11 Modelling the Economy, Transport and Environment Triangle, with an Application to Dutch Maglev Projects

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Abstract

This chapter discusses modelling the ETE triangle from the perspective of the welfare consequences of local and regional policy measures. It argues that the interaction between the economy and the transport system needs to be modelled using sectors, household types, transport modes and spatial zones. For urban agglomerations, using a land-use/transportation interaction type of model should be weighed against using a spatial computable general equilibrium type of model. For interregional applications, a spatial equilibrium approach is superior because it enables the incorporation of economies of scale, substitution between inputs and heterogeneity of outputs. Furthermore, it is argued that – at the local and regional level – environmental externalities may be modelled without taking account of feedback effects on the economy and the transport systems. The modelling philosophy is applied to four Dutch magnetic levitation rail proposals showing that the location and trajectory of new transport infrastructures have an important impact on the size and mix of its direct transport effects, indirect economic effects and external environmental effects.

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11.1 Introduction

Modelling the interactions between the economy, the transport system and the environment (the ETE triangle) involves a wide range of choices. We discuss these choices from the perspective of analysing the impact of policy measures on people's welfare at the spatial scale of individual cities and regions. It is important to note that the limitation of *sub-national policy measures* minimises the necessity to model the impact of exogenous factors at the macro level, such as technological breakthroughs and the growth of the world economy, since sub-national policy models can be based on exogenously provided national or international economic scenarios. The limitation of studying only *welfare effects* also constrains the choices at hand, but less so. The reason is that although the population in a particular country may care about the state of the environment in the rest of the world, it probably does not care about the state of the transport system and the economy elsewhere. This implies that the environmental impacts need to be modelled globally to be relevant to local policy decisions.[1] This is not a major complication, since the feedback effects of global environmental impacts of local policy measures back on the local economy, transport and environment are negligible.

In this chapter, we first compare the interactions between the elements of the ETE triangle, which prove to be different in nature. Next, the impact of the economy and the transport system on the environment and its consequences for modelling at the local and regional level are discussed in more detail. Finally, the interactions between the economy and the transport system are discussed in more detail, along with the modelling implications of the aim to simulate the impacts of policy interventions on the economy and the transport system. As an application of the modelling approach, four competing proposals to install new magnetic levitation (Maglev) rail projects in the Netherlands are discussed.

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11.2 The Different Nature of the Three Types of Interaction

Within this chapter, decisions about the production and consumption of transport services and of other goods and services will be treated separately. Hence, our definition of the economy and of economic activities is exclusive to the transport system and transport services.

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At the local and regional level, possible *transport* policy measures relate to such instruments as traffic tolls, the construction of new transport infrastructure, the (subsidised) provision of public transport and parking space. In some countries, local authorities may have additional powers such as levying fuel taxes and other transport-related taxes, such as parking tariffs. Generally, these instruments either have an explicit spatial dimension (i.e. location) or have spatially strongly different impacts on the supply and demand for transport services and thus also on the (spatial) functioning of the economic system in the city or region in question.

In market economies, local and regional authorities generally have limited possibilities to intervene in the economic system directly. At the local and regional level, possible *economic* policy measures relate to such instruments as taxing different types of land use, installing zoning regulations and sometimes also providing for rental housing, office space and labour market matching. With the exception of labour market matching, these instruments all have an explicit spatial dimension and will thus also influence the demand for transport services in a spatially differentiated manner.

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Two conclusions follow from the above discussion and may be summarised as follows (see also Fig. 11.1):

[1] The recent guideline for social cost-benefit analyses of transport infrastructure projects in the Netherlands (CPB/NEI, 2000), for instance, restricts the measurement of the economic impacts to the national economy but insists on including worldwide environmental impacts, despite the obvious inconsistency in spatial scale (cf. Oosterhaven, 1999).

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1. Modelling the interactions between the economy and the transport system can only be done sensibly when it is done spatially.
2. The interaction between the economy (i.e. production, consumption) and the transport system, in principle, runs both ways.

Neglecting the interdependent and essentially spatial nature of the relationship between the economy and the transport system will result in biased local and regional policy recommendations.

To discuss the relationship between the environment on the one hand, and the transport system and the economy on the other, a distinction must be made between global impacts and local/regional impacts. Modelling *global* environmental impacts of local and regional policy measures is relatively simple, since feedback effects at the local/regional level are empirically negligible. Modelling their *local* environmental impacts is relatively complicated, since the spatial dimension (i.e. location) of the local impacts is at the heart of any local policy model. Let us take emissions as an example. Emissions occur at specific locations. Since their diffusion is spatial, the subsequent impact on welfare may be quite different in densely and sparsely populated neighbourhoods.

The question of whether the feedback effects of local environmental impacts on the local economy or the local transport system are relevant is difficult to answer. Heavily disturbed and polluted neighbourhoods may become less attractive for households and even for firms. Consequently, location decisions and the demand for transport services will be influenced. But just as the feedback effects of global environmental impacts tend to be small, so are the feedback effects of local environmental impacts on the local level.

