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Elhorst, J. Paul; Oosterhaven, Jan; Romp, Ward E.

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INTEGRAL COST-BENEFIT ANALYSIS OF MAGLEV TECHNOLOGY UNDER MARKET IMPERFECTIONS

J. Paul Elhorst, Jan Oosterhaven and Ward E. Romp¹

SOM-theme C: Coordination and growth in economics

Abstract

The aim of this article is to assess a proposed new mode of guided high speed ground transportation, the magnetic levitation rail system (Maglev), and to compare the results of a partial cost-benefit analysis with those of an integral CBA. We deal with an urban-conglomeration as well as a core-periphery Maglev project and also try to explain why the older German Maglev proposal to connect two large, but distant cities (Hamburg and Berlin) was rejected.

The empirical outcomes of our study provide policy information on the interregional redistribution of working population and labor demand and whether these projects are worthwhile in terms of national welfare. They also show that the additional economic benefits due to market imperfections vary from -1% to +38% of the direct transport benefits, depending on the type of regions connected and the general condition of the economy. Hence, a uniform 'additional to direct benefit' ratio does not exist.

Keywords

Magnetic levitation, monopolistic competition, regional labor market, integral cost-benefit analysis, The Netherlands

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¹ Respectively, associate professor, professor and PhD student in spatial economics. Address: P.O. Box 800, 9700 AV Groningen, The Netherlands, phone: +31-50-363.3740, fax: +31-50-363.7337, email: j.p.elhorst@eco.rug.nl, oosterhaven@eco.rug.nl.

1. INTRODUCTION

Any proposal for an entirely new transport scheme requires a thorough and systematic appraisal process. The SACTRA report (1999, p.179-189) recommends that the appraisal process be structured so as to include the following questions:

1. what is the rationale for the transport improvement;
2. what is the pattern of gains and losses, in both economic activity and jobs, which will arise from the transport improvement; and
3. what are the benefits/disbenefits of the transport improvement, calculated using a partial cost-benefit analysis and using an integral cost-benefit analysis. The objective of an integral analysis is to make as complete an estimate as possible of the total economic benefits/disbenefits including, as far is possible, the environmental effects.

The aim of this article is to assess a proposed new mode of guided high-speed ground transportation, the magnetic levitation rail system (Maglev), and to compare the results of a partial with those of an integral cost-benefit analysis.

Presently, the Dutch government contemplates the construction of two Maglev projects, each with two variants. A description and the rationale for these projects is presented in section 2. The Maglev projects are part of a larger set of policy proposals, which consists of different rail systems (also regular and high-speed rail), different routes, different service levels (frequency, schedule, waiting time), and different price levels. This article focuses on the Maglev projects, because a thorough and systematic evaluation of this entirely new transport mode is not yet available in the transport literature. Vuchic and Castello (2002) have compared critical systems characteristics of Maglev technology, among which investment costs, operating and maintenance costs and energy consumption, with high-speed rail, but have not carried a cost-benefit analysis. Van Wee *et al.* (2003) have explored methods for more completely incorporating environmental effects in cost-benefit analysis and have illustrated this using a couple of examples, among which Maglev. In this paper we deal with an urban-conglomeration and a core-periphery Maglev project and also try

to explain why the older German Maglev proposal to connect two large, but distant cities (Hamburg and Berlin) was rejected.

Two seminal reports (SACTRA, 1999; CPB/NEI, 2000) have recently pointed out that a partial (also called ‘conventional’) cost-benefit analysis may either underestimate or overestimate the benefits/disbenefits, because it is conducted on the assumption of a closed economy with perfect competition. To explain the meaning of this statement, it is important to make a distinction between direct and indirect effects (in the UK called ‘wider effects’). *Direct economic* effects include cost and benefits for the owner, the operator and the users of the transport improvement, such as investment cost, exploitation cost and revenues, and transport cost and time benefits for freight and people given *existing* locations of firms and people. *Indirect economic* effects include cost and benefits of the transport improvement that are passed on to producers and consumers in other markets, which may lead to relocation of firms and people, and the subsequent interregional generation and redistribution of income and employment (Rietveld and Nijkamp, 2000; Oosterhaven and Knaap, 2003). In addition to these effects through markets, there will be direct and indirect effects that are *external* to the market, such as congestion, safety, pollution and other environmental impacts (cf. SACTRA, 1999; CPB/NEI, 2000; Rothengatter, 2000).

An integral social cost-benefit analysis will include the costs and benefits related to the direct as well as to the indirect responses of economic agents, will relax the assumption of perfect competition where relevant, such as on product markets, the labor market and the housing market, and will also consider cross-border effects (see also Mackie *et al.* 2001). The perfect competition and closed economy assumptions nonetheless provide an important benchmark, because the calculation of the direct transport benefits is sufficient as an estimate of the total economic benefits when these assumptions hold. This is because cost and benefits of the transport improvement that are passed on to producers and consumers in other markets do not change the size of welfare effects under these assumptions. Consequently, one could ignore them. By contrast, when the benchmark is not valid, indirect responses of economic agents, in addition to the usual external effects, require explicit modeling attention as they may generate - possibly considerable - additional welfare gains or

losses. Theoretical studies already produced some information on the “additional economic to direct transport benefits” ratio (SACTRA, 1999, p.101), but convincing empirical evidence is still lacking. This paper attempts to throw empirical light on this ratio.

According to the SACTRA report (1999, p.180), the current state of the art of appraisal modeling does not account adequately for all the important responses in product, labor and housing markets. In section 3 we briefly describe four linked models that, although there is room for improvement, are able to determine the additional economic cost and benefits of new transport infrastructure under imperfect competition. First, a commuter location model projects the spatial relocation of the working population. Second, an interregional monopolistic competition equilibrium model projects the spatial relocation of labor demand. Third, an interregional input-output multiplier matrix translates working population changes into consumption-related labor demand changes. Fourth, a labor market regime switch model measures the efficiency changes on regionally imperfect labor markets.

We also present the main indirect effects on regional labor supply and demand to address the question which regional pattern of gains and losses, in both economic activity and jobs, as a result of the urban-conglomeration and core-periphery Maglev projects arise. This also opens the opportunity to evaluate whether the stated project aims are met.

Section 4 describes the methods and models used to value the direct transport cost and benefits and the external effects in general terms, and the result of the welfare valuation of the indirect economic effects in more detail, with special attention to the issue of how market imperfections are incorporated. Further implications, conclusions and some words of caution are pointed out in the last section.

