

# 5 Spatial Economic Impacts of Transport Infrastructure Investments

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## Summary

Estimating the spatial economic impacts of transport infrastructure is an unsolved issue that has plagued economic science for a long time. This paper will give an overview of the basic problem, the contributions of the empirical literature, the modelling approaches used until now, a recent application, and a perspective on how to proceed.

The basic problem lies in establishing the '*anti monde*', that is, the economic development that would have occurred without the investment in infrastructure. This basic problem is burdened with uncertainty about the direction of the impact of new transport infrastructure on the regions or nations affected. As infrastructure reduces the cost of both imports and exports of goods and services, the net effect is not clear.

Macro economic research only gives indications about the demand and supply effects of bundles of historical investments in infrastructure. This only with considerable debate about the econometrics and the causality implied by the estimations. Moreover, macro research has only limited value when taking decisions on specific infrastructure projects. Surveys among firms and consumers have various measurement problems, but they also have the advantage of providing *ex ante* micro information. Among the major disadvantages are strategic answers, sample selection and the inability to capture indirect effects on non-using firms or consumers.

Economic potential models for interregional infrastructure and land-use/transportation interaction (LUTI) models for intra-urban infrastructure provide the best empirical answers to the question of the economic impacts

of transport investments. Both approaches, however, show one major defect, namely an unsatisfactory foundation in economic theory. A promising alternative is provided by the new economic geography models that are evolving into more broadly based spatial computable general equilibrium models (SCGE models).

Results of a recent Dutch application of a new SCGE model with 14 sectors and 548 municipalities on a proposed transrapid (magnetic levitation train) project from Schiphol Airport to Groningen City, confirm that the SCGE approach has a high potential. Moreover, its implementation appeared to be far easier than was expected. Some aspects and outcomes of this recent study will be discussed in more detail.

Despite these difficulties, empirical literature has produced some general qualitative outcomes. First and foremost, both SCGE models and potential models show the same spatial pattern of impacts of infrastructure. On an isomorphic plane, investments in line infrastructure (road, rail, air and waterways) produce butterfly type of spatial patterns with diminishing impacts as the butterflies grow larger. Improvements in point infrastructure (terminals and harbours) produce concentric ring impact patterns.

Second, there appears to be general agreement on the fact that new infrastructure produces minimal impacts in countries with abundant infrastructure services. This holds with one major exception. When new infrastructure resolves strong capacity limits in either point or line infrastructure, the local effects will be considerable but mostly at the expense of cities and regions close by.

## **Introduction**

When considering the economic effects of transport infrastructure, first, one has to make a distinction between direct and indirect effects, temporary and permanent effects, and market and non-market or external effects (see Table 5.1).

*Temporary* economic effects will occur during construction, directly and indirectly through demand effects. Less discussed, but equally important, are indirect supply or crowding-out effects, both through the capital market as a consequence of the need for finance and through the labour market as a consequence of drawing on specific spatial and occupational segments of that market. Besides, there will be direct temporary external effects, such as noise and environmental disturbances during construction activities, and indirect temporary external effects, such as emissions due to backward economic effects (far) away from the actual construction sites.

**Table 5.1 Type of Effects of Transport Infrastructure Investments**

		Temporary:	Permanent:
Direct	via markets: external effects:	Construction effects Environmental effects	Exploitation and time saving effects Environmental, safety etc. effects
Indirect	via demand: via supply: external effects:	Backward expenditure effects Crowding-out effects Indirect emissions	Backward expenditure effects <b>Productivity and location effects</b> Indirect emissions etc.

*Permanent* direct economic effects include exploitation costs as well as transport costs and time benefits for people and freight. These user benefits, mostly, are the prime reason for investing in infrastructure projects. When this is the case, one speaks of a *passive infrastructure policy*, meaning that investments primarily follow the growing demand for transportation where it occurs, and attempts to avoid or mediate the costs of congestion. Passive infrastructure policy decisions typically will be made only on the basis of a positive net national total of users' benefits minus investment, exploitation and external cost.