Hence, two additional conclusions can be drawn (see also Fig. 11.1):

3. The interactions between the economy and the transport system on the one hand, and the environment on the other, may be modelled as a one-sided dependency of the environment on the economy and the transport system. This implies that environmentally motivated policy interventions in both the economic and the transport system may be treated exogenously.
4. Global environmental impacts can be specified non-spatially as opposed to local and regional environmental impacts that need to be specified spatially.

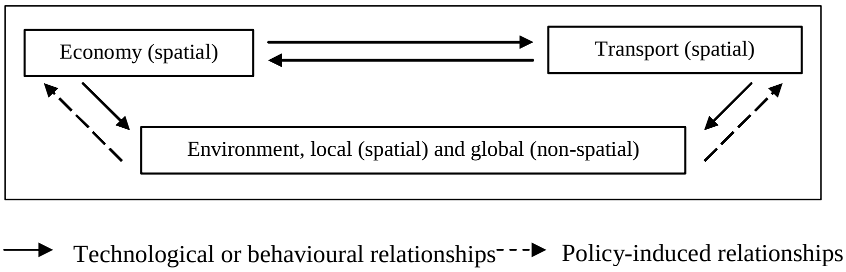

Fig. 11.1. The nature of the ETE triangle at the local level

11.3 Modelling Environmental Impacts

Many environmental impacts of both transport and economic activities are externalities; i.e. actors do not take account of the environmental impacts when deciding on their production and consumption levels and mix.

Environmental impacts of decisions about the production and consumption of transport services constitute an important subcategory of all externalities, called *transport-upon-environment* externalities. Another important category of externalities of transport production and consumption decisions relates to such externalities as traffic congestion and traffic accidents. The valuation of these *transport-upon-transport* externalities is psychologically different from that of environmental externalities. The reason is that congestion and accidents are commonly viewed as risks that people voluntarily choose to be subject to when they decide to produce or consume transport services. By contrast, environmental externalities are commonly viewed as involuntary risks, since they affect people that do not produce or consume the transport services in question.

When the transport system and the economy are treated as separate entities, as in this chapter, no significant externalities seem to exist between the two systems. At the local and regional level, most of the *economy-upon-economy* externalities tend to be pecuniary and they are probably not very significant. For example, firms capture only a part of the direct transport benefits of new infrastructure because competition forces them to pass some or all of these benefits on to their clients. Non-pecuniary benefits at the local and regional level are probably restricted to transfers of knowledge, especially through the local labour market. At the local and regional level, *transport-upon-economy* and *economy-upon-transport* externalities do not seem to be different in nature from the economy-upon-economy externalities discussed above.

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Comparable to the transport system, but with a different mix, pollution, noise and the contribution to global warming appear to be the most important externalities originating from the economic system, i.e. *economy-upon-environment* externalities.

From an environmental policy viewpoint, it is helpful to distinguish between intermediate and final externalities. *Intermediate* externalities may be defined as *non-environmental* externalities between actors in the transport system and the economy, which lead to (further) location, consumption and production reactions. These externalities must be modelled if they are significant, such as the transport-upon-transport and economy-upon-economy externalities discussed above. *Final* externalities may be defined as …-upon-environment externalities, which do not lead to further behavioural reactions of actors in the economy or the transport system.

It is to be noted that this distinction is not necessarily related to the distinction between direct and indirect environmental externalities, as both are final externalities in the sense defined above. The importance of the *direct/indirect distinction* is apparent when life-cycle analyses (LCA) of the total environmental cost of transportation are considered. LCA is best done by combining direct process data with more aggregate input-output data (Wilting, 1996). In an application to Dutch freight transportation, the direct/indirect energy use in the production and maintenance of infrastructure and means of transportation appeared to be 82/18% of the total energy use in road freight, 55/45% in rail freight and 40/60% in inland water transportation (Bos, 2000). Although these percentages are different and sensitive to assumptions made, data used and, especially, effects included, the rank order of the direct impacts did not appear to be different from the rank order of the total impacts. Essentially the same conclusions apply to Dutch passenger transportation (Bouwman, 2000). However, rank orders do change in applications at a more detailed level, as in GMC/Argonne (2002, cited in Harrington and McConnell, 2003, p.250) that studies the use of different fuels.

The recommendation to distinguish intermediate and final externalities, and to neglect intermediate ones when estimating environmental impacts, implies that some indirect (backward) environmental externalities may also be neglected. This will not influence the rank order of the externalities per transport mode, as the Dutch LCA research has shown for final externalities alone. Perhaps more important is the problem that all of these direct/indirect calculations neglect the spatial dimension. Although the environmental cost involved in these national LCAs relates to the global level, the estimation of these global environmental costs is generally based on data of (sub-)national cost structures.