2. THE TWO MAGLEV RAIL PROJECTS

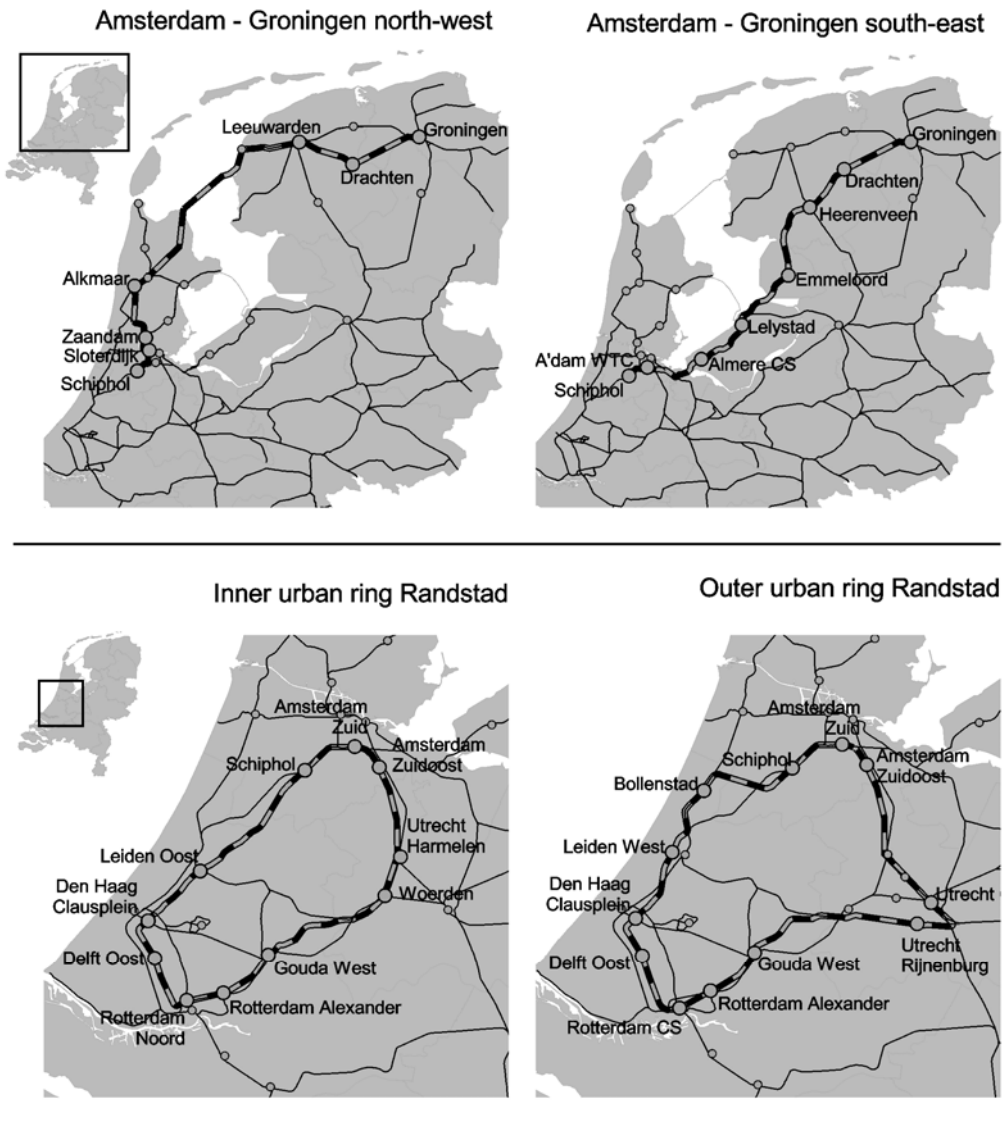
In this section we give a description of the urban-conglomeration and the core-periphery Maglev projects and address the first question: the rationale for these projects.

Figure 1 shows the proposed trajectories of the two Maglev projects, each with two variants: (1) an inner ring and an outer ring connecting the four largest cities of the Netherlands (Amsterdam, The Hague, Rotterdam and Utrecht). The inner ring is shorter as it calls at the edges of Rotterdam and Utrecht, while the outer ring has more stations and also calls at the city centers of Rotterdam and Utrecht; (2) a direct connection between Schiphol Airport (near Amsterdam) and Groningen, either running along the north-west coast of the “IJsselmeer”, a large lake in the middle of the country, or running south-east of it through the new polders of Flevoland.



The cities of Amsterdam, The Hague, Rotterdam and Utrecht are all located in the so-called Randstad region, the economic core of the Netherlands. This region is highly urbanized with high densities of both people and businesses. Groningen is the largest city in the North, a peripheral region with a rural character, even though its income share from agriculture is rather small.

The major stated aim of a fast rail link within the Randstad is to improve its internal public transport accessibility. This in turn is hoped to reduce traffic congestion and therefore to also improve the Randstad’s internal accessibility by car. Both may strengthen the Randstad’s competitive position in attracting internationally mobile economic activities. Besides, compared to other regions in the Netherlands, the need for space for new residential areas and industrial sites is much more urgent in the Randstad. With the help of new fast rail links, it might be possible to direct the urbanization process away from the remaining vulnerable agricultural and natural areas within the Randstad, which is the secondary aim of this link.

Figure 1: Proposed four magnetic levitation trajectories



Legend

- (Main) station along trajectory
- Existing (main) station
-  Proposed trajectory
-  Existing trajectory

The major stated public 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 could live in the North while working in the Randstad. This increases demand for locally produced goods, which initiates a multiplier process leading to higher regional production and employment. A fast rail link would also lower the prices of services to and from firms located in the North, possibly shifting the competitive balance in favor of locations in the North in spite of the ‘two-way road’ argument (SACTRA, 1999, p.16). Both effects are seen as the key to further economic development.

The secondary aim of a fast rail link between the Randstad and the North is to relieve the Randstad’s capacity constraints in transport, land and labor markets, which result in loss of time, high transport costs, high housing prices, high cost of living, and labor shortages. As these costs are partly external, they do not fully deter the spatial concentration of people and economic activities, since such costs are not taken into account in private location, consumption and production decisions (cf. Elhorst *et al.* 1999). Whether a fast rail connection to the North will really produce the desired relieve in the Randstad remains to be shown, as the flow of industry away from the economic core up till now is mainly directed towards adjacent regions and not towards the periphery (Boeckhout and Haverkate, 1995).

3. INDIRECT ECONOMIC EFFECTS

This section contains a brief description of the modeling set-up. The description here is only meant to better understand the calculation of the costs and benefits in the next section. Details of the models introduced below, the commuter location model, RAEM and the employment multiplier matrix of commuting migrants, are given in successively Elhorst and Oosterhaven (2003), Oosterhaven and Knaap (2003), and Oosterhaven (2005). In the second part of this section we address the question which regions gain and which regions lose as a result of the Maglev projects and evaluate whether the stated public aims are met.

3.1 Modeling set-up

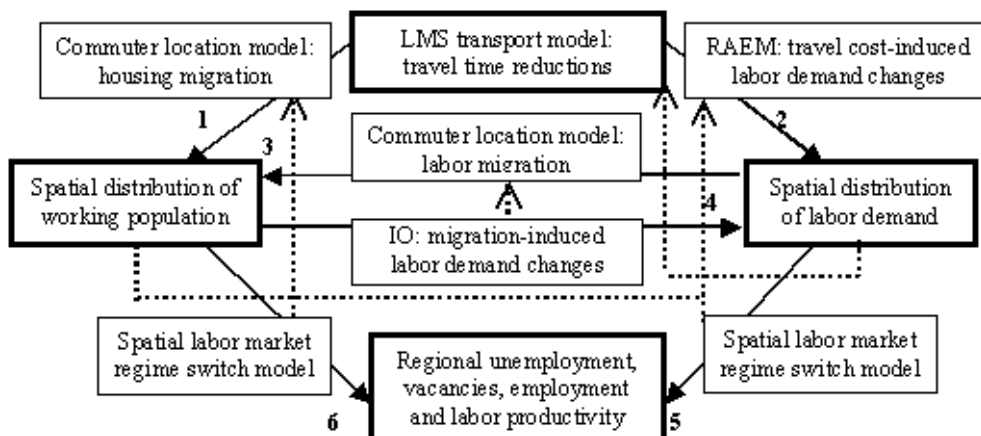
As illustrated in figure 2, the indirect economic effects in this study are modeled as two independent main effects and two derived interaction effects, in both cases one effect on the size of the working population and one on the size of labor demand. All four projects are evaluated in comparison with a baseline scenario. This scenario is based on the moderate “European Co-ordination” scenario of the CPB (1997).