Besides direct effects, there will of course also be permanent indirect economic effects. First, these relate to the backward expenditure effects of the exploitation and use of infrastructure. Second, these relate to the so-called programme or induced effects, which are defined as the consequences of the reduction in transport cost for production and location decisions of people and firms, and the subsequent effects on income and employment of the population at large (Rietveld and Nijkamp, 2000). Naturally, these supply-driven effects will, in turn, also have demand effects.

When attaining these cost-induced effects is the main objective of investing in infrastructure, one speaks of an *active infrastructure policy* that tries to influence location and production decisions of firms and thus tries to induce private investments. Besides a hopefully positive net national total of benefits and cost, active infrastructure policy decisions will typically be motivated either by the pattern and size of the regional re-

distributive effects and/or by the expected size of the national generation effect.

Besides these permanent economic effects there will also be permanent effects that are external to the market, such as noise, safety, emissions and environmental disturbances (Rothengatter, 2000). Moreover, the indirect economic effects also cause indirect external effects that need to be incorporated in the analysis when a fair valuation of investments in alternative transport systems is concerned (e.g. Bos, 1998, for the indirect energy use and emissions of different freight transport systems).

In this paper we will concentrate on the indirect effects of infrastructure on the regional and national economy (the cursive effects in Table 5.1). First, we will discuss the various methodological approaches available to tackle this complicated problem. Second, we will present some empirical results of a spatial CGE model for the Netherlands, which was recently built to estimate the indirect effect of proposals for new rail infrastructure between the West and the North of the country. Finally, we will summarise the main conclusions that may be drawn from the empirical work in this field.

### **Methods to Estimate the Economic Impacts of Infrastructure Investments**

There is a large amount of literature on the economic impacts of infrastructure (Blonk, 1979, Vickerman, 1991; Rietveld and Bruinsma, 1998) as well as a large variety of methods to estimate these impacts (Oosterhaven *et al.*, 1998; Rietveld and Nijkamp, 2000). The methods most used are the following:

- micro surveys with firms;
- estimations of quasi production functions;
- partial equilibrium potential models;
- regional and macro economic models;
- land-use/transportation interaction (LUTI) models; and
- spatial computable general equilibrium (SCGE) models.

Below we will briefly review these approaches.

#### *Micro Surveys with Firms*

There is a rich theoretical literature on the influence of infrastructure and accessibility on the location decisions of firms. The past theoretical

literature emphasises the importance of minimising transport cost (Weber, 1909), which 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 transportation cost as compared to other costs such as labour costs (Dicken, 1986). An interesting exception is McCann (1998) who replaces the concept of transportation 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 be explained by its low transportation cost to the rest of Europe due to the Rotterdam harbour and Schiphol airport transport networks.

This literature, however, does not serve to answer the empirical question about the impacts of specific types of infrastructure in specific locations (Oosterhaven *et al.*, 1998). To 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. The answers also 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 transportation 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 (Pellenbarg, 1998).

The second strand of micro survey research tries to investigate the historical or future impacts of specific infrastructure investments. The outcome of this type of research is often rather dubious, since the purpose of the investigation is seldom hidden, and firms tend to answer positively even when the project at hand is of little importance to their own firm. Such strategic and socially desirable answers are very difficult to evade (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. Finally, 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).

### *Quasi Production Functions, Accessibility and Potential Models*

Within macroeconomics the infrastructure debate started with the claim that the productivity decline in the USA 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:

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

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

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).

The direction of causality is not easily detected statistically, as infrastructure may both follow and lead economic growth. To sort out the causality issue very long series of panel data (both  $t$ 's and  $r$ 's) are needed, but these are hardly available (for a recent Dutch attempt, see Van Ewijk, Hakfoort and Schnieders, 2000).

Measurements of the infrastructure *stock* fail to take account of the actual supply of the infrastructure services that determine its productivity contribution (for instance, infrastructure 'white elephants' are part of the stock but do not produce services). Historically found macro elasticities are of no use when the decision about specific individual projects has to be taken, as such projects are both specific in type (line, point, etc.) and specific in their location within the network.

As a result no clear conclusion has been reached. Macro production elasticities of infrastructure are found to vary considerably among the different studies. They sometimes have negative signs and often are not found to be significant (for an overview see Sturm, 1998). At the regional level, comparable attempts have been made, using several infrastructure stock indicators, but here the results are hardly more clear (Rietveld and Nijkamp, 2000).