11.4 Modelling Transport-Economy Interactions

There is city-level information that shows that lower population densities may be associated with fewer car miles per capita travelled (Newnan and Kenworthy, 1989). At the micro level, however, Dunphy and Fischer (1996) found evidence of fewer car miles and more public transport miles per capita for people living in higher density communities. In addition, they found that demographic characteristics determined location choice and travel behaviour simultaneously. Kitamura *et al.* (1997), using travel diary data, found personal attitudes to driving, the environment and other factors to be more important in explaining travel behaviour than land-use variables. The extensive literature on the balance between the number of jobs and the number of houses, following Hamilton's (1982) provocative article on the concept of 'wasteful commuting', comes to a more or less comparable conclusion. The extent of wasteful commuting diminishes when more explanatory variables are added, such as double-earner families, different spatial distributions of particular job qualifications and discrimination in the housing market (White, 1999). Reviewing the literature on the relationship between land-use and travel demand, Harrington and McDonnell (2003, p.214) came to the following conclusions:

1. Compared with other variables, most studies find either no or only small effects of land-use variables on travel measures, such as vehicle miles travelled or vehicle ownership.

2. Urban form tends to have more impact on vehicle ownership than on miles travelled, and the effect tends to be greater at very high densities (i.e. above 5000 people per square mile, Walls *et al*., 2002).
3. There are differences in land-use impacts through the effect on travel (time and distance) cost, at least for non-work trips.

This means that, even with significant effects at very high densities, policies directed at changing existing land-use are probably less effective in affecting travel patterns than policies that influence (time and monetary) travel cost more directly.

This last relationship also plays a central role in theoretical models of urban form. In the monocentric base model (Alonso, 1964), commuters trade off lot size (i.e. density) and transportation cost. Using this model, the long-term decline in real (time and distance related) travel cost provides a straightforward explanation of suburbanisation and decreasing urban densities (Pickrell, 1999). In contrast, high land prices (i.e. density), high cost of road construction, and traffic congestion in the inner cities result in high generalised private transportation costs, which together may open the way to public mass transit. It also offers an alternative explanation for the decentralisation of housing and jobs (Ingram and Liu, 1999).

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In addition to the relationship between urban form and travel behaviour, that between urban form and domestic and holiday behaviour may also be of (environmental) importance. After controlling for different household characteristics, Diepen (2000) found that travel behaviour, holiday behaviour and domestic energy use depended on the residential neighbourhood. In the inner cities of two Dutch towns, each with about 150,000 inhabitants, total energy use per comparable household appeared to be lower. Interestingly, she did not find total energy use to be lower in sustainably designed neighbourhoods with sustainably designed houses. The location of other city neighbourhoods in relation to the city centre and the number of competing destinations appeared to be much more important.

This brief review indicates that spatially detailed models provide the only way to adequately model the interaction between the economy and the transport system at the local and regional levels, especially when one is interested in environmental externalities associated with local transport and land-use regulation. Below, we will further 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 location models. They generally employ a *system dynamics* type of modelling and are primarily 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. In this respect, the LINE model stands out as it is a LUTI type of interregional model for the whole of Denmark (Madsen and Jensen-Butler, 2003). LUTI models have a long history of gradual development over many decades and are currently 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 are typically comparative static equilibrium models of interregional trade and location based on microeconomic theory, using utility and production functions with substitution between inputs. Firms may operate with economies of scale in markets with monopolistic competition of the Dixit-Stiglitz (1977) type. Empirical applications of this last approach are to be found in Venables and Gasiorek (1996) and Bröcker (1999). Interesting theoretical simulations with a SCGE model with a land market are to be found in Fan *et al.* (1998). These models are part of the new economic geography school (Krugman, 1991, Fujita *et al.*, 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, with a new methodology that is still in its infancy.

The practical feasibility of LUTI models is wide. In particular, the transport sub-models are known to be very adequate in estimating all kinds of transport price and quantity impacts of policy measures in the transport sector itself. Given the scientific uncertainty in relation to the location behaviour of firms and the decrease in the relative cost of freight transport over time, this does not hold true 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, the location choices of service providers mainly play a role at the intra-urban level. Consequently, the strength of LUTI models lies especially in estimating the impact on *intra-urban* location decisions rather than in estimating the interregional locational 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 cost-benefit analysis (CBA underpinned by welfare theory). At best, consumer choices relating to transport and location decisions are modelled and estimated by means of a *discrete random utility approach*. In contrast, producer location decisions are seldom modelled by means of discrete profit maximising behaviour, and 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 either on continuous consumer choices or on both discrete and continuous producer choices.

SCGE models, typically, are theoretically well-suited for this evaluation task (see Venables and Gasiorek, 1998). The SCGE modelling problem, at the moment, is not theoretical in nature but rather empirical and computational. Consistent estimation of all the necessary consumption and production 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 also problematic, especially because of the highly non-linear character of the behavioural equations. Another problem is that SCGE models

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are not easily understood, making it difficult for policymakers and other researchers to assess the validity of the results.

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. However, this detail is achieved at the cost of mathematical and theoretical sophistication, which results in assumptions of perfect competition, fixed ratios, linear relations and the absence of economies of scale.

