume effects are found to be negative for the urban agglomeration project (-1,300 jobs for the inner ring and -2,000 for the outer ring variant). This is due to the fact that this project increases the pressure on the already tight Randstad labour market and increases unemployment in the rest of the country. By contrast, the volume effects of the core-periphery project are found to be positive (+ 3,900 jobs for the north-west and + 3,200 for the south-east variant). The main reason here is the mirror of the one above. The smaller price effects will be discussed in the overall evaluation in the next paragraph.

It is to be noted that the above approach only offers a first approximation of the efficiency effects on the labour market. Both sets of four cases assume a behavioural *regime switch* between labour supply surplus and supply shortage regions, while the UV or Beveridge curve assumes a convex relationship. One improvement in future research would be to incorporate the labour market within the SCGE model using the job search approach of Pissarides (2000) (see van Ommeren *et al.*, 2002, for an outline).

3.5 Direct versus indirect versus additional economic benefits

The above interregional labour demand and supply shifts, and the national total of the regional employment and productivity changes, can only be compared with each other, as well as with the direct transport benefits, when the framework of a social cost-benefit analysis is used to value all these effects. In social CBA's it is usually assumed that all non-transport markets are working perfectly, and that there are no international effects. The direct transport benefits, in such cases, are simply passed on through different markets, and end up in increases or decreases of aggregate consumers' welfare. This means that the analyst can limit him/herself to a partial CBA of the transport cost and benefits, and the external effects, since the indirect economic impacts do *not* produce *additional* benefits or costs (SACTRA, 1999; CPB/NEI, 2000).

Using a purely theoretical model, Newbery (quoted from SACTRA, 1999, p.101) argues that the potential bias due to the prevalence of imperfect competition in partial CBA's is generally too small to worry about, as the truly additional benefits only amount to 2.5% of the direct transport benefits. By contrast, Venables and Gasiorek (quoted from SACTRA, 1999, p.101), using a more elaborate theoretical model, find that most model permutations show additional benefits of around 30%, and that only a few exceed 60%. However, empirical evidence corroborating these ratios is lacking. Moreover, both approaches assume a marketclearing labour market[4]. The present study offers the first possibility to underpin these opinions with empirical data.

To secure the comparability and additionality of the results, they are all valuated using the same valuation rules (NEI, 2000, 2001). Thus, it is assumed that the construction of the new rail infrastructure takes place over the period 2010-2015 and that the exploitation revenues and time benefits start at 100% from 2016 onwards. Total indirect economic effects are assumed to arise over a five-year period, starting at 20% in 2016 and reaching 100% in 2020. The net present value (NPV) is calculated for 2010 (in prices of 2000), using a social discount rate of 4% over a 30-year period (2010-2040).

The direct transport benefits reported in Table 2 consist of exploitation revenues and travel time benefits. The exploitation revenues have been calculated at prevailing distancedependent prices in public transport by first class. The time benefits of commuting trips in public transport have been calculated assuming a value of time of 7.00 euro per hour in 2000, two trips a day, 220 working days each year, and annual growth rate of 1.1%[5]. The time benefits of non-commercial social trips have been calculated starting with a value of time of 4.30 euro per hour in 2000, 285 trip days, and a growth rate of the value of time of 0.6%.

The total consumer surplus of commercial and shopping trips has been calculated using the SCGE model, and an annual growth rate of 1.6%. This last estimate has been split up between direct transport benefits (exploitation revenues and time benefits) and the additional benefits due to increased competition and more variety in product markets. Table 2 shows the direct transport benefits to be largest in the longer Outer Randstad ring project and smallest in the north-west Schiphol-Groningen project that runs along the least populated cities. The additional benefits due to product market imperfections are rather small compared to the direct benefits, but relatively large in the case of the core-periphery project (namely 5.6% and 8.6%) and very small for the urban agglomeration projects (around 1.6%). This difference is due to regional differences in the ratio of price to marginal cost, which (in the SCGE model) has been estimated to be less than 1.2 for core regions and more than 1.3 for peripheral regions, whereas that ratio would be 1.0 under universal perfect competition[6].

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[4] Newbery also does not deal with additional welfare gains accruing from linkage effects and agglomeration effects and the entry and exit of firms (SACTRA, 1999, p.101).