When a detailed spatial division of the study area is used, the last two problems above may be remedied when some measure of the *economic accessibility* of region  $r$  is used in (1) instead of the stock of infrastructure (for overview, see Jones, 1981; Rietveld and Bruinsma, 1998):

$$Accessibility_r = \sum_s Y_s f(c_{rs}) \quad (2)$$

In (2)  $f$  is a downward sloping (gravity or preferably entropy) function of the communication cost between region  $r$  and region  $s$  ( $c_{rs}$ ). 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. The inability to deal with the multi-regional use of infrastructure is the fundamental flaw of the stock measures for individual regions in (1).

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

$$Potential_r = Y_r \sum_s Y_s f(c_{rs}) \quad (3)$$

This almost directly follows from the fact that (3) is proportional to the total flow of traffic from region  $r$  (Wilson, 1974; Jones, 1981), which in its turn is proportional to the total size of the economy of region  $r$ . Evers and collaborators (Evers *et al.*, 1987; 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.<sup>1</sup>

Their approach was shown to have a micro economic (logit) foundation based on profit maximising locational behaviour of firms, and 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 a spatial impact pattern could also be produced by the even more satisfactory use of a spatial CGE model.

#### *Regional and Macro Economic Models*

Incorporating (2) in (1) provides a solution to the last two problems of the quasi production function approach. However, it does not solve the first

two problems mentioned. To do that one needs a structural equation approach. The partial equilibrium potentials model using accessibility measures only provides a first step. The conceptual basis of a more comprehensive approach is given in Figure 5.1 (adapted from FNEI, 1984 and Rietveld and Nijkamp, 2000).

**Figure 5.1 A conceptual model of transport infrastructure impacts.**

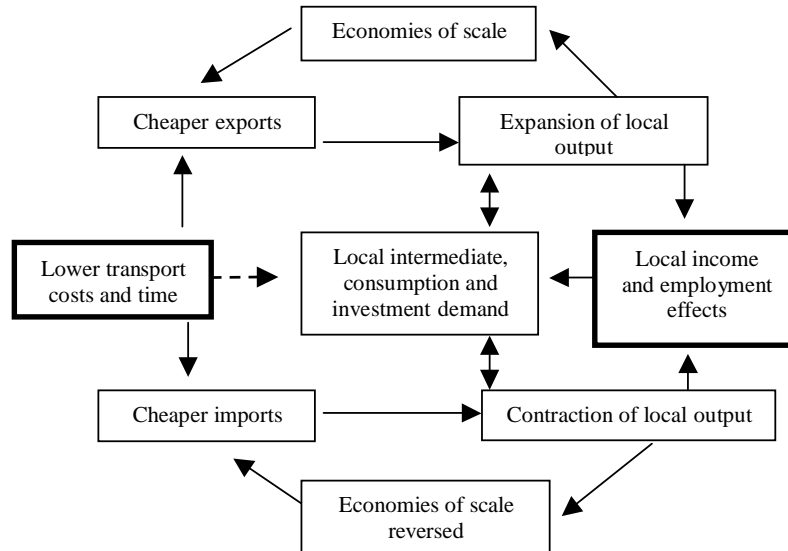


Figure 5.1 shows that all indirect economic impacts start from the supply side with transport cost and time gains. It further emphasises that new or improved infrastructure, in principle, may have both positive and negative economic effects for any region that is influenced by the consequent reduction in communication cost. For some sectors and products increased accessibility may boost that 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. These positive and negative effects may well be enhanced because of economies of scale. When present, (internal) scale economies at the firm level will increase already positive impacts, whereas they may further the negative impacts for other sectors. These findings will be modified and complicated because of inter-industry and consumption demand feedbacks, which may lead to further (external) cluster economies for other not directly affected firms.

Finally, the dotted line indicates the direct effect of (generalised) transport cost savings on the demand for all non-transport products. This indicates that the net regional or national welfare effect of new infrastructure tends to be positive, unless the contraction effects are really heavy and, of course, unless the project is too costly when compared to its benefits.

The possible crowding-out effects of the investment are not shown in Figure 5.1. Typically, macro economic models are well suited to model these effects (Van de Klundert, 1993; Toen-Gout and Van Sinderen, 1995; Eijgenraam, 1995). The question, however, is whether they may also be used to model the impacts that are shown in Figure 5.1.