The current, still young SCGE models have the opposite properties, namely a lack of detail and sound empirical foundation, but a sophisticated theoretical foundation and complex non-linear mathematics. The latter is precisely the reason why SCGE models are able to model economies and diseconomies 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 the welfare effects, in particular of the non-transport benefits of new infrastructure, which is absent in most LUTI models.

The modelling requirements that follow from our discussion are summarised in Table 11.1. Whether a further piecemeal improvement of LUTI models is preferable to the implementation of a theoretically superior but as yet untested alternative is essentially a matter of preference and belief. DSC/ME&P (1998) confess to the piecemeal improvement strategy. We would like to advocate the more promising but also more risky development of empirically based SCGE modelling, at least when interregional as opposed to intra-urban problems are examined, as is illustrated in the next section.

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Table 11.1. Requirements for modelling the ETE triangle at the local level

Spatial economy	Transportation	Environment
– sectors	– modes	– local, by destination zones
– household types	– freight/passenger types	– global, no zones
– land use by zones	– origin/destination zones	
– type of markets		

11.5 An Application to Dutch Maglev Proposals

11.5.1 Introduction

Since 2001, the Dutch government has been considering two magnetic levitation (Maglev) rail projects, each with two variants. (1) An inner ring or an outer ring connecting the four largest cities (Amsterdam, The Hague, Rotterdam and Utrecht) in the heavily urbanised economic core in the west of the Netherlands (the so-called Randstad region). (2) A direct connection between Schiphol Airport in the Randstad region and Groningen in the more peripheral, rural north, either running along the south-east or along the north-west shore of the IJsselmeer lake in the middle of the country (see Fig. 11.2, for the four trajectories).

The primary aim of a fast rail ring within the Randstad is to improve its internal accessibility by public transport. In turn, this may reduce traffic congestion and therefore also improve its internal accessibility by car. Both may strengthen the Randstad's competitive position in attracting internationally mobile economic activities. In addition, compared to other regions in the Netherlands, the need for space for new residential areas and industrial sites is much more pressing in the Randstad. With new fast rail links, it might be possible to direct the urbanisation process away from the remaining vulnerable agricultural and natural areas within the Randstad.

The primary aim of a fast rail link between the Randstad and the north is to stimulate the lagging northern economy. With a fast rail link, people would not have to leave the north for jobs in the Randstad, instead they could commute to them. This would increase demand for locally produced goods, which would in turn initiate a multiplier process leading to a higher level of regional production and employment. A fast rail link would also lower the prices of services both supplied and demanded by firms located in the north, possibly shifting the competitive balance in favour of locations in the north in spite of the 'two-way road' argument (SACTRA, 1999, p.16).

Both effects are seen as a key to the further economic development of the northern Netherlands.

The secondary objective of a fast rail link between the Randstad and the north is to relieve the Randstad's capacity constraints in transport, land and labour markets, which result in losses of time, high transport costs, labour shortages, high housing prices and high cost of living. As these costs are partly external to private decision-makers, they do not fully deter the spatial concentration of people and economic activities, as such costs are not taken into account in private location decisions (Elhorst *et al.*, 1999). Whether a fast rail connection to the north will produce the desired relief in the Randstad remains to be seen, as the flow of industrial activity away from the economic core so far has mainly been directed towards adjacent regions and not towards the periphery.

The net present value of the investment costs of the inner and the outer Maglev ring in the Randstad are estimated at EUR 6,835 and EUR 9,088 billion, respectively, and that of the core-periphery Maglev along the north-west or the south-east of the IJsselmeer at EUR 7,500 and EUR 6,666 billion, respectively. Each estimate includes a mark-up for uncertainties and risk. It has been assumed that the construction of the rail infrastructure would take place in the period 2010-2015 and that its use would start after completion. Costs and benefits are calculated as net present values for 2010 (in prices of 2000), using a social discount rate of 4% over a 30-year-period (2010-2040). Every project is evaluated in comparison with a spatially detailed baseline scenario that is based on the moderate 'European Coordination' macro-economic scenario of the CPB (1997).