The starting point of the estimation of the indirect economic effects are the expected travel times in 2020 before and after the proposed changes in the transport network. These travel times are derived from a standard 4-stage transport model (called LMS), which uses fixed spatial distributions of employment and population (Daly, 2000, section 2.2). One of the most striking consequences of the project proposals is the fall of the total travel time by public transport in both core-periphery projects below its counterpart by car, even during normal hours, which is quite unique for a public transport system.² In the urban-conglomeration projects the public transport travel times, although much lower than before, still remain higher than their counterparts by car.

The *first main effect* (arrow 1) relates to housing migration of the working population. When travel times diminish, people may increase the quality of their housing accommodation and living environment, by increasing their commuting journey length, without changing their commuting journey time. This principle has been used to develop a *commuter location model* that takes actual commuting time behavior as given and then predicts where people choose to live given the location of their jobs. This model is an extension of the popular multinomial logit model and has similarities with the competing-destinations spatial choice model of Pellegrini and Fotheringham (1999).

² It is 96-100 minutes by Maglev, including entering and egressing time, as against 135 minutes by car on the distance of almost 190 km between the endpoints of the line.

Figure 2: Modeling scheme for calculating the indirect economic effects



Actual commuting behavior is approached by a commuting time distribution matrix, which specifies the percentage of commuters by mode (car at peak hours, public transport and slow transport), by time class (25 classes of 5 minutes) and by type of municipality (four biggest cities, municipalities with a railway station and municipalities without a railway station), based on 70,886 observations (CBS, 1999). Modal substitution shifts within this matrix have been modeled with the help of an almost ideal demand system (AIDS). Using this set-up, the commuter location model transforms the spatial distribution of employment into a spatial distribution of the working population across 548 municipalities, dependent on the willingness to commute and on municipality-by-municipality travel time matrices for the three modes of transport.

To test the fit of the model, this transformation has also been made dependent on the housing stock. Although each individual is free to choose a particular house, the entire population is constrained by total housing supply in each municipality on the short term. It appeared that - with this extension and after aggregation - 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%.

In the long term, new houses can be constructed. Most empirical evidence summarized by Whitehead (1999) suggests that market supply is potentially responsive to changes in demand in that the long-run price elasticity of supply is equal to or greater than unity. Research has shown that the majority of the working population in the Netherlands has a preference for larger lots in areas with more green (Elhorst *et al.* 1999; VROM, 2000; Rouwendal and Meijer, 2001). Although this preference can be measured by different variables, the obvious one is the available land in each municipality.^{3,4} For this reason, the available land is more suitable to simulate longer run residential changes, provided that the housing market has time to adjust itself to the changes in the transport system and the related changes in residential preferences.

The commuter location model is used to forecast the working population for each municipality in the baseline scenario and in each project variant using municipality-by-municipality travel time matrices for the three modes of transport during peak hours. The difference between these forecasts is used as an estimation of housing migration.

The *second main effect* (arrow 2) 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 firms 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 basically different NEG types of models. In the footloose labor models pioneered by Krugman (see Fujita *et al.*, 1999), locations close to markets pay higher real wages than locations farther out. They consequently attract labor, 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

³ This includes land for existing buildings and excludes land not suitable for building (e.g., water areas).

⁴ Housing prices are an alternative, because housing prices go up when more commuters choose a particular location (e.g. Anas, 1995). Rising housing prices, however, will lead to

industries model developed by Venables (1996), the process of cumulative causation is not driven by footloose labor but by cost and demand linkages between industries. Firms in downstream industries will have lower intermediate input costs if they locate close to upstream firms, while market access draws upstream industries to locations with relatively many downstream firms and consumers.

In this study a Venables type of NEG model has been developed and estimated. It is called RAEM, after the Dutch acronym for spatial computable general equilibrium model. The reason for not using the footloose labor model is that the basic system of wage determination in the Netherlands is for national single-industry agreements, which are binding by law to all firms and workers in the sector throughout the country (see for this classification, Layard *et al.* 1991, p.519). In other words, sectoral wages are assumed equal throughout the country and regional labor supply is assumed to follow regional labor demand. In contrast to standard NEG models, RAEM distinguishes between freight and passenger transport, the latter consisting of personal business travel and shopping travel by the customers of firms. 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 off-peak hours travel times by car and public transport, weighted by their corresponding shares in business/shopping travel.

To reach maximum empirical accuracy, 14 sectors and 548 municipalities have been distinguished. The elasticities of substitution, one for each sector, and the transport parameters of this NEG model have been calibrated by minimizing the sum of squared residuals of predicted and observed trade flows. These observations are taken from 14 bi-regional input-output tables of the twelve provinces in the Netherlands and the greater Amsterdam and greater Rotterdam regions (RUG/CBS, 1999, Eding *et al.* 1999). The predictions are obtained by aggregation (548 municipalities to 14 regions). The R^2 of this model appeared to be 0.51 based on 588 observations (14 sectors \times 14 regions \times flows of export to, import from, and intra-regional transactions per sector, per region).

new supply in the long run, as a result of which housing prices themselves would underestimate long-run residential population change.

RAEM is used to forecast labor demand for each municipality in the baseline scenario and in each project variant. The difference between these forecasts is used as an estimation of the travel cost-induced employment changes.

The *first derived effect* (arrow 3) is the reaction of the working population to the travel cost-induced change in labor demand, and is labeled as labor migration. Note that the commuter location model predicts housing migration as a result of changes in travel times with a *given* level employment in each municipality (arrow 1), whereas this run of the commuter location model measures labor migration as a result of *changes* in employment opportunities (arrow 3). It should be stressed that labor migration has been restricted to tertiary educated labor only (35% of total labor), since primary and secondary educated labor is assumed to be immobile. Total migration is the sum of housing migration and labor migration (arrow 1+3).

The *second derived effect* (arrow 4) relates to consumption-induced employment changes caused by the total migration of workers. Due to lack of data, this last indirect effect is not determined at the level of the 548 municipalities, as were the three previous effects, but at level of the 40 NUTS-3 regions in the Netherlands. It uses a 40x40 employment multiplier matrix of working migrants, which is again based on the 14 bi-regional input-output tables. The total labor demand effect is the sum of the travel cost-induced and consumption-induced employment effect (arrow 2+4).

One restriction of this modeling set-up is that only first-order effects are taken into account (the solid arrows in figure 2). The two main and the two interaction effects have been modeled such that the endogenous output of one model is the exogenous input of the subsequent model and that the same variable is not modeled twice (see also Oosterhaven and Romp, 2003). When the solid arrows 1 to 4 in figure 2 are passed through once, the calculation of first-order effects is finished.

In principle, it would be possible to take account of higher-order effects (the dotted arrows in figure 2) and to go on until convergence occurs. In that case, an iterative procedure results in which each iteration starts with a new run of the LMS transport model based on adjusted spatial distributions of employment and population. Similarly, RAEM must start with the adjusted spatial distribution of population, while the commuter location model then also should take account of

consumption-induced employment changes. Since these higher-order effects are very small compared to their baseline scenario levels, they are not of interest empirically.

3.2 Modeling results by region

The first objective of the *urban-conglomeration* proposals, as stated in section 2, is to strengthen the Randstad's international competitive position. Due to travel cost-induced and consumption-induced interregional employment redistribution within the Netherlands (see figure 4), employment in the Randstad will increase by 1,750 jobs in the inner variant and by 2,050 jobs in the outer variant. International redistribution of employment is estimated to lead to a further increase of about 1,300-1,420 jobs in the Randstad (BCI, 2001). The second objective is to direct the urbanization process away from the remaining vulnerable agricultural and natural areas within the Randstad. In both variants, approximately 1,500 working people (housing and labor migrants) will leave the Randstad (see figure 3). In sum, the Randstad benefits little in terms of both jobs and reduced pressure.