As follows from Figure 5.1, regional and national economic models need to be multi-sectoral 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 transportation module is needed to generate this information. But even then, regional and national economic models will suffer from the fact that they do not have a spatial dimension, except for the presence of imports and exports to the rest of the world. Consequently, they will have great difficulty to capture the differences in the impacts when different locations of the same infrastructure investments are concerned.

#### *LUTI and SCGE Models*

Spatially detailed models provide the only way to adequately model the economic impact of new transport infrastructure. Here we will discuss 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 transportation models and 'land-use' or better location models. They mostly employ a *system dynamics* type of modelling and are primarily developed to predict future growth and to analyse policy scenarios for large urban conglomerations (e.g. 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 transportation, etc. (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 often operate

under economies of scale in markets with monopolistic competition of the Dixit-Stiglitz (1977) type. One of the few empirical applications of this approach is found in Venables and Gasiorek (1996). Interesting theoretical simulations with a SCGE model with a land market are found in Fan *et al.* (1998). A recent Dutch application will be discussed in the next section. These models are part of the new economic geography school (Krugman, 1991; Fujita, Krugman and Venables, 1999) and have been 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, which for a mature methodology with heavy investments in its empirical implementation is not surprising. Especially the transportation sub-models are known to be rather adequate in estimating all kinds of transportation price and quantity impacts of policy measures in the transportation sector itself. Given the scientific uncertainty around the location behaviour of firms, this does not hold to the same degree for the impact of transport measures on the location of firms. In view of the decrease of the relative cost of freight transportation over time, this is not too surprising. The relative cost of passenger transportation, however, has been increasing over time, mainly because of the increase in time costs due to increases in congestion and increases in real income. For this reason, the location of service activities can be explained much better than the location of industrial activities. As the location of most service activities primarily follows that of people and industrial activities, its location choices mainly play a role on the intra-urban level. Consequently, the power of LUTI models in estimating the interregional location effect of transport measures is much less than that of estimating the impact on intra-urban location decisions.

Finally, most LUTI models are not well able 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). Whether this is the case, mainly depends on how consumer and producer behaviour is modelled and estimated. In the best LUTI models consumer choices relating to transportation and location decisions are usually modelled and estimated by means of a discrete random utility approach. Producer location decisions, however, are seldom modelled by means of discrete profit maximising behaviour, whereas producer production and price decisions are practically always modelled using some kind of fixed ratios. As a consequence, most LUTI models will provide reasonable estimates of direct transport user benefits. Sometimes they will also provide 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 (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 (i.e. stable) projections is problematic too, especially because of the highly non-linear character of the behavioural equations.

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, i.e. they usually contain many different zones, transport modes, households type, firms type, 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 existing, still young SCGE models have opposite properties, namely a lack of detail or 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 the theoretically handicapped, but in practice successful LUTI models is preferable to the implementation of a theoretically superior, but as 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. Our experience in model building tells us that the introduction of additional causal mechanisms or additional actors produces much more differences in the outcomes than a further differentiation of already present relationships and actors. We would rather like to stress the potentially dead-end character of that approach, and would like to advocate the more promising but also more risky start of empirically based SCGE modelling.

Two problems, however, remain. LUTI models are inherently more dynamic than the comparative static SCGE models. The latter, for the moment, are only able to compare the outcomes of different equilibrium states, such as:

- benefits of generalised transport cost reductions due to changing prices, production, consumption and trade, while holding the number of firms and the number of workers per region constant; showing what could be labelled as the *short-run* effects;
- benefits of transport cost reductions when the number of firms per region is allowed to change showing *medium term* effects;
- benefits when the number of workers is allowed to change too; showing the *long-run* effects of new transport infrastructure.

A truly dynamic SCGE approach is theoretically possible but raises a whole new series of issues (Knaap, 2000).

To some, it is not the comparative static but the equilibrium character of SCGE models that poses the fundamental problem. But this seems to be a less serious one as SCGE models may well incorporate disequilibrium features, e.g. (regional) unemployment caused by (nationally) set inflexible wages (Van den Berg, 1999, and the next section). In fact, solving the highly non-linear SCGE models becomes much simpler numerically when all kinds of prices, quantities and ratios are fixed, as is frequently done in the LUTI models.