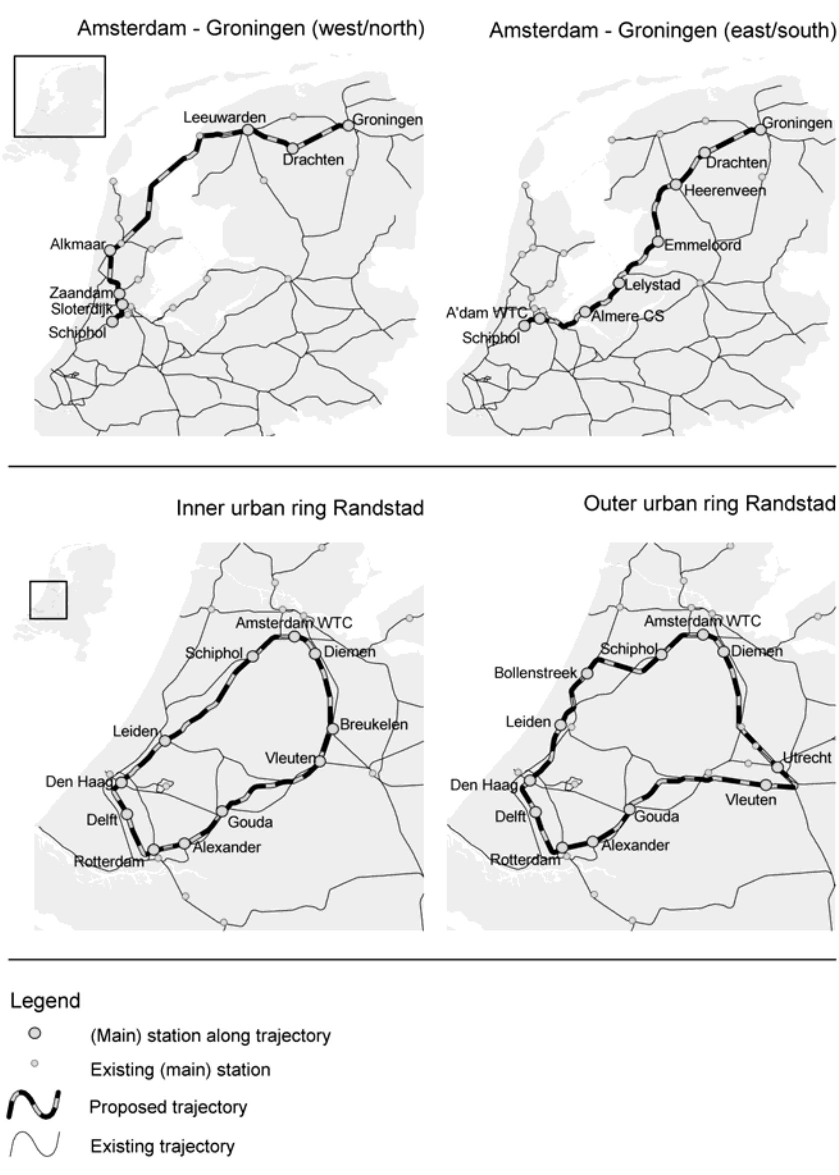

Fig. 11.2. Trajectories for the four proposed Maglev rail projects

The research concerning the four Maglev proposals was part of wider investigations considering different routes, different service levels (frequency, schedule, waiting time), different price levels as well as different rail systems, such as regular rail and high-speed rail services and their accompanying infrastructure investments. In addition to direct transport effects and direct external (environmental) effects, which have been studied in the usual fashion, these investigations stand out as they also consider indirect effects. The estimated direct transport cost and benefits include operating costs and revenues, and transport costs and time benefits for both people and freight. The estimated indirect economic benefits relate to the so-called forward programme or induced effects. These are defined as the consequences of the reduction in transport cost for production, market and location decisions of people and firms, and the subsequent interregional redistribution effects with respect to income and employment of the population at large.

In view of the theoretical considerations in the first part, the second part of this chapter will discuss in particular the efforts to model the interaction between the economy and the transport system, as well as the welfare effects of congestion and environmental impacts. The welfare effects will be scaled by computing them as a percentage of the investment costs.

11.5.2 Modelling the Interaction between the Economy and the Transport System

One of the main benefits of new infrastructure is the time benefit for people. We are particularly interested in the time benefits *by car* that occur due to reduced congestion as people substitute public transport for car transport. These time benefits can be split into direct effects, as usually calculated under the assumption of a fixed spatial distribution of population and employment, and indirect effects that are due to the changes in these spatial distributions.

The direct benefits of reduced congestion are taken from NEI (2001a, 2001b) and have been calculated using a more or less standard 4-stage transport model (called LMS), which explains and predicts commuting flows, provided that the marginal totals of the trip distribution matrices are given. For major transport improvements, such as the Maglev proposals considered here, this approach is unsatisfactory, as the spatial distribution of population and employment is not exogenous to changes in the transport system.

To model these indirect economic effects, we additionally considered two relatively independent main indirect effects and two derived interaction effects, as shown in Fig. 11.3.

The *first main effect* 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 the length of their commuting journey without changing their commuting journey time. This principle has been used to develop a *commuter location model* that takes actual commuting behaviour as given and then projects where people will choose to live given the location of their jobs.

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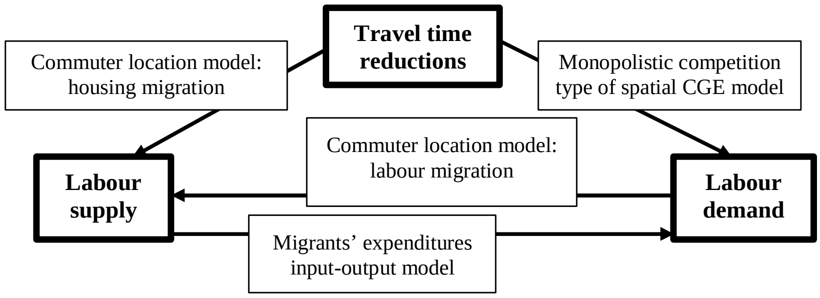

Fig. 11.3. Modelling scheme for calculating indirect economic effects in the Maglev application

Actual commuting behaviour is approximated by a commuting time distribution matrix, which specifies commuter shares by mode (car, 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 matrix is based on 70,886 observations, while potential changes in modal shares have been modelled with the help of an almost ideal demand system (AIDS, see Elhorst and Oosterhaven, 2003, for further details). With this set-up, the commuter-location model transforms the spatial distribution of employment into a spatial distribution of working population, both across 548 municipalities, dependent on the willingness to commute, and on municipality-by-municipality travel-time matrices for the three modes of transport during peak hours.