When looking at other regions and at intra-regional changes within the Randstad, it is further found that both variants strengthen the process of sub-urbanization. Within the four big agglomerations, the central municipalities of Amsterdam, Rotterdam, the Hague and Utrecht experience a population decrease compared to the baseline scenario, whereas surrounding municipalities that are close to a Maglev station experience a population increase, even though their number of jobs decrease (see figure 3). This sub-urbanization process partly extends to the regions east of the Randstad and to a lesser extent also to the peripheral North. By contrast, the South of the Netherlands loses from a fast rail link within the Randstad, in terms of both employment and population.

Figure 3: Total of residential and labor migration per Maglev variant

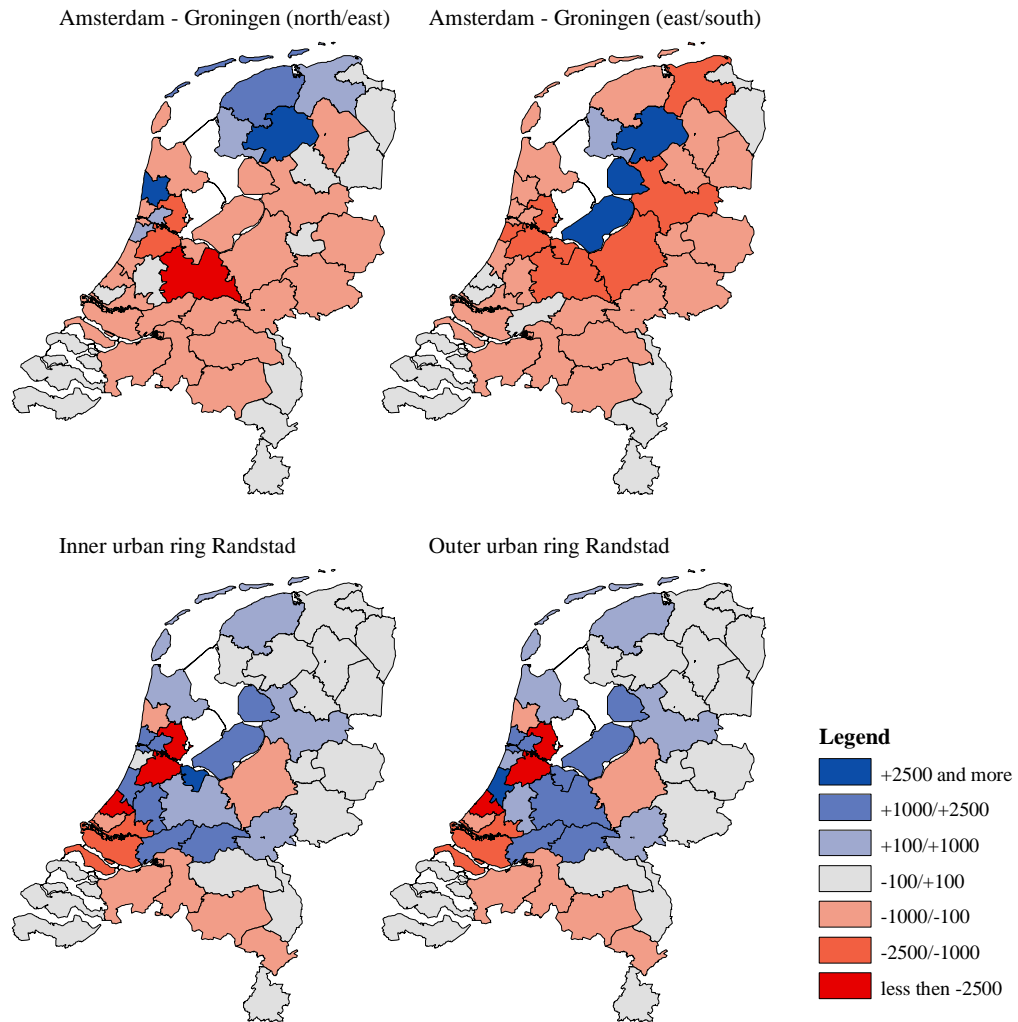
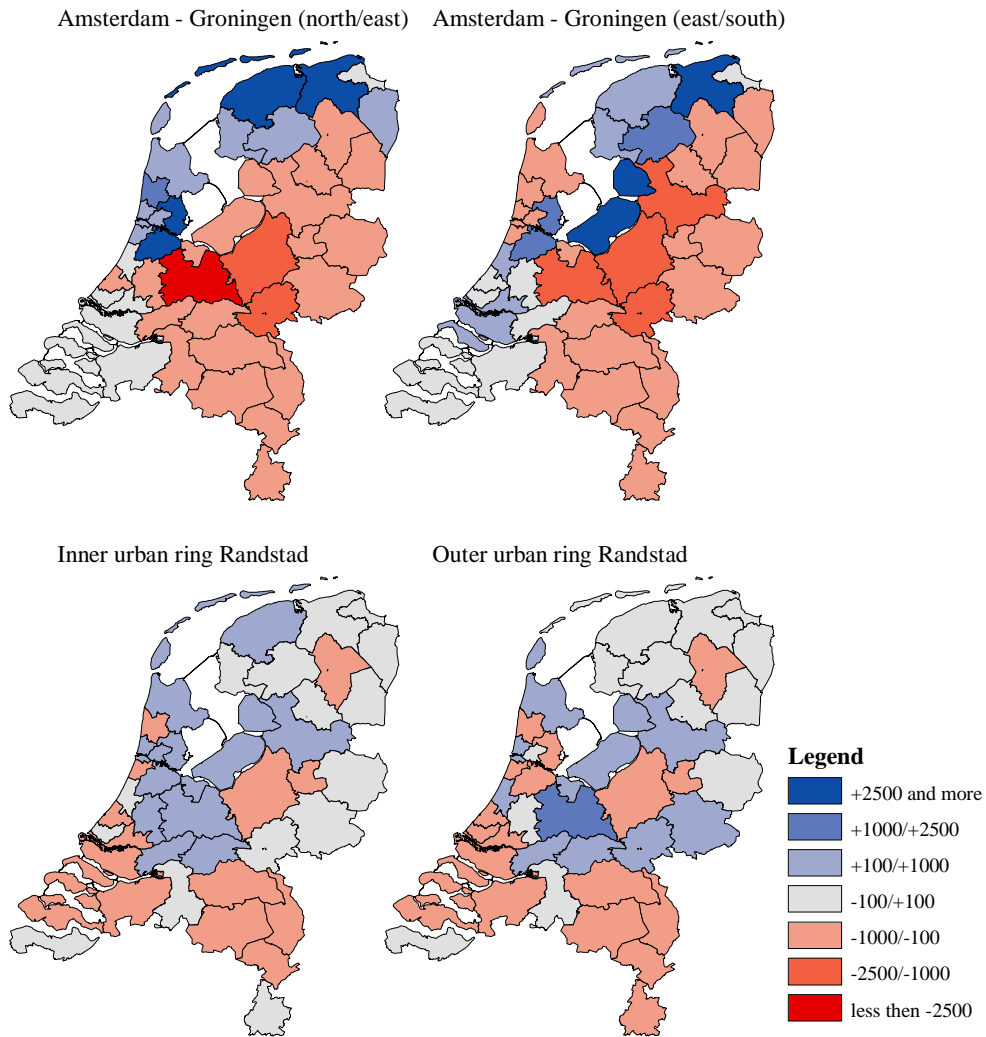


Figure 4: Total of travel cost- and migration-induced changes in labor demand



The first objective of the *core-periphery* proposals is to stimulate the peripheral North. Due to travel cost-induced and consumption-induced employment changes (see figure 4), labor demand in the North will increase with 3,600 jobs in the south-east variant and by 7,350 jobs in the north-west variant. The working population

(housing and labor migration) will increase by 2,100 people in the south-east variant and by 5,550 people in the north-west variant. In sum, the North indeed catches up. Furthermore, it may be concluded that the north-west variant is approximately twice as effective as the south-east variant.