### **Results of a Spatial CGE Model to Evaluate Dutch Rail Proposals**

Some of the capabilities and problems of SCGE models may be illustrated with the recent construction and application of such a model to evaluate six alternative Dutch rail projects (Elhorst *et al.*, 2000 for the whole study).

These projects all connect the relatively rural Northern Netherlands (containing the provinces of Groningen, Friesland and Drenthe) with the

heavily urbanised Randstad (containing the cities of Rotterdam, the Hague, Amsterdam and Utrecht, and their connecting surroundings). The faster rail connection should run through the new polder province of Flevoland, which used to be part of the former Zuiderzee. At present the rail connection between Groningen City and Schiphol Airport runs around the former Zuiderzee. Hence, rail travel distances and time will be shortened considerably, but car distances and time will hardly change as even a doubling of the modal share of rail will reduce the modal share of cars only slightly. The six different rail alternatives are summarised in Table 5.2.

**Table 5.2 Description of the rail variants with their travel times Groningen-Schiphol (in minutes)**

REF	Reference scenario or zero-alternative, including the so-called Hanze-line from Lelystad to Zwolle, which is not yet constructed	118
HIC	Hanze-line intercity, the only difference with REF is its higher speed	102
HHS	Hanze-line high speed, including rail shortcuts and a TGV only calling at major stations	71
ZIC	Zuiderzee-line intercity, a new rail track from Lelystad to Groningen with conventional trains	89
ZHS	Zuiderzee-line high speed, as ZIC but including a TGV only calling at three major stations	65
MZM	Trans-rapid metro, a new magnetic levitation rail system from Schiphol to Groningen calling at all 6 intermediate stations 6 times per hour	59
MZB	Trans-rapid high speed, as MZM but calling at the 6 stations 2 times, at the 3 major stations 2 times, and running a shuttle 2 times from Schiphol to Almere in Flevoland only	45

For details on the Dutch SCGE model (RAEM) model we refer to Knaap and Oosterhaven (2000). Here we will discuss only some of its most salient features and some of the problems in its implementation and application.

RAEM models demand, output and trade of 14 industries in 548 municipalities with one (presently) immobile household sector. All markets are of the monopolistic competition type and each firm in each industry produces one and only one variety of the product of that industry. In all production and utility functions the varieties  $x_i$  are added to  $Q_j$  with the following CES-function (Dixit and Stiglitz, 1977):

$$Q_j = \left( \sum_{i=1}^n x_i^{1-1/\sigma} \right)^{1/(1-1/\sigma)} \quad (4)$$

In (4)  $\sigma$  represents the elasticity of substitution among the  $n$  different varieties of industry  $j$ .

All utility and production functions have a Cobb-Douglas specification. The production function only uses intermediate inputs and labour:

$$Y_j = L_j^\alpha \left( \prod_{i=1}^m Q_i^{\gamma_i} \right)^{1-\alpha} \quad (5)$$

In (5)  $\alpha$  gives the substitution elasticity between labour and the total of the intermediate inputs and  $\gamma_i$  gives the substitution elasticities among the intermediate inputs from different sectors.

In the equilibrium all prices are a function of all other prices. In this solution the complement of the quantity aggregate (4) is the following price index function:

$$G_j(p_{1j}, \dots, p_{nj}) = \left[ \sum_{i=1}^n p_{ij}^{1-\sigma} \right]^{1/(1-\sigma)} \quad (6)$$

In (6)  $p_{ij}$  is the price of variety  $i$  delivered to sector/consumer  $j$ . These purchasing prices are, of course, inclusive of the transport and communication cost of delivering variety  $i$  to sector/consumer  $j$ .