In addition, the transformation has been made dependent on the relative attractiveness of each municipality as a residential area. Although the location choice of each individual is free, the entire population is constrained by the total housing supply in each 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 predicted with an average error of 7%. The amount of available land, however, better approximates the spatial preferences of people, the majority of whom prefer larger lots in areas that are greener (Elhorst *et al*., 1999; VROM, 2000). For this reason, the amount of available land is used to simulate longer term residential changes, assuming that the housing market has time to adjust to the changes in the transport system and to follow these residential preferences.

The *second main effect* relates to travel-cost induced employment changes. If the transport costs of inputs and outputs change differentially in different locations, the optimal location and production size of the firm is expected to change. New economic geography (NEG) theory has pointed out that imperfect competition and increasing returns to scale in transport-using sectors are reasons why traditional location approaches may produce inaccurate estimates. There are two different NEG types of models. In the footloose labour models pioneered by Krugman (see

Fujita *et al*., 1999), locations close to markets pay higher real wages than locations away from the major markets. They consequently attract labour, which further enlarges the market and causes a further concentration of economic activity. The forces of concentration depend on the level of trade costs and the proportion of the population that is mobile in response to wage differences.

In the vertically linked industries model developed by Venables (1996), the process of cumulative causation is not driven by footloose labour but by cost and demand linkages between industries. Firms in the downstream industry will have lower costs if they locate close to upstream firms, they save trade costs on their intermediate inputs, while market access considerations draw the upstream industry to locations with relatively many downstream firms. In this study, a Venables-type of NEG model, called RAEM, the Dutch acronym for a spatial computable general equilibrium model, has been developed and calibrated (see Knaap and Oosterhaven, 2000). In contrast to the footloose labour type of NEG model, the working population in RAEM is assumed to be immobile and therefore cannot cause agglomeration. The reason for abandoning the footloose labour model is that wages in the Netherlands do not differ much between regions because they are determined on a national sectoral scale by collective bargaining. Consequently, there is little incentive to migrate between regions in order to receive a higher wage. Instead, the wage level has been assumed equal throughout the country, while the commuter location model is used to model the location choice of the working population.

In contrast to standard NEG models, it has been assumed that transport costs relate to both freight and passengers (personal business travel and shopping travel by the customers of the firm). Just as in standard NEG models, the transport cost mark-up on f.o.b. prices for freight depends on distance, but for passengers it is made dependent on travel time. Furthermore, it has been assumed that the travel times related to personal business travel and shopping travel are different from those in the commuter location model. Instead of the three modes of transport and their corresponding travel times during peak hours in the commuter location model, travel time in RAEM consists of the travel time by car and by public transport during off-peak hours weighted by their modal shares in business/ shopping travel.

One of the basic problems of monopolistic competition models of the spatial economy is the estimation of their parameters such that they reproduce recent history and simultaneously provide plausible (in particular, stable) projections. This is a difficult issue because of the non-linear character of the behavioural equations. To reach maximum accuracy, 14 sectors and 548 municipalities have been identified. Cobb-Douglas production and consumption expenditure shares have been taken from the (coincidentally also) 14 bi-regional input-output tables of the twelve Dutch provinces and the greater Amsterdam and greater Rotterdam regions (RUG/CBS, 1999, Eding *et al*., 1999). The 14 crucial elasticities of substitution, which *inter alia* determine the extent of market competition, and the 4 distance parameters, have been estimated econometrically. This is done by minimising the sum of squared residuals of predicted and observed trade flows taken from the bi-regional input-output tables (i.e. 588 flows of exports to, imports from and intra-regional transactions of the 14 regions, for the 14 sectors studied). The R^2 of regressing the observed (log) flows of

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trade on the (log) flows predicted by the model (without intercept) is 0.51. Although there is room for improvement,[2] any change in the model would lead to a compensating change in the parameters then to be re-estimated, which may have not much influence on the outcomes of the model.

The *first derived effect* is the subsequent reaction of the working population to the predicted change in production and labour demand, and is labelled *labour migration*. Note that the commuter location model predicts housing migration as a result of reduced travel times starting with a *given* level of employment in each municipality, whereas this run of the commuter location model measures labour migration as a result of *changes* in employment opportunities. Total migration is the sum of housing migration and labour migration.