The second objective of the core-periphery proposals is to relieve the Randstad. In the south-east variant 8,800 people will leave the Randstad and in the north-west variant only 1,300 people. Now, the south-east variant is far more effective. To detail this last difference, we further look at the intermediate region in both variants.

The Top of the province of North Holland, located to the north of the Randstad and halfway the north-west variant, is connected with the North by a 32 kilometer long dike (see figure 1). Just as the North, it is a peripheral region with a rural character, a shortage of jobs and a relatively high unemployment rate. A fast rail link through this region does not appear to be of much help, mainly because no extra stop is planned above Alkmaar (see Oosterhaven and Romp, 2003, for the rationale). The number of jobs will increase by only 100, while its working population will even decrease by 100.

Flevoland is also located halfway the Randstad and the North, but along the south-west variant. In this case, a fast rail link is extremely effective. Employment will increase by 4,450 jobs and the working population by 11,500 people (also see the figures 4 and 3). There are several explanations for this remarkable difference. Flevoland has three stations located along the new line, one of them (Emmeloord) not yet connected to the rail network (see figure 1). The region has been reclaimed from the sea in the 1960s and 1970s, and still has lots of space, while its most populous municipality (Almere) is located within 30 kilometers from Amsterdam and Utrecht. For these reasons, Flevoland is very attractive to Randstad commuters. The results confirm this: 95% of migration into Flevoland consists of housing migration and only 5% of labor migration.

4. NATIONAL COSTS AND BENEFITS

Although regional gains and losses in population and jobs provide useful information for policy purposes, they can be ignored in a national cost-benefit analysis when

product, labor and housing markets are characterized by perfect competition and a closed economy.⁵ If they are not, an integral cost-benefit analysis is needed. Therefore, in this section most attention is given to the estimation of the additional welfare effects due to market imperfections and cross border effects (see table 1 for the integral results).

4.1 Direct benefits and costs

Investment costs, exploitation costs and exploitation revenues are direct benefits and costs. The investment costs of the inner and the outer Randstad Maglev ring are estimated at 6,835 and 9,088 billion Euro. The investment cost of the north-west and the south-east variant of the Schiphol-Groningen Maglev are estimated at 7,500 and 6,666 billion Euro. Each estimate includes a mark-up for uncertainties and risk. Exploitation costs (as a percentage of the revenues) and exploitation revenues have first been estimated by NEI (2000, 2001) using the LMS transport model with the given baseline spatial distribution of employment and population. This approach is inadequate, because these spatial distributions are not exogenous to changes in the transport system. For this reason, the initial estimates of the LMS model have been adjusted on our part for the endogenous changes in employment and population discussed in the previous section. Besides the exploitation costs and revenues of the new rail link, avoided exploitation costs and loss of revenues on existing rail links are also taken into account.

Timesavings and reduced congestion are direct benefits. One of the prime reasons to invest in infrastructure is the time benefit for people. This benefit has been estimated by means of the cost-benefit analysis rule of half (Button, 1993, p. 183):

$$\sum_{i=1}^N \sum_{j=1}^N \sum_{m=1}^M 0.5 * (C_{ijam}^0 + C_{ijam}^1) * (T_{ijam}^0 - T_{ijam}^1) * VOT_{am}, \quad (1)$$

⁵ Assuming that efficiency is the only criterion.

where C_{ijam}^0 and C_{ijam}^1 denote the estimated flows from municipality i to municipality j of passengers engaged in activity a using transport mode m , before and after the change in the transport system. T_{ijam}^0 and T_{ijam}^1 denote the corresponding travel times and VOT_{am} denotes the value of time of activity a per transport mode m . Differences in VOT s per activity and mode, and differences in the models used for different travel motives, lead to a distinction between commuting trips, commercial trips (for business and shopping purposes) and other trips, as well as between car and public transport.⁶

The time benefits of *commuting* trips by public transport have been calculated using the results for C_{ijam}^0 and C_{ijam}^1 from the commuter location model, a VOT of 7.00 euro per hour, 2 trips a day, 220 working days each year, and an annual VOT growth of 1.1%.⁷

The time benefits of faster *commercial trips* and of *other trips* by public transport have been calculated by substituting the results of the LMS model (NEI, 2000, 2001) into (1), the first with a VOT of 15,38 Euro per hour, 285 trip days, and an annual VOT growth of 1.6% and the second with a VOT of 4,30 Euro per hour, 285 trip days, and an annual VOT growth of 0.6%.

The time benefits *by car* are due to reduced congestion. These benefits have been split into direct congestion effects, which are calculated under the assumption of a fixed spatial distribution of jobs and people, and indirect congestion effects, which are due to the changes in the spatial distributions of jobs and people. The direct congestion benefits are taken from NEI (2000, 2001), while the determination of the indirect congestion benefits is based on a previous study (Elhorst *et al.* 1999). Note that when jobs and people move from relatively overcrowded to relatively rural regions, as in the core-periphery projects, all associated traffic also moves and thus contributes to an indirect reduction of congestion cost.

⁶ Slow transport appeared to be of minor importance, as congestion and the number of people substituting car or public transport for slow transport appeared to be extremely small.

⁷ In the baseline scenario the real wage rate increases by 1.7% each year (Table 1). HCG (1998) has estimated the income elasticity of the VOT for commuting trips about 0.65. Consequently, in the baseline scenario, this VOT grows by 1.1% each year.

4.2 Additional welfare effects due to market imperfections

The change of the consumer surplus calculated by RAEM measures (i) the *time savings and exploitation revenues of commercial trips by public transport* reported above as direct benefits, and (2) the additional welfare benefits (disbenefits) due to *increased (decreased) competition and increased (decreased) variety of products for firms and consumers*. This is one of the strengths of NEG models. Since a utility function is part of the model, any change of the exogenous variables in the model can immediately be translated into a change of consumer surplus. In RAEM the change of consumer surplus is valued at the national consumption level. Another strength is that the substitution elasticities, which measure the degree of monopolistic competition, have been estimated. If a particular sector is perfectly competitive, its substitution elasticity would tend to infinity and, as a result, the additional welfare effects to zero. To compute the additional welfare benefits, the time benefits and exploitation revenues of commercial trips have been deducted from the consumer surplus change.