The way in which transport costs are included in the prices is decisive for the functioning of this type of model. In the monopolistic competition model the equilibrium mark-up, including the transport cost mark-up, is such that price is equal to average cost but larger than marginal cost. In view of the problem at hand, RAEM uses a new bi-modal (freight/people) transport cost mark-up:

$$p^* = [f_g(d_g)]^\pi \cdot [f_p(d_p)]^{1-\pi} \cdot p \quad (7)$$

In (7)  $\pi$  gives the importance of freight ( $g$ ) transport for the transportation cost of the sector at hand. Information on this parameter proved to be scarce. Hence, expert judgement was used to 'guestimate' the 14 sectoral  $\pi$ 's needed. In (7)  $f$  follows the usual specification of *iceberg* transport cost (e.g. Bröcker, 1998):

$$f(d) = 1 + v \cdot d^\omega \quad (8)$$

In (8)  $v$  and  $\omega$  are parameters to be estimated and  $d$  are the distances. For freight, simple road kilometres are used as freight distances do not change in the application. For people, transport cost varies between the infrastructure variants (see Table 5.2). The travel times used are weighted averages between times for cars, slow traffic (bikes etc.) and public transport. In the simulations only the last type of travel times changed, along with the modal shares. Both types of changes were derived from a very detailed transport model (LMS, see NEI, 2000, and Elhorst *et al.*, 2000).

The estimation and calibration of RAEM proved to be complicated, a situation that is quite common with both spatial and non-spatial CGE models. In fact, three types of parameters were used:

- parameters ‘gestimated’ by experts. These included the relative importance of freight as compared to the transportation of people, the weight of non-transport location factors as compared to transport cost, and share of non-tradeables per industry;
- parameters derived from recent Dutch bi-regional input-output tables (RUG/CBS, 1999). These included the input cost shares for the 14 industrial sectors and the one household sector per region;
- econometrically estimated parameters. The latter include all substitution elasticities and the remaining parameters of the transport cost functions.

The last estimation was done for all 18 parameters simultaneously, minimising the squared *logsum* error of the actual and the predicted trade flows. The estimation uses the 588 observations on trade flows that could be derived from the IO tables (namely three flows, on exports, imports and intra-regional deliveries, for 14 sectors in 14 regions). When all transport costs relate to freight, prices rise by 21 per cent after 100 km. When all transport relates to people, prices rise by 15 per cent after 100 minutes of travel. With an average elasticity of 12, total sectoral output halves after 21 km of freight transport and after 22 minutes of people transport.

After estimating all parameters, RAEM was calibrated on a projection of the Dutch economy for a reference scenario in 2020 (CPB, 1997), introducing an ‘unexplained productivity’ parameter per sector per region. Not surprisingly, these parameters were especially high for service industries, since SCGE models as yet are not capable of projecting structural shifts in the sector shares per region.

Besides, this first Dutch SCGE model had to interact with a labour migration model and an input-output expenditure model for labour migrants (Elhorst, *et al.*, 2000). Consequently, certain variables such as population and the number of firms had to be kept constant. This, unfortunately, meant that (internal) scale economies and (external) cluster economies could not be detected yet. Only the *short run* impacts discussed previously were estimated. Tables 5.3 and 5.4 show a summary of the outcomes.

**Table 5.3 Change in jobs per region per infrastructure variant compared to reference scenario, EC 2020**

$\Delta$ Jobs	HIC	HHS	ZIC	ZHS	MZB	MZM
Northern Netherlands	650	1800	900	2000	3500	3100
Randstad	250	400	1200	1800	2200	2500
Flevoland	350	600	400	900	2100	2500
Rest of the country	-1250	-2900	-2500	-4700	-7800	-8100

First, Table 5.3 shows the spatial redistribution of jobs over the Netherlands due to executing each of the variants separately. Regions at the end of the line (the Randstad and the North) together with the region along the line (Flevoland) profit at the cost of the rest of the country. The rest of the country experiences a relative deterioration in its competitive position, especially on the economically largest market in the West of the country. Clearly the effect of speed is decisive, but also the trajectory of the variant plays a role. The Hanze-line variants HIC and HHS only increase the speed along an almost unchanged trajectory. Hence, especially the economic core area (the Randstad) hardly profits from this improvement, whereas it profits clearly more from the four other variants that involve new trajectories to the North.

The aggregate outcomes in Table 5.3 of course hide a substantial redistribution of jobs at lower spatial levels of analysis. The underlying material at the level of 14 sectors and 548 municipalities, for instance, shows that the bulk of the employment effect in the North relates to the services sector in the city of Groningen. This is not too surprising as only business travel times improve, while Groningen is by far the largest (service) city in the North and also enjoys the largest %-gain in travel time to the largest sub-market of the Netherlands, that is the Randstad. Other sub-regions in the North, such as those to the east and south of the city of Groningen show negative employment effects as their relative competitive

position deteriorates compared to northern cities closer along the new infrastructure.