The *second derived effect* relates to consumption-induced employment changes caused by the total migration of workers. Due to a lack of data, this effect is not determined at the level of the 548 municipalities, as were the three previous effects, but rather at the level of the 40 Dutch NUTS-3 regions, using a 40x40 employment multiplier matrix of working migrants (see Oosterhaven, 2005, for details). This matrix is again based on the 14 bi-regional input-output tables. The total labour demand effect is the sum of the travel cost-induced and consumption-induced employment effects.

The empirical results may be summarised as follows (see Oosterhaven and Elhorst, 2003, for details). The primary aim of the urban-conglomeration proposals is to strengthen the (international) competitive position of the heavily urbanised Randstad. The results in this respect indicate that, due to the redistribution of labour demand within the Netherlands, employment in the Randstad will increase by 2,400 jobs with the inner variant and by 2,750 jobs with the outer variant.[3] When looking at other regions and at intra-regional changes within the Randstad, it has been found that the urban rail link would strengthen the process of suburbanisation. Within the four big agglomerations, the central municipalities of Amsterdam, Rotterdam, The Hague and Utrecht would experience a population decrease, whereas surrounding municipalities close to a Maglev station would experience a population increase. This suburbanisation process would also extend to the regions adjacent to the Randstad. These regions would experience a decrease in the number of jobs, whereas their populations would increase. By contrast, the more peripheral regions such as the north of the Netherlands would hardly benefit from a fast rail link within the Randstad, neither in terms of employment nor in terms of population.

The primary aim of the core-periphery proposals is to stimulate the peripheral north. The results in this respect indicate that employment in the north would increase by 3,950 jobs with the south-east variant and by 8,050 jobs with the north-west variant. The working population would increase by 4,000 people in the south-east variant and by 9,400 people in the north-west variant. In sum, the north would

[2] RAEM is currently being further developed together with TNO Inro (Delft) and the Free University Amsterdam.

[3] From an international viewpoint, employment in the Randstad would further increase by about 1,300-1,420 jobs (BCI, 2001).

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indeed catch up. Furthermore, it can be concluded that the north-west variant would be about twice as effective in stimulating the north, than the south-east variant, whereas the core-periphery projects would be far more effective in creating jobs in the north than the intra-core projects.

The secondary aim of the core-periphery proposals is to relieve the (land, traffic and labour) pressures in the Randstad. The results indicate that in the south-east variant 7,045 people would leave the Randstad, whereas in the north-west variant the working population in the Randstad would increase by 100 people. This implies that, in view of this secondary aim, the south-east variant would be far more effective than the north-west variant, whereas both intra-core projects would be counter-productive in this respect.

11.5.3 A Welfare Evaluation of External Effects

Although the interregional redistribution of economic activities described above provides useful information for policy purposes, it falls short of a welfare assessment of the new infrastructure. Here, the results of a welfare evaluation of most of the external effects are given. They are recorded in Table 11.2. The first two lines present direct and indirect transport-upon-transport externalities. The last four lines represent final environmental externalities.

The estimates of the *direct benefits of reduced congestion* are taken from NEI (2001a, 2001b). The outcomes are derived from a large 4-stage transport model of the Netherlands (LMS), which explains and predicts commuting flows, provided that the marginal totals of the trip distribution matrix are given. Remarkably, the core-periphery variants do not lead to any reduction of direct congestion, although it was found that about 6% of the car commuters between the cities with a train station along the north-west and south-west variant would switch to public transport. For the Netherlands as a whole, it involves about 8,000 commuters per day. Although 6% is relatively high, the reduction mainly occurs outside the urban core where congestion is not a major problem.

In contrast, the congestion effects found for urban-conglomeration proposals show that these fully meet the first objective of reducing congestion; with the inner ring, congestion cost declines by 36% of the investment costs. The percentage found for the inner ring is greater than that for the outer ring for two reasons. First, the inner ring is cheaper and shorter (140 km against 170 km) as it stops at the edges of Rotterdam and Utrecht. Second, the inner ring attracts more passengers who leave their cars because of the relatively large time benefits, whereas the outer ring – connecting city centres – attracts more new passengers and passengers who already use other forms of public transport.

The determination of the *indirect benefits of reduced congestion* is based on Elhorst *et al.* (1999). When the number of people and jobs decrease in the urban core and increase in the peripheral regions, so will the amount of traffic. When the amount of traffic decreases in the urban core and increases in the peripheral region, absolute congestion costs decrease considerably in the core region and increase only slightly in the peripheral regions. From Table 11.2, it is clear that all projects lead to a more

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balanced spread of traffic over the country but that this effect is much larger for the core-periphery projects, especially for the south-east variant. This is because in this variant many more people leave the urban core.