[5] In the EC baseline scenario the real wage rate increases by 1.7% each year. HCG (1998) has estimated that the income elasticity of the value of time for commuting trips is approximately 0.65. Consequently, the value of time grows by 1.1% each year in the EC scenario.

[6] These figures are comparable to those found by Harris (1.16 to 1.29, see SACTRA, 1999, p.101).

The labour market efficiency benefits have been calculated assuming that the proportion of people with primary and secondary education is 65%, that labour productivity grows at 2.3% each year, and that a job produce a net value added of 36,192 euro in for all types of workers and of 29,218 euro for a worker with primary or secondary education in 2000. Volume (employment) effects, already discussed, appear to be far more important than price (productivity and qualitative matching) effects. The largest price effects, found for the coreperiphery projects, are *negative* as several core regions with labour supply shortages experience a decline in productivity due to a drop in labour demand.

Table 2. Direct (transport) and indirect (wider economic) benefits of four Dutch Maglev proposals [1)]

	Inner urban ring Randstad	Outer urban ring Randstad	Schiphol-Groningen, north-west	Schiphol-Groningen, south-east
Direct transport benefits [2)]	3,457	5,499	2,627	3,305
Indirect product markets' benefits	54	80	151	284
Net geographical job benefits	- 487	- 904	2,278	1,715
Net geographical productivity benefits	143	231	- 431	- 334
Qualitative labour matching benefits	51	59	9	7
Quantitative labour matching benefits	- 250	- 306	162	266
Ratio of additional to direct benefits in %	- 14%	- 15%	83%	59%

[1)] Net present value in 2010, millions of euro, price level 2000, discount rate 4%.

[2)] Exclusive of the external effects on congestion.

In short, the results for the urban conglomeration proposals and those for the coreperiphery proposals in Table 2 are widely different. These differences are mainly explained by the fact that the core regions are more densely populated and have projected labour supply shortages in 2020, whereas the peripheral regions are more sparsely populated and are projected to have labour supply surpluses. Taking all results together, the last line of Table 2 shows the additional benefits to be between +59% and +85% of the direct transport benefits in the case of the core-periphery projects and to be around –15% in the case of the urban conglomeration projects[7]. These results are clearly different from those in the theoretical studies of Newbery, and Venables and Gasiorek described above. The idea that the additional benefits are too small to worry about must be rejected. Even more interestingly, although the phenomenon of negative additional benefits is recognised theoretically, both studies were not able to specify the circumstances under which this phenomenon might occur. We therefore conclude that our empirical study yields important empirical findings that, up to now, are thought impossible and prove that Newbery's critique of including market imperfections was rather premature.

[7] When housing market imperfections, international redistribution of economic activity and external effects (congestion, and CO_2 and NO_x emissions) are included, the size of additional benefits even increases to 80-98% of the direct benefits for the core-periphery projects and become a positive 3-10% for the urban conglomeration projects (Elhorst et al., 2002).

4. Conclusion

In this paper an overview has been given of the different approaches found in the literature for estimating the permanent indirect economic impacts of investments in transport infrastructure. From this overview it is concluded that land-use/transportation interaction (LUTI) models provide the best-tested approach, which is most suited for infrastructure issues at the level of large urban conglomerations. Spatial computable general equilibrium (SCGE) models provide a theoretically more satisfying approach, which is especially suited to model the interregional impacts of new or improved transport infrastructure at the larger spatial scale of entire countries.

In the empirical application, the first Dutch SCGE model (RAEM) has been combined with three ad hoc models. Ideally, all these models need to be incorporated into one single SCGE model. The present results, nevertheless, convincingly show the need of incorporating an analysis of (labour) market imperfections into the evaluation of infrastructure investments. They also show that a simple uniform multiplier to derive the additional economic benefits from the direct transport benefits does not exist, as the ratio of the additional to direct benefits is strongly dependent on the type of regions connected, the trajectory at hand, the type of market imperfections and the general state of the economy.

Finally, to all policy makers and researchers who have difficulty to understand SCGE models: Unfortunately there is no simple solution to cracking the complicated problem of estimating indirect economic impacts.

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