Besides these regional (re-distributive) effects, there are also important national (generative) effects, shown in Table 5.4. This is a little surprising, as economies of scale are not yet allowed. There is a minimal decrease in national employment (not shown), because labour becomes relatively more expensive compared to total intermediate inputs. Total output (GDP), however, increases as savings in transport cost lead to lower prices and more demand. Most of the lower prices are passed on to consumers who also enjoy their own direct transport cost savings, which result in an overall reduction of consumer prices ( $\Delta$ CPI).

Besides lower prices, consumers and firms also enjoy a greater variety of available consumption and intermediate goods. For example, people along the Transrapid line will be able to go to the opera in Amsterdam and return the same evening, something that is hardly possible today. Because of the explicit utility function(s), RAEM, as any other SCGE model, is able to translate the utility gain in the equivalent consumer income increase ( $\Delta$ Y) that would have been necessary to reach the same change in utility (welfare). In the case of the Transrapid these gains amount to more than 250 million euro yearly, which has to be compared with an investment cost of 5-7 billion euro.

**Table 5.4 Changes in output, prices and consumer welfare per variant compared to the reference scenario, EC 2020**

		HIC	HHS	ZIC	ZHS	MZB	MZM
$\Delta$ GDP	(in %)	0.004	0.010	0.004	0.010	0.016	0.016
$\Delta$ CPI	(in %)	-0.02	-0.06	-0.02	-0.05	-0.09	-0.09
Eqv. $\Delta$ Y	(in million euro)	64	156	56	153	262	251

Finally, there is the interesting phenomenon that the increase in output is much, much smaller than the decrease in the CPI. Part of this difference is explained by the peculiar implications of using iceberg type transport costs. Reducing iceberg type transport costs does not free-up transport sector inputs, such as labour and intermediate inputs. Instead it results in less product being ‘melted away’ during transportation. This implies that the supplier needs to produce less to satisfy the same level of demand on the part of its customers. Hence, the consumption of non-transport products is able to increase more than the production of non-transport products. This unwarranted fact went unnoticed in the literature until now.

When a macro SCGE is used, this property does not pose a serious problem as the macro economic output is inclusive of transportation output that does (implicitly) reduce. In a multi-sectoral SCGE, however, these iceberg type transport costs imply a serious *mis-specification* as they lead to an underestimation of the output effects in the non-transportation sectors, especially in those sectors for which transport cost reduces most, whereas the opposite should be the case. RAEM, in fact, found the largest positive output effects in the public utility sector that only indirectly uses the transportation of people.

### Some General Empirical Regularities

From the experience with RAEM and from earlier experience with potential models (Evers *et al.*, 1987) some general conclusions as regards the shape of the spatial pattern of the impacts of new infrastructure may be drawn. A fundamental difference appears between the impacts of point infrastructure (terminals and harbours) as opposed to the impacts of line infrastructure (roads, rail and waterways) (see Figure 5.2).

First, results are discussed when space is *isomorphic*, that is without differences in economic densities and without differences in transportation costs, which means that in equation (2) all  $Y_s$  are equal and all  $c_{rs}$  are strictly proportional to physical distance.

In the case of line infrastructure, Figure 5.2 shows the results for a simple uni-modal traffic plane, such as a rural region with only rural roads. In such an isomorphic plane, improvements in line infrastructure, such as a first stretch of a motorway, will produce *butterfly patterns* of diminishing impacts. In the smallest butterfly the impacts will be most positive. When the butterflies get larger the impacts will turn to negative and with still larger butterflies they will fade to zero.

In the case of improvements in point infrastructure, the isomorphic case is more complicated as terminals only have economic meaning in a multi-modal traffic case. Thus, the basic isomorphic point infrastructure case may best be imagined with two separate uni-modal isomorphic traffic planes that get a (better) connection in the point at hand. In that case, improvements in point infrastructure will produce simple *circles patterns* of diminishing impacts. As the circles become larger and larger, the impacts get smaller, become negative, and finally approach zero.