Table 11.2. Welfare impacts of the external effects in percentage of investment costs

	Randstad Maglev, inner ring	Randstad Maglev, outer ring	Schiphol-Groningen, north-west	Schiphol-Groningen, south-east
Direct congestion benefits	36.0	16.5	0	0
Indirect congestion benefits	0.3	0.2	0.9	3.1
CO_2 and NO_X emission effects	1.6	0.4	-2.5	-2.5
Net open landscape benefits	0.4	0.3	1.1	3.8
Noise pollution cost	-0.7	-9.9	-5.1	-6.7
Qualitative estimate of remaining non-valued environmental effects	-/+	-/+	--	--

The *final environmental externalities* of a new rail link relate to the natural environment, carbon dioxide and nitrogen oxide emissions, noise, external safety, and land-use effects. Three different effects must be considered. First, the construction and service of a new rail link causes direct environmental cost through increased emissions and negative landscape impacts. Second, by contrast, the substitution of new public transport for old car transport causes environmental benefits through reduced emissions. Third, the relocation of employment and population may indirectly cause environmental costs or benefits in different regions, which may lead to a net national welfare effect. Although many of these effects are quantified, only the open landscape impacts, the CO_2 and NO_x emissions and the noise impacts could be valued in monetary units.

The welfare effects of changes in *CO_2 and NO_x emissions* are taken from NEI (2001a, 2001b, see also Wee *et al.*, 2003). Remarkably, they are positive for the urban-conglomeration projects and negative for the core-periphery projects. The explanation is that the urban-conglomeration projects, especially the inner variant, encourage far more people to leave their cars than the core-periphery projects, as discussed above. In the case of the intra-core projects, this more than compensates for the high energy use of the Maglev system.

Net *open landscape benefits* occur because of the relocation of people and jobs. The restrictive spatial planning in the Netherlands aims at preserving open agricultural and natural landscapes. These are most scarce in the urbanised western part of the country and relatively abundant in the least urbanised northern part of the Netherlands, which leads to considerable price differences for technically comparable housing (Creusen, 1999). Especially in the core-periphery variants, the relocation of housing and jobs results in less pressure on open landscapes in the Randstad and more pressure in the north, which leads to a net increase in welfare. Housing price differentials are used to estimate the relative valuation of open landscapes in the different parts of the country.

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Second, public investment costs for developing new residential areas and construction costs in densely populated regions tend to be higher than in sparsely populated regions. In addition to this, they also tend to be higher in urbanised parts within these types of regions than in non-urbanised parts (Sievers and Keers, 1992). The total estimate of the benefits due to imperfections in the housing market is derived from Elhorst *et al*. (1999). The results regarding the open landscape benefits are comparable to those concerning the indirect benefits of reduced congestion because they are based on the same interregional relocation figures reported in section 11.5.2.

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The welfare impact of *noise pollution* depends on factors such as the driving speed of the trains, the number of train passengers and the number of people living along the new rail tracks. It also depends on whether the new railway line is combined with existing road or railway infrastructures. In the latter case, annoyance hardly increases and may even remain unchanged if the noise emission of the Maglev falls (more than 3dB) below that of road traffic (for example, if the Maglev reduces speed when approaching a stop). The annoyance effect of the inner variant of the urban-conglomeration project is relatively small (Gotink, 2003) as it is almost completely combined with the existing road infrastructure. By contrast, the annoyance effect of the outer variant of the urban-conglomeration project is ten times higher. This is striking because it is almost completely combined with the existing railway infrastructure. Apparently, a combination with continuous noise-producing road infrastructure is much less disturbing than a combination with infrequent noise-producing railway infrastructure. The annoyance effect of noise pollution in the core-periphery projects lies midway between the two urban-conglomeration projects because these projects are partly combined with existing road and partly with existing railway infrastructure.

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First attempts to evaluate the direct external effects on *external safety and the natural environment* indicate that these effects are relatively small. The ‘-/+’ sign in the urban-conglomeration projects is used to indicate that the non-valued environmental effects are negative with respect to the built and natural environment and are positive with respect to safety, such that the overall effect is uncertain.

11.6 Conclusion

This chapter has discussed modelling the ETE triangle from the perspective of the welfare consequences of local policy measures. It has been argued that economy-transportation interaction needs to be modelled using sectors, household types, transport modes and spatial zones. For urban agglomerations, using a land-use/transportation interaction type of modelling should be evaluated against using a spatial computable general equilibrium type of model. For interregional applications, a spatial equilibrium approach is superior because it enables the incorporation of economies of scale, substitution between inputs and heterogeneity of outputs. Furthermore, we conclude that – at the local and regional level – environmental externalities may be modelled without taking account of feedback effects on the economy and the transport system.

The modelling philosophy is applied to four Dutch magnetic levitation rail proposals. When concentrating on the welfare effects of congestion changes and the environmental impacts, the greatest strength of the urban-conglomeration projects is their reduction of congestion, whose valuation is up to 36% of the investment costs when connecting the edges of cities. As this type of connection also attracts more passengers who leave their cars, a net decrease in carbon dioxide and nitrogen oxide emissions is possible. Noise pollution can be kept within bounds if the new railway line is combined with the existing road infrastructure. The greatest strength of the core-periphery projects is their reduction of congestion and pressure on open landscapes in the urban core due to the differential growth of employment and population from relatively overcrowded to relatively rural regions, whose combined valuation accounts for up to 7% of the investments costs if its route is carefully chosen.

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