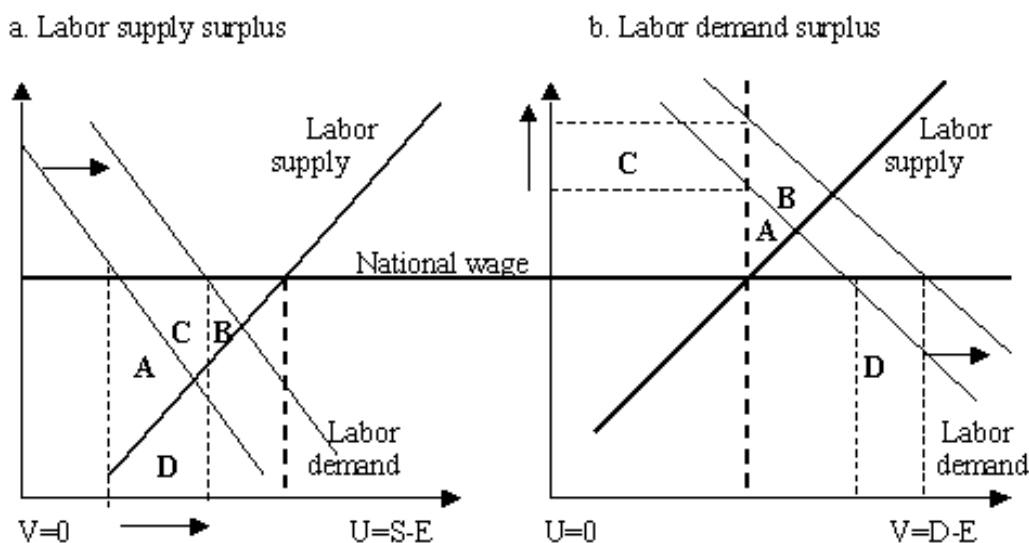
Additional welfare effects on the labor market might occur due to regional imbalances. Recall that RAEM assumes a uniform national wage level within each sector and that the reaction of the working population to the travel-cost change in labor demand is modeled assuming that primary and secondary educated labor is immobile. Since tertiary educated labor is assumed to be perfectly mobile, no additional welfare gains or losses can occur in this market segment. To measure the national efficiency effects on the primary and secondary segment of the labor market, an unemployment-vacancy regime switch model has been developed. Its basic assumption is that regions either have a labor supply surplus (with unemployment) or a labor demand surplus (with unfilled vacancies).⁸

First, we consider *spatial matching benefits* (indicated by arrow 5 in figure 2), which are caused by interregional shifts in labor demand, holding regional labor supply constant. When regional wages within a sector are fixed, an increase in labor

⁸ One improvement in future research would be to incorporate the labor market within the RAEM model using the job search approach of Pissarides (2000) with a convex instead of a regime switch relationship between surplus and shortage (see Van Ommeren *et al.* 2002, and Thissen, 2004).

demand works out quite differently when it occurs in regions with a supply surplus as opposed to regions with a demand surplus. Figure 5 describes the two different regimes. The upward sloping line is the labor supply curve reflecting the reservation wage of the unemployed. The downward sloping lines are the labor demand curves before and after the transport improvement. When the wage is fixed above its equilibrium sector-level, labor supply exceeds labor demand ($S > D = E$), causing unemployment, $U = S - E$, with zero vacancies. When the wage is fixed below its equilibrium sector-level, labor demand exceeds labor supply ($D > S = E$), causing unfilled vacancies, $V = D - E$, with zero unemployment.

Figure 5: Effects of regional labor demand shifts under different labor market regimes



In the case of a supply surplus (figure 5, panel a), a demand increase of ΔD will then lead to an equally large increase in employment ΔE and a subsequent reduction of unemployment ΔU . Triangles A and B indicate the welfare forgone due to a nationally fixed regional wage within a sector, before and after the introduction of the new infrastructure. It is important to note that these triangles reflect non-realized

inefficiencies, which therefore should not be counted in a cost-benefit analysis. By contrast, the area **A+C** reflects the inefficiency that is actually taken away by the introduction of the new infrastructure and therefore it is counted.⁹

A quite different story applies in the case of a demand surplus (figure 5, panel b). Then a labor demand increase of ΔD will lead to an equally large increase of unfilled vacancies ΔV , without an increase of employment. Triangles **A** and **A+B** reflect the welfare forgone due to a nationally fixed regional wage within a sector, before and after the introduction of the new infrastructure. Again, both should not be counted, because they relate to non-realized inefficiencies. What is counted is the effect of the increase in labor demand on labor productivity, rectangle **C**, as the increase in demand in this case will lead to a crowding-out of employment in less productive sectors with lower wages.¹⁰

Note that this does not contradict the assumption that the basic system of wage determination in the Netherlands is for national single-industry agreements, which are made binding by law. Alternatively, employers may pay wages above what the sector agreement requires. Empirical research by Blanchflower and Oswald (1994) has pointed out that people who work in regional labor markets with higher unemployment rates earn a lower wage. The regional unemployment elasticity of pay is generally -0.1 , which implies that a doubling of the unemployment rate causes a 10% lower wage. Even when this adjustment is taken up in the calculation, it is still the average regional wage per worker and labor productivity that increase.

The empirical estimate of the spatial matching benefits (inclusive of the corrections on the consumer surplus estimate from RAEM) depends on the wage elasticities of regional labor supply and demand, which have been estimated at 0.2 and -0.5, respectively, and it depends on the labor productivity change as a percentage of the net value added of the non-realized labor demand changes, which has been estimated at 10%. This calculation is carried out for each sector. Finally, note that

⁹ Note that **A+C+D** in the case of a travel cost-induced increase in labor demand is already included in the consumer surplus change estimated by RAEM. Hence, in that specific case **D**, the loss of leisure of the formerly unemployed, needs to be deducted to avoid double counting.

¹⁰ Note that **D** in the case of a travel cost-induced increase in labor demand is already included in the consumer surplus estimated by RAEM. Hence, in that specific case, next to adding **C**, the non-realized change in labor demand **D** needs to be deducted to avoid double counting.

opposite effects occur in panel a and b of figure 5 when labor demand shifts to the left instead of to the right.

Except for spatial matching benefits, *spatial market size benefits* occur when existing firms are able to access a larger spatial pool of workers, holding regional labor demand constant (indicated by arrow 6 in figure 2).

Qualitative size benefits occur as firms access better matching skills of all educational levels. In the empirical analysis these benefits are related to the increased willingness of *workers* to commute over longer distances. The latter has been approximated by the increase in the number of workers crossing the borders of the 40 NUTS-3 regions, calculated with the commuter location model discussed in the previous section. We assume that 10% of this number will actually result in a better skill match, which in turn is assumed to produce a 10% higher labor productivity.

Quantitative size benefits occur when *inactive* members of the working age population are also willing to look for work over longer commuting distances and when firms in labor demand surplus regions are able to thus fill up otherwise unfulfillable vacancies. This number of inactive people is estimated at 15% of the working people with primary and secondary education that are willing to commute over longer distances from regions with a labor supply surplus to regions with a labor demand surplus.

Finally, *international labor market benefits* occur when the increased international competitiveness results in an international shift of labor demand into specific Dutch regions. The estimates of these shifts are taken from TNO (*et al.* 2000, using Bröcker, 1999) and BCI (2001). Subsequently, the labor market regime switch model described by figure 5 has been used to determine the extent to which shifts in the demand for primary and secondary educated labor result in increases in employment in the case of labor surplus regions or in increases in labor productivity in the case of labor shortage regions. In the case of tertiary educated labor, the national labor demand increase is translated into a labor productivity increase, again set equal to 10% of the net value added of the non-realized demand change.¹¹

¹¹ The net value added of a job is estimated at 36,192 Euro for all workers, at 29,218 Euro for primary or secondary educated workers and at 49,144 for tertiary educated workers, while labor productivity grows by 2.3% per year (see table 1).

4.3 External costs and benefits, and the NPV

The main external cost and benefits of a new rail link relate to landscape effects, noise, safety, and emissions of all kind.

Landscape effects are primarily related to demand changes on the housing market, as people do not take account of the loss of open agricultural and natural landscapes when looking for a place to live. In a free land market, these external effects would cause too much land to be allocated to housing. The restrictive spatial planning in the Netherlands aims at preserving open agricultural and natural landscapes. This policy can be said to be successful if the external effects would be fully internalized in housing prices. Although there is evidence of a considerable price differential of technically comparable housing between the urban and peripheral parts of the Netherlands (Creusen, 1999), it goes too far to say that these external effects are fully internalized. One reason is that the Dutch government also subsidizes housing programs. If the existing housing market is inefficient due to external effects that are not fully internalized or due to subsidies that strengthen these inefficiencies, then a relocation of people and jobs may lead to additional welfare effects.