Second, Figure 5.2 shows results when (economic) space is *non-isomorphic*. The basic circular and butterfly pattern then get distorted. The way in which this happens is best understood with a close eye on (2).

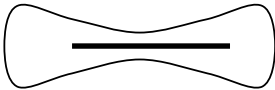
In the presence of a major agglomeration, the areas at the opposite end of the infrastructure improvement profit most, whereas the areas close by will *not* profit despite this closeness. On the agglomeration side of the new line or new transshipment point, the pattern will be undistorted and show its basic circular or butterfly form. Comparable types of distortion result when barriers to spatial interaction, such as country borders, are included in the analysis.

Figure 5.2 is also useful when discussing infrastructure impacts at the level of a specific regional delimitation. Let us consider the outer circle or outer butterfly limits where the impacts reduce to zero. The area within this limit may be called the *influence area* of the infrastructure improvement studied. The total effect within this influence area may be either zero or positive. In the zero case, the infrastructure only has *re-distributive* effects within the influence area. In the positive case, the net positive effect is usually labelled a *generative* effect.

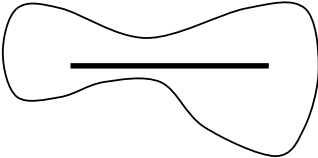
**Figure 5.2 Different spatial impact patterns of transport infrastructure**

*Impacts of Line Infrastructure (roads, rail, etc.)*

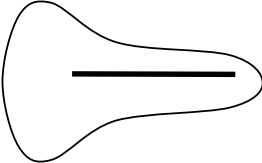
In isomorphic space



With unequal economic densities (e.g. an agglomeration)

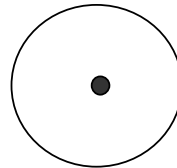


With unequal transport costs (e.g. a border barrier)

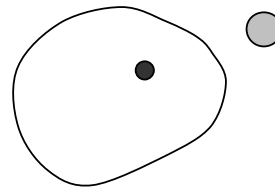


*Impacts of Point Infrastructure (terminals etc.)*

In isomorphic space



With unequal economic densities  
(e.g. an agglomeration)



The literature appears to agree that the generative effects of new or improved infrastructure are minimal when mature, well-developed economies are involved (Blonk, 1979; Vickerman, 1991; Rietveld and Bruinsma, 1998). The re-distributive effects at lower spatial levels of analysis may be larger, especially when network bottlenecks are removed. The principle reason for this general conclusion lies in the small relative (%) reduction in generalised transport costs that is attainable in mature economies. One may only expect sizeable %-reductions when entirely new transport infrastructure with structurally lower transport costs or times, is under consideration. But even then, as in the case of the Transrapid rail variants, impacts may be moderate, as the %-reduction over the whole transportation chain is much lower than that over the new rail part of the chain. Moreover, mature economies typically supply competing modes of transportation (road next to rail) which further reduces the impacts of infrastructure improvements, especially when the latter concern the mode with the smaller modal share, as was the case with the Transrapid application.

The impacts of new infrastructure in developing countries - for the opposite reasons - often are considerable. Such countries have fewer or no competing transportation modes, whereas the existing modes are of such a

low quality that most improvements tend to result in relatively large %-reductions in generalised transport cost.

## Conclusion

In this paper we have given an overview of the different approaches found in the literature to estimate the economic impacts of investments in transport infrastructure. From this overview it can be 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 infra-structure at a larger spatial scale.

This paper further discussed the recent Dutch construction and application of a 14-sector, 548-municipality SCGE model (RAEM). Both the construction and the application to a series of recent Dutch rail proposals showed this approach to be very promising, especially with regard to the possibility to produce a cost-benefit consistent valuation of consumer welfare changes. The application also showed that the standard SCGE use of iceberg type of transport costs leads to a serious misspecification when multi-sectoral CGE models are being built.

Finally, the paper concluded with the circular and butterfly type of spatial patterns that will be found with Potential and SCGE type of models, and the paper presented an explanation for the small generative impacts as opposed to the sometimes quite large re-distributive impacts in the case of mature well-developed economies.

## Notes

- 1 The rail connection of this study includes the ZHS variant (see Table 5.2) analysed in the following section.

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