Especially in the core-periphery variants, the relocation of housing and jobs results is expected to lead to less pressure on open landscapes in the Randstad and more pressure in the North, whereas in the urban-conglomeration variants the inefficiencies are expected to rise. The total estimate of the benefits due to imperfections on the housing market is based on a previous study (Elhorst *et al.* 1999) and is related to the spatial redistribution of the working population (see the numbers reported in section 3.2).

Three other external effects must be considered. First, the construction and the service of a new rail link cause direct external costs. Second, the substitution of public transport for car transport causes indirect external benefits. Third, the relocation of employment and population may cause indirect external cost or benefits in different regions. Although many of these effects are quantified, only *CO₂ and NO_x emission effects* (Van Wee *et al.* 2003) and *noise hindrance* (Gotink, 2004) could be valued in monetary units.

Adding all discounted, monetized cost and benefits gives the *net present value* (NPV). In table 1, all monetized cost and benefits and the NPV are calculated for 2010 (the starting year of the construction), using prices of 2000 and a social discount rate of 4%, over a 30-year period and over a 50-year period.¹² The 4% and the 30-year period are standard in Dutch social cost-benefit analysis (CPB/NEI, 2000). The problem with the 30-year period, however, is that it does not cover the life of the projects. The problem with our alternative 50-year period is that the social discount rate of 4% does not cover the risks of the projects. Therefore, we have also calculated the internal discount rate over both periods. The internal discount rate, especially over the 50-year period, shows with how much the social discount rate may be raised for risks without obtaining a negative NPV.

4.4 Integral cost-benefit analysis results

From table 1 it can be seen that the total *benefits* of the urban-conglomeration projects are almost twice as large as those of the core-periphery projects. Furthermore, it can be seen that the composition of the benefits is very different.

The *urban-conglomeration* projects have higher time benefits, negative instead of positive spatial labor market matching benefits, and higher labor market size and international benefits. Moreover, both direct congestion and emissions are reduced, due to substitution between car and rail. This is especially the case with the inner ring that has far less passengers and exploitation revenues than the outer ring project, as it mainly connects the edges of the large cities (see figure 1). The majority of the inner ring passengers, however, leave their cars because of the relatively large time benefits, whereas the outer ring - connecting city centers - attracts much more new passengers and passengers that used other forms of public transport.

¹² Besides, the construction of the new rail link is assumed to take place over the period 2010-2015, with 33, 17, 20, 20 and 10% of the cost occurring per subsequent year in the urban-conglomeration projects, and with 10, 15, 30, 30 and 15% per year in the core-periphery projects (NEI, 2000, 2001). The exploitation cost and revenues, and time benefits are assumed to start at 100% from 2016 onwards. Indirect economic effects are assumed to rise over a five-year period, starting at 20% in 2016 and reaching 100% in 2020.

Table 1: Social cost-benefit analysis of four magnetic levitation systems under the EC-scenario: NPV in 2010, millions of Euro, price level 2000, discount rate 4%

	Inner ring Randstad	Outer ring Randstad	Amsterdam- Groningen, north-west	Amsterdam- Groningen, south-east
Exploitation revenues	480	2,298	1,090	1,357
Time benefits commuting trips	1,554	1,667	662	650
Time benefits business/shopping trips	670	723	733	1,137
Time benefits other trips	753	811	164	161
Directly reduced congestion	2,231	1,360	0	0
Additional consumer benefits (RAEM)	54	80	129	284
Indirectly reduced congestion	21	20	59	184
Spatial labor market matching benefits ¹⁾	-344	-561	315	260
Spatial labor market size benefits	288	393	39	87
International labor market benefits	431	451	301	301
Landscape related benefits	27	25	69	221
Emission benefits (CO ₂ and NO _x)	98	34	-160	-146
Noise hindrance	-29	-269	-90	-118
Total benefits	6,233	7,032	3,312	4,378
Investment costs	6,189	8,229	6,501	5,875
Exploitation costs	2,358	3,048	894	1,094
Net present value 2010-2040	-2,313	-4,244	-4,083	-2,591
Internal discount rate	0.7	-0.9	-0.9	-0.5
Net present value 2010-2060	-532	-2,374	-2,880	-1,020
Internal discount rate	3.4	2.2	1.6	3.0
Non-monetized benefits ²⁾	++	+	++	++
Non-monetized costs ³⁾	-/+	-/+	--	--
Regional redistribution fair?	-/0	-/0	++	+

1) Inclusive of the corrections to avoid double counting part of the consumer surplus in line 3.

2) Qualitative estimate of scale, cluster, image and second-order economic effects.

3) Qualitative estimate of remaining environmental and safety effects.

The *core-periphery* projects help congestion only indirectly as on balance people and jobs are leaving the Randstad. Since substitution from cars is negligible and magnetic levitation uses about four times as much energy, the emission effects are negative instead of positive. Compared to the urban-conglomeration projects, the core-periphery projects have positive instead of negative spatial labor market matching

benefits. This is due to the fact that these projects decrease the pressure on the tight Randstad labor market and decrease unemployment in the rest of the country (see the numbers reported in section 3.2). In addition to this, the south-east variant has relatively high consumer surplus benefits (time benefits business/shopping and additional consumer benefits) and high open landscape benefits, as it uses the less vulnerable new polders for longer distance sub-urbanization instead of sub-urbanization into the valuable old landscapes of the Randstad.

The reported impact of noise hindrance depends on factors such as the driving speed, the number of passages and the number of people hindered. Besides, it depends on whether the new railway line is combined with existing railway or existing road infrastructure. The impact of the inner variant of the urban-conglomeration project is relatively low, because it mainly connects city-edges and is almost completely combined with existing road infrastructure with its own continuous noise hindrance. The noise impact of the outer variant of the urban-conglomeration project is almost ten times as large, because it has more stops at inner-city stations and because it is mainly combined with existing railway infrastructure with its own non-synchronized, discontinuous noise hindrance.

The investment *costs* of course depend on the length of the routes and the extent to which they have to be constructed in an urban or in a rural environment. The latter explains why the urban-conglomeration projects are more expensive, and also why the longer outer variant connecting city centers is more expensive than the inner variant connecting the edges of the main cities. The exploitation costs of the urban-conglomeration projects are much higher than of the core-periphery projects. Since their operational frequency is 10 versus 6 trains per hour, about twice as much trains are needed and about 15% more personnel. Consequently, exploitation costs exceed the exploitation revenues in the urban-conglomeration projects.

5. CONCLUSIONS

5.1 Profitability of Maglev falls short

When all monetized costs and benefits are summed over a 30-year period, none of the projects has a positive net present value (NPV). With a more realistic 50-year period the NPV increases significantly, but remains negative for all projects. For both periods, it is shown that the inner variant clearly outweighs the outer variant of the urban-conglomeration project, while the south-east variant clearly outweighs the north-west variant of the core-periphery project. However, the internal discount rate of all projects still falls short of the required 4%, so none of the considerable risks of the new magnetic levitation technology are covered, which implies that the Dutch government better thinks twice before allocating resources to any of these projects.

The above conclusion could change if the non-monetized costs and benefits would be large, but that is not the case. Compared to the additional economic benefits that are covered, we believe the additional, non-modeled economic benefits to be minor. As to the non-monetized external cost, first attempts to evaluate the impacts on safety and the natural environment have shown that these are relatively small and not necessarily negative (Van Wee *et al.*, 2003). The “-/+” sign in the urban-conglomeration projects in table 2 is used to indicate that the non-monetized external effects are negative with respect to the build and natural environment, and positive with respect to safety, such that the overall sign is uncertain.

Finally, the effect on national efficiency - measured by the sum of the NPV and all non-monetized effects - should be balanced against the effect on interregional equity. This is a typical political evaluation that, if considered relevant, weighs in favor of, especially, the north-west variant of the core-periphery project, and slightly against both urban-conglomeration projects.

Table 1 showed that the effects of transport improvements are strongly dependent on specific *regional* circumstances and conditions. All results are calculated in deviation from the moderate “European Co-ordination” scenario of the CPB (1997). This baseline scenario, however, describes only one of the possible national futures.

Other futures are described in the more pessimistic “Divided Europe” scenario and the more optimistic “Global Competition” scenario (also CPB, 1997). The main characteristics of these scenarios are summarized in table 2.

Table 2: *Main economic indicators of three scenarios for the Netherlands, 2000-2040*

	European Coordination	Divided Europe	Global Competition
<i>Variables measured in annual % changes</i>			
Contractual wages	3.7	4.8	3.2
Consumer price index	2.0	3.3	1.4
Labor productivity	2.3	1.8	2.5
Gross domestic product	1.8	1.2	2,4
<i>Variables measured in levels in 2020</i>			
Population (×1000)	17,717	16,205	16,890
Employment (×1000)	7,512	6,334	7,802
Unemployment (%)	4.5	8.0	2.8

Table 3 shows that the effects of transport improvements are also dependent on the general *national* and *global* conditions, as the outcomes of the monetized cost and benefits are quite different for these three different macro scenarios.

In the Divided Europe scenario, the negative net present value (NPV) of all projects becomes worse, on average by 28%. As the unemployment rate in the Divided Europe scenario is 8%, not only peripheral regions but also the urban core is characterized by a labor supply surplus. Under this condition, new (international) labor demand can be satisfied without displacing other jobs, whereas geographical matching benefits disappear. In the Global Competition scenario, the negative NPV of all projects improves (except for the inner variant), with on average 13%. The differences in size and composition of the benefits between this scenario and the European Co-ordination scenario are less remarkable.

Table 3. Net present values of the monetized cost and benefits, and additional to direct benefit ratios, for the period 2010-2060, under different macro-economic scenarios*

<i>Net Present Values in million Euros</i>	Inner ring Randstad	Outer ring Randstad	Amsterdam-Groningen, north-west	Amsterdam-Groningen, south-east
Basic scenario: European Coordination	-532	-2,374	-2,880	-1,020
Pessimistic scenario: Divided Europe	-1,705	-2,717	-3,108	-1,172
Optimistic scenario: Global competition	-602	-1,823	-2,770	-731
<i>Additional economic to direct transport benefits ratio in %</i>				
Basic scenario: European Coordination	8	6	32	34
Pessimistic scenario: Divided Europe	7	6	32	35
Optimistic scenario: Global competition	0	-1	34	38

* See further Table 2.

The present integral cost-benefit analysis for the Dutch Maglev proposals also throws more light on the outcome of the older German Maglev proposal to connect two large, but distant cities (Hamburg and Berlin). Exploitation revenues and reduced congestion will be relatively low, as this project competes more with air transport and relatively less with private car transport. Time benefits due to commuting and housing benefits will be very small, as the distance between these two cities is simply too large for commuting and only one intermediate stop has been planned. Spatial labor market matching benefits and labor market size benefits will hardly occur, as both cities will have about the same labor market characteristics. This means that already six types of benefits from table 2 will be lost or will be significantly smaller. Consequently, this type of project may be expected to have a lower, perhaps even negative, internal discount rate.

5.2 No uniform ratio of additional to direct benefits

An important issue is the ratio between the benefits that are calculated with our (almost) integral social cost-benefit analysis and the benefits that would have been calculated under the condition of perfect competition and a closed economy. Using a purely theoretical model, Newbery (quoted from SACTRA, 1999, p.101) argues that the potential bias in partial CBA's, due to imperfect competition, is generally too small to worry about, as the truly additional benefits only amount to 2.5% of the direct transport benefits. By contrast, Venables and Gasiorek (also in SACTRA, 1999, p.101), using a more elaborate theoretical model, find that most model permutations show additional economic benefits of around 30%, while only very few permutations exceeding 60%. However, empirical evidence corroborating these ratios is lacking. Moreover, both approaches assume a clearing labor market and a closed economy.¹³

The present study offers the first possibility to underpin these theoretical simulations with empirical data, while it also accounts for labor market imperfections and cross-border effects. Table 3 shows that the additional benefits in the core-periphery projects are much larger than in the urban-conglomeration projects. Partly, this can be explained by the fact that that price mark-ups above marginal cost - due to monopolistic competition instead of perfect competition - were estimated to range from less than 20% in central regions to over 30% in peripheral regions. These figures are comparable to those found by Harris (16% to 29%, quoted from SACTRA, 1999, p.101). Another explanation is that our analysis not only covers product markets, but also labor markets, which from a spatial viewpoint are all but perfect. In the core-periphery projects almost every additional effect with regard to these markets appears to be positive, whereas several are negative in the case of the urban-conglomeration projects.

Taking all additional economic benefits together, the second panel of table 3 shows the additional benefits to lie between +32% and +38% of the direct transport

¹³ Newbery also does not deal with additional welfare accruing from linkage and agglomeration effects, and the entry and exit of firms (SACTRA, 1999, p.101).

benefits in the case of the core-periphery projects and between -1% and $+8\%$ in the case of the urban-conglomeration projects.¹⁴

These last numbers are clearly different from those in the theoretical studies of Newbery, and Venables and Gasiorek (discussed above). This leads to the following conclusions. (1) The hypothesis that the additional economic benefits are too small to worry about must be rejected. (2) The use of a uniform ‘additional economic benefits to direct transport benefits’ ratio to approximate these additional benefits must be rejected also. (3) Although having negative additional benefits is theoretically recognized as possible, no study has yet been able specify the circumstances under which this might occur. Our study proves this to be empirically possible, and relates it to adverse impacts on tight and loose regional labor markets.

5.3 Contribution to the literature

The contribution of this paper to the literature is thus twofold. First, it is one of the first studies that have attempted to measure the comprehensive net total of all social costs and benefits of new transport infrastructure, taking account of the effects of imperfect competition and an open economy. The results show that a uniform ratio to derive the additional economic benefits from the direct transport benefits does not exist, as that ratio proves to be strongly dependent on the type of regions connected, the trajectory at hand, the type of market imperfections and the general state of the economy. Second, it is one of the first studies that have attempted to measure this net total for magnetic levitation rail systems. The empirical results show that we cannot give a positive answer to the basic question whether the Maglev system is worthwhile to the Dutch society, since the internal rate of discount falls short of the required 4% even when a 50-year time horizon is used.

Finally, we briefly consider the main uncertainties involved. The results obtained with respect to housing migration may have been overestimated, as they have been calculated at prevailing prices and assume that positive demand shifts on

¹⁴ Note that these last results improve upon and correct our earlier and higher estimates (Oosterhaven and Elhorst, 2003). The improved modeling of labor market imperfections and

the housing market will be accommodated. The results may have been underestimated if the willingness to commute continues to grow. The results obtained with respect to employment changes and labor migration may have been underestimated, as the spatial equilibrium model used (RAEM) does not yet take account of scale, cluster, and imago effects. Finally, interactions between shifts in labor supply and shifts in labor demand are not yet incorporated into the labor market regime switch model. As a result, some of the net productivity and net job effects on the labor market may have been overestimated.

Although important results have been reached by means of carefully combining different model approaches, a further integration of the models used is definitely called for. This will of course change the specific empirical outcomes of our analysis, but we believe that it will not change our two main qualitative conclusions.

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adding the correction for the implicit labor market effects in RAEM cause the difference